

# The Impacts of Climate Change on Connecticut Agriculture, Infrastructure, Natural Resources and Public Health



A Report by the Adaptation Subcommittee to the Governor's Steering Committee on Climate Change

2010



## Acknowledgements

The Adaptation Subcommittee would like to acknowledge the climate change projection work, including counsel of its members, from the New York Panel on Climate Change (NPCC 2009) and the Northeast Climate Impacts Assessment (NECIA; Frumhoff et al. 2007) used in the analysis of climate change impacts to Connecticut, summarized in this report. The Adaptation Subcommittee also would like to acknowledge the commitment and dedication of all of the Adaptation Subcommittee workgroup members.

### Cover Photos

CT Intertidal Flat: Photograph by Ken Metzler, CT Department of Environmental Protection (CT DEP), retired

Maple Leaf: Photograph by Paul J. Fusco, CT Department of Environmental Protection (CT DEP), Wildlife Division

CT Shoreline Flooding: Sidney Gale

Mosquito: Photograph by Michael Thomas, The Connecticut Agricultural Experiment Station (CAES)

<b>EXECUTIVE SUMMARY.....</b>	<b>4</b>
<b>I. INTRODUCTION.....</b>	<b>6</b>
<b>THE NEED FOR ADAPTATION.....</b>	<b>6</b>
<b>ASSESSING THE IMPACTS OF A CHANGING CLIMATE.....</b>	<b>7</b>
<b>II. CLIMATE CHANGE PROJECTIONS AND RISK ASSESSMENT.....</b>	<b>8</b>
<b>CLIMATE CHANGE SCENARIOS AND FUTURE PROJECTIONS.....</b>	<b>8</b>
<b>THE RISK ASSESSMENT PROCESS.....</b>	<b>10</b>
<b>III. KEY FINDINGS BY WORKGROUP.....</b>	<b>13</b>
<b>AGRICULTURE WORKGROUP.....</b>	<b>13</b>
<b>INFRASTRUCTURE WORKGROUP.....</b>	<b>17</b>
<b>NATURAL RESOURCES.....</b>	<b>19</b>
<b>PUBLIC HEALTH.....</b>	<b>22</b>
<b>IV. WORKGROUP INTERSECTIONS.....</b>	<b>25</b>
<b>WATER QUALITY AND QUANTITY.....</b>	<b>25</b>
<b>EDUCATION.....</b>	<b>26</b>
<b>ECOSYSTEM SERVICES.....</b>	<b>26</b>
<b>BUILDINGS.....</b>	<b>27</b>
<b>TRANSPORTATION.....</b>	<b>27</b>
<b>INTERSECTIONS BEYOND STATE BORDERS.....</b>	<b>27</b>
<b>V. RECOMMENDATIONS.....</b>	<b>29</b>
<b>AGRICULTURE.....</b>	<b>29</b>
<b>INFRASTRUCTURE.....</b>	<b>29</b>
<b>NATURAL RESOURCES.....</b>	<b>29</b>
<b>PUBLIC HEALTH.....</b>	<b>30</b>
<b>VI. PUBLIC COMMENT.....</b>	<b>31</b>
<b>VII. NEXT STEPS.....</b>	<b>33</b>
<b>WORKS CITED IN THIS DOCUMENT.....</b>	<b>34</b>
<b>APPENDIX A: RISK ASSESSMENT QUESTIONS.....</b>	<b>35</b>
<b>APPENDIX B: AGRICULTURE.....</b>	<b>36</b>
<b>APPENDIX C: INFRASTRUCTURE.....</b>	<b>83</b>
<b>APPENDIX D: NATURAL RESOURCES.....</b>	<b>130</b>
<b>APPENDIX E: PUBLIC HEALTH.....</b>	<b>165</b>
<b>APPENDIX F: PUBLIC COMMENTS ON THE DRAFT WORKGROUP REPORTS.....</b>	<b>189</b>

# Executive Summary

## Background

In accordance with Section 7 of Public Act No. 08-98, *An Act Concerning Connecticut Global Warming Solutions*, the Governor's Steering Committee (GSC) on Climate Change established an Adaptation Subcommittee. The GSC charged the Adaptation Subcommittee with evaluating, "the projected impact of climate change in the state on: (1) Infrastructure, including, but not limited to, buildings, roads, railroads, airports, dams, reservoirs, and sewage treatment and water filtration facilities; (2) natural resources and ecological habitats, including, but not limited to, coastal and inland wetlands, forests and rivers; (3) public health; and (4) agriculture." This assessment effort is to be followed by a report due in mid-2010 that also contains the results of the above impacts assessment and, "...recommendations for changes to existing state and municipal programs, laws or regulations to enable municipalities and natural habitats to adapt to harmful climate change impacts and to mitigate such impacts."

## Approach

The Adaptation Subcommittee established four working groups, Agriculture, Infrastructure, Natural Resources and Ecological Habitats and Public Health. The Adaptation Subcommittee chose qualified subject matter co-chairs from amongst its members to lead the workgroups. Each workgroup then assembled a team of experts to assess the risk of climate change impacts to key planning areas and associated features from changes in precipitation, temperature and sea level rise occurring at three temporal benchmarks during this century (2020, 2050 and 2080). The workgroups surveyed Connecticut stakeholders for their opinions through numerous meetings and strategic planning workshops.

## Key Findings

Most of the *agricultural* features assessed by the Agriculture Workgroup were found to be highly impacted by climate change, and most of these impacts were negative. The top five most imperiled agricultural planning areas or features in Connecticut were maple syrup, dairy, warm weather produce, shellfish and apple and pear production. There were opportunities for production expansion, including biofuel crops and witch hazel and grapes, with the future climate, as well as benefits identified for all agricultural planning areas.

The *infrastructure* planning areas determined by the Infrastructure Workgroup to be the most impacted by climate change were coastal flood control and protection, dams and levees, stormwater, transportation and facilities and buildings. Infrastructure planning areas were most affected by changes in precipitation and sea level rise, which could cause substantial structural and economic damage.

The *Natural Resources* Workgroup determined that the ecological habitats at the highest risk from climate change may be Cold Water Streams, Tidal Marsh, Open Water Marine, Beaches and Dunes, Freshwater Wetlands, Offshore Islands, Major Rivers, and Forested Swamps. These habitat types are broadly distributed from Long Island Sound and the coast to the upland watersheds and forests across Connecticut. The degree of impact will vary but, likely changes

include conversion of rare habitat types (e.g., cold water to warm water streams, tidal marsh and offshore islands to submerged lands), loss and/or replacement of critical species dependent on select habitats, and the increased susceptibility of habitats to other on-going threats (e.g., fragmentation, degradation and loss due to irresponsible land use management, establishment of invasive species).

The *Public Health* Workgroup determined that climate change will have the most impact on public health infrastructure, environmental justice communities, air quality and extreme heat ailments and vector-borne diseases. Climate change will impact public health infrastructure including hospitals, health departments, emergency medical services, private practices and shelters, due to direct impacts from extreme weather events, and increased use of resources to treat and shelter victims. Specifically, environmental justice communities may be most impacted by the lack access to adequate public health infrastructure, including shelter or evacuation transportation. Decreased air quality may increase the incidence of, and exacerbate existing respiratory ailments, and increased extreme heat events will increase heat-induced ailments, especially in those populations who do not have the benefit of air conditioning. Finally, climate change may alter ecosystems in a way that may favor increased vector survival, replication, biting frequency, and geographic range.

### **Recommendations and Next Steps**

All of the recommendations from the Adaptation Subcommittee workgroups centered on the need for additional research and monitoring programs to determine more precise risk, including the true financial risk of climate change. Many of the workgroups also found it difficult to completely account for all of the features in their assigned universe, prompting the need for further definition. Furthermore, the workgroups felt that monitoring long-term changes in temperature, precipitation and sea level is needed to more closely define future trends in climate change.

With the conclusion of the climate change impacts assessment phase, the Adaptation Subcommittee will next develop recommended adaptation strategies for the most impacted features of Connecticut agriculture, infrastructure, natural resources and public health. Adaptation strategies and related implementation plans will be detailed in a report due to the Connecticut General Assembly in mid-2010.

### **Public Participation**

The Adaptation Subcommittee involved stakeholders and experts across a wide range of topics. Workgroup members included scientists, engineers, farmers, local and state policy makers, public health officials, planners and small-business owners. Most had many years of practical experience in their field of expertise. In addition, the Subcommittee held two public information sessions, where members of the public were invited to comment on the draft findings.

# I. Introduction

## The Need for Adaptation

The United Nations Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment, released in 2007, concludes that it is “unequivocal” that the climate is warming. The findings of the Northeast Climate Impacts Assessment show that the Northeast has been warming at a rate of nearly 0.5 degrees F per decade since 1970, with winter temperatures rising faster, at a rate of 1.3 degrees F per decade since 1970. This warming correlates with the following climate changes across the region:

- More frequent days with temperatures above 90° F;
- A longer growing season;
- Less winter precipitation falling as snow and more as rain;
- Reduced snowpack and increased snow density;
- Earlier breakup of winter ice on lakes and rivers;
- Earlier spring snow melt resulting in earlier peak river flows; and
- Rising sea-surface temperatures and sea levels.

The debate continues on the degree of change that can be expected to occur over the course of the 21<sup>st</sup> century. Scenarios vary dependent upon the level of success that is attained in mitigating the emissions of greenhouse gases. Continued efforts to reduce greenhouse gas emissions will significantly affect the overall change predicted by the models, however, while the models show significant variation later in the century they arrive at similar results under varying emission scenarios for mid century. The unequivocal evidence that our climate is warming dictates that adaptation planning is prudent and necessary to ensure the future viability of the built and natural environs and the health and safety of the public.

Adaptation planning efforts are not at cross purposes with greenhouse gas mitigation efforts. While most recent work is directed at reducing emissions, greenhouse gases are long lived in the atmosphere. This means that even if greenhouse gas emissions ceased tomorrow, we would still be subject to climate change related to historic emissions. A focus on how to adapt to the change already underway should not be interpreted to suggest that there be any diminishment in emission reduction efforts and policies. In fact, adaptation planning can work in concert with mitigation efforts by further supporting the need for more energy efficient buildings, water conservation and biodiversity/ecosystem services conservation. Similarly, adaptation efforts without the coordinated efforts of mitigation planning could result in unfavorable mitigation outcomes.

This initial report focuses on the impacts of climate change on the built and natural environment, agriculture and public health in Connecticut. Strategies to adapt to these potential impacts will be the subject of additional task force work and a second report due out later this year.

Connecticut's adaptation planning efforts mirrors adaptation planning efforts from other states, including Northeast regional planning efforts, and the expressed interest of the federal government.

### **Assessing the Impacts of a Changing Climate**

In accordance with Public Act No. 08-98, *An Act Concerning Connecticut Global Warming Solutions*, Section 7 required the Governor's Steering Committee on Climate Change to establish an Adaptation Subcommittee. The Adaptation Subcommittee has been charged with evaluating, "the projected impact of climate change in the state on: (1) Infrastructure, including, but not limited to, buildings, roads, railroads, airports, dams, reservoirs, and sewage treatment and water filtration facilities; (2) natural resources and ecological habitats, including, but not limited to, coastal and inland wetlands, forests and rivers; (3) public health; and (4) agriculture." This assessment effort is to be followed by a report due in mid-2010 that considers the results of the above impacts assessment and, makes "...recommendations for changes to existing state and municipal programs, laws or regulations to enable municipalities and natural habitats to adapt to harmful climate change impacts and to mitigate such impacts."

Given this charge, the Adaptation Subcommittee established four working groups, Agriculture, Infrastructure, Natural Resources and Ecological Habitats and Public Health. The Adaptation Subcommittee chose qualified subject matter co-chairs from amongst its members to lead the workgroups. Each workgroup then assembled a team of experts to assess the climate change impacts and survey Connecticut stakeholders for their opinions through numerous meetings and strategic planning workshops.

### **Adaptation Subcommittee Members**

- Co-chair Amey Marrella, Chair, GSC and Commissioner, CT DEP
- Co-chair Lise Hanners, State Director, CT TNC
- Commissioner F. Philip Prelli, Agriculture Workgroup Co-chair, CT DoAG
- Steven K. Reviczky, Agriculture Workgroup Co-chair, CT Farm Bureau
- Denise Savageau, Infrastructure Workgroup Co-chair, Greenwich Municipal Official
- Paul Stacey, Infrastructure Workgroup Co-chair, CT DEP
- William Hyatt, Natural Resources Workgroup Co-chair, CT DEP
- Dr. Adam Whelchel, Natural Resources Workgroup Co-chair, CT TNC
- Commissioner J. Robert Galvin, represented by Pamela Kilbey-Fox, Public Health Workgroup Co-chair, CT DPH
- Dr. Dennis McBride, Public Health Workgroup Co-chair, Milford CT DPH
- Thomas R. Baptist, CT Audubon
- Commissioner Peter Boyton, represented by Dana Conover and Anthony Dembek, CT DEMHS
- Commissioner Raeanne V. Curtis, represented by Jeff Bolton, CT DPW
- Commissioner Joseph Marie, represented by Colleen Kissane and Paul Corrente, CT DOT
- Joan McDonald, CT DECD
- State Senator John McKinney, represented by Jacqueline Ferro or Rob Pordrier
- Commissioner Thomas R. Sullivan, represented by George Bradner, CT DoI
- Mark Way, Swiss Reinsurance
- Dr. Robert Whitlach, UConn
- State Representative Patricia M. Widlitz
- Norman Willard, EPA Region 1
- Dr. Michael Willig, UConn
- Dr. Gary Yohe, Wesleyan University
- Paul Farrell, CT DEP
- Bob Kaliszewski, CT DEP
- Roslvn Reeps. CT DEP

## Climate Projections for the Next Century (NPCC 2009)

### Temperatures

- Temperatures may increase by 4 to 7.5°F by the end of the century.
- There may be more days over 90 and 100° F.
- Heatwaves may increase in frequency, duration and intensity.
- Extreme cold events may become less frequent.

### Precipitation

- Precipitation may increase by 5 to 10% by the end of the century.
- More precipitation may fall in the winter.
- More of the winter precipitation may fall as rain.
- There may be more severe storm events causing flooding.
- Droughts may increase in frequency, duration and intensity.

### Sea Level Rise

- Sea level may increase by 12 to 23 in by the end of the century.
- Sea level may increase by 41 to 55 in by the end of the century with the 'Rapid Ice-Melt Sea Level Rise' scenario.
- There may be more coastal flooding caused by extreme storm events.

## II. Climate Change Projections and Risk Assessment

### Climate Change Scenarios and Future Projections

In an effort to make the best use of existing good science and analysis developed by others, and at the same time address our resource and time constraints, the Adaptation Subcommittee opted to focus the initial assessment of impacts on Connecticut using the climate change projections for annual air temperature, precipitation and sea level rise from the New York Panel on Climate Change (NPCC), detailed in the document *Climate Risk Information* (2009). NPCC used global climate models (GCM) based on methods and emissions scenarios (A1B, A2, B1) from the Intergovernmental Panel on Climate Change (IPCC) to develop quantitative projections for temperature, precipitation, sea level rise and extreme weather events (e.g., droughts and wet weather) for temporal benchmarks of 2020, 2050 and 2080. NPCC used a combination of sixteen GCMs and three emissions scenarios to produce data for temperature, precipitation and extreme weather events. NPCC also added a 'rapid ice melt' scenario to the IPCC scenarios to produce a more up-to-date projection of future sea level rise in the New York City area.

Some have commented that we should consider newer data or conduct more site specific modeling for Connecticut. Both may be warranted in the future and will likely be part of our adaptive strategy design considerations. In the near term, the NPCC projections enabled the Adaptation Subcommittee to successfully complete Connecticut's first climate change adaptation impacts analysis. Other benefits of the NPCC efforts include:

- The NPCC models are based on sound science with methods developed by the IPCC;
  - The baseline data used in the NPCC models is very similar to Connecticut weather data;
  - The NPCC projections have sufficiently down-scaled the IPCC emissions scenarios and GCMs to suit the Tri-State area;
  - The NPCC GCM resolutions range from as fine as ~75 x ~100 miles to as coarse as ~250 x ~275 miles, with an average resolution of approximately 160 x 190 miles, which covers virtually all of the state of Connecticut; and

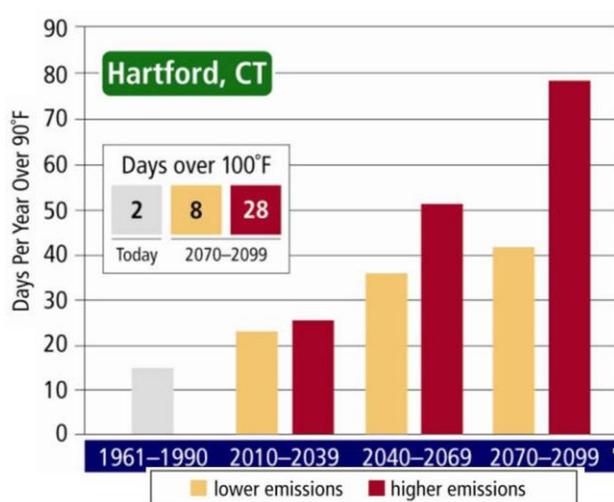
- The Subcommittee is working under both resource and time constraints.

The Subcommittee compared the NPCC data with northeast-specific data from the synthesis report of the Northeast Climate Impacts Assessment (NECIA), a collaboration between the Union of Concerned Scientists and a team of independent scientific experts to assess global warming impacts and future adaptations in the northeast (Frumhoff et al. 2007; Table 2.1).

**Table 2.1:** A comparison of the NPCC (2009) and NECIA (Frumhoff et al. 2007) projections for mean annual air temperature, precipitation and sea level rise.

	Baseline		Early Century		Mid-Century		Late Century	
	NPCC (1971-2000)	Northeast	NPCC	Northeast	NPCC	Northeast	NPCC	Northeast
Air Temperature (°F)	55	?	1.5-3	1.5-4	3-5	2-8	4-7.5	3-14
Days over 90°F	14	15	23-29	23-26	29-45	36-51	37-64	41-79
Days over 100°F	0.4	2	0.6-1	N/A	1-4	N/A	2-9	8-28
Precipitation	46.5 in	?	0-5%	little change	0-10%	little change	5-10%	20%-30%
Sea Level Rise (in.)	N/A	relative to 2005	2-5	0.5-1	7-12	4-5	12-23	9.6-16.1
Sea Level Rise- Rapid Ice Melt (in.)	N/A	N/A	5-10	N/A	19-29	N/A	41-55	N/A

The NECIA only used the high and low IPCC emissions scenarios when calculating their climate change projections and did not incorporate more advanced ice sheet melt data into their projections. NECIA also used baseline data from the whole northeast, a broader and much more climate diverse area (encompasses USDA vegetation hardiness zones seven to three) than the more focused radius around New York City covered by the NPCC (hardiness zones seven to five).



**Figure 2.1:** Days per year over 90 and 100 ° F for the lower and higher IPCC emissions scenarios (Frumhoff et al. 2007; see NECIA [www.climatechoices.org/ne/](http://www.climatechoices.org/ne/)).

Therefore, the projections for annual air temperature, precipitation and sea level rise and extreme event projections that will be used for Connecticut are the NPCC projections listed in comparison Table 2.1 above, for time frames of 2020, 2050 and 2080. However, the NECIA data includes Hartford, Connecticut-specific data projections of days over 90 and 100 degrees Fahrenheit. The Subcommittee agreed that this data should be taken into consideration during the Subcommittee’s work (Figure 2.1).

The degree of change to our future climate in Connecticut is to a large degree dependent on how successful we are in mitigating global greenhouse gas emissions. Each new success or failure toward achieving these reductions will influence the next model and ultimately result in changes to the projections. Any system as complex as the global climate, will require an iterative evaluation. Climate driver and site specific analysis is likely to be a key component of many of the resulting adaptive strategies.

The workgroups on Public Health and Agriculture also evaluated projections of air quality data, particularly ambient carbon dioxide and ozone concentrations. The carbon dioxide concentrations used by NPCC in their scenarios are provided in Table 2.2. Projecting concentrations of ground level ozone is a more complicated matter, which is highly dependent on both precursor emissions and regional weather conditions. It is, therefore, difficult to make long-term predictions of ground level ozone concentrations.

**Table 2.2:** Carbon dioxide levels (ppm) for IPCC climate change scenarios B1, A1B and A2, which were used in the NPCC (2009) report. Current carbon dioxide levels are approximately 380 ppm.

CO <sub>2</sub> (ppm) for Climate Change Scenarios Used in NPCC Report (Current levels 380 ppm)				
Year	B1	A1B	A2	Average
2020	412	420	417	416.33
2050	488	532	532	517.33
2080	537	649	698	628.00

## The Risk Assessment Process

To provide consistency during the risk assessment process across the four workgroups, the Adaptation Subcommittee and workgroup chairs agreed to focus primarily on three climate drivers, temperature, precipitation and sea level rise, with the climate driver of air quality used where appropriate. Extreme weather events would be factored into the corresponding climate driver (e.g., the extreme event of heatwaves would be considered under temperature). The Adaptation Subcommittee and workgroup chairs also agreed to use the primary temporal benchmarks, 2020, 2050 and 2080, to coincide with the NPCC (2009) projections.

During initial organizational meetings, the workgroup members compiled a list of features and, as necessary, sub-features of their assigned subject (see the Agriculture Workgroup Table 1 located in Appendix B for examples of planning areas and associated features). These features and sub-features were then aggregated into planning areas, and assessed during the risk assessment process.

While the risk assessment described below utilized what appears to be a quantitative approach, the inherent limitations of the analytical tools delivered a more qualitative result. These results allowed us to develop a gross prioritization enabling the workgroups to focus their attention on the appropriate planning areas. Furthermore, these analyses were broad based; a more defined vulnerability analysis may be needed to define specific adaptive strategies.

The risk assessment process was conducted through a mix of workshops and online survey tools. Experts and stakeholders completed the risk assessment forms and surveys facilitated by trained team leaders. Group discussion, recorded by a facilitator, and individual responses to sensitivity and adaptation questions listed on a questionnaire form (Appendix A; adapted from Snover et al. 2007), as well as a risk matrix (Figure 2.2) were completed for each feature. The risk matrix provided a space for each individual to evaluate the planning areas or features by the (1) likelihood impact by climate change by the year 2080 ('Likelihood of Occurrence'), (2) the severity of impact by 2080 ('Magnitude of Impact'), (3) the primary climate driver ('Climate Driver'), and (4) the likely time horizon for impacts to occur and urgency for action during the temporal benchmarks of 2020, 2050, or 2080 ('Time Urgency'). (In most of the workshops,

participants marked the risk matrix box as either positive or negative, depending on the nature of the impact.)

Name \_\_\_\_\_ Planning Area \_\_\_\_\_ Feature \_\_\_\_\_

Expertise Low 1 2 3 4 5 High

**Risk Matrix\*** Mark a "+" (positive impact) or "-" (negative impact) in one box for the risk assessment of the feature listed above.

		Likelihood of Occurrence			
		Low	Moderate	High	Virtually Certain/Already Occurring
Magnitude of Impact	High				
	Medium				
	Low				

\*Risk equals the likelihood of occurrence multiplied by the magnitude of the impact, and is categorized as low (L), Medium (M) or High (H).

<b>Climate Driver</b> (Rank the below climate drivers from 1 to 4, with 1 having the most impact, or "NI" if the climate driver does not have an impact on the feature.)	
Precipitation	
Temperature	
Sea Level Rise	
Air Quality (CO <sub>2</sub> and ozone)	

<b>Time Urgency</b> (Mark an "X" next to the timeframe when the climate change impact to the feature will need to be addressed)	
2020	
2050	
2080	

Other Comments (space available on the back):

**Figure 2.2:** The third page of the risk assessment worksheet that was filled out by participants in the August 2009 agriculture risk assessment workshop. Participants noted if the impending impact from climate change was positive (“+”) or negative (“-“), and the degree that the impact was likely to happen and the magnitude of that impact in the risk matrix. Participants also were asked to rank the climate drivers, precipitation, temperature, sea level rise and air quality, from one to four (one having the most impact), and mark the timeframe when the climate change impact to the feature would need to be addressed (i.e., 2020, 2050 or 2080).

Risk Matrix					
		Likelihood of Occurrence			
		Low (1)	Moderate (2)	High (3)	Virtually Certain/Already Occurring (4)
Magnitude of Impact	High (3)	Medium (3)	High (6)	High (9)	High (12)
	Medium(2)	Low (2)	Medium (4)	High (6)	High (8)
	Low (1)	Low (1)	Low (2)	Medium (3)	Medium (4)

**Figure 2.3:** Risk matrix with associated risk categories (Low, Medium, High) and risk scores, which were determined by multiplying the likelihood of occurrence by the magnitude of impact. The final score for each feature was determined by the most often given answer for the risk category and the average of all of the risk scores (the risk scores could be positive or negative based on the impact).

Risk for each feature was quantified by assigning positive or negative values of 1 (risk category= low) through 4 (risk category= high) to the 'Likelihood of Occurrence' and 1 (risk category= low) through 3 (risk category= high) to the 'Magnitude of Impact' components of the matrix (Figure 2.3). Likelihood and magnitude scores were multiplied to calculate values ranging from 1-12 for each of the blocks in the ranking table. Responses from each participant were thus transformed into numerical values that were averaged to produce risk scores. Each feature then was ranked first by the most often given answer for the 'Risk Category' (i.e., low, medium or high) then by the average of all of the 'Risk Scores' (average positive scores denote an overall positive impact to the feature due to climate change, while average negative scores denote an overall negative impact to the feature due to climate change), and finally by the 'Time Urgency' most often given answer (2020, 2050 or 2080; with an answer of 2020 being the most at risk). The top two most often given 'Climate Drivers' also were recorded in the risk data table. (For an example of risk assessment data analysis, see Table 2 in Appendix B featuring the Agriculture Workgroup risk assessment data.)

### III. Key Findings By Workgroup

The full analysis performed by each workgroup is captured in the individual reports presented in the appendices of this report. These reports provide far greater detail on the evaluation and potential impacts. Presented below is a summary of the key findings from each workgroup.

#### Agriculture Workgroup

The Agriculture Workgroup examined impacts on ten planning areas (Table 1 located in Appendix B). Most of the agricultural features were determined to be highly impacted by climate change, and most of these impacts were negative. The top five most imperiled agricultural planning areas or features in Connecticut were maple syrup, dairy, warm weather produce, shellfish and apple and pear production (Table 2 located in Appendix B).

There were opportunities for production expansion, including biofuel crops and witch hazel and grapes, with the future climate, as well as benefits identified for all agricultural planning areas.

#### The Top Five Most Impacted Agriculture Planning Areas or Features

1. Maple Syrup
2. Dairy
3. Warm Weather Crops
4. Shellfish
5. Apple and Pear Production

#### Maple Syrup

Maple Syrup production in Connecticut will be the most impacted agricultural feature. In fact, maple syrup production in Connecticut may be impossible by 2080, particularly at lower elevations, due to predicted increases in temperature, especially increases in late winter/early spring nighttime temperatures (the dichotomy of warm days and freezing nights are needed to induce sap flows). Reduced maple syrup production and sugar maple trees will bring additional economic impacts to communities, such as Hebron, that hold dedicated maple syrup festivals, and leaf-peeping tourism during the fall, since maple sugar trees are responsible for some of the most vibrant fall foliage colors. Furthermore, many foresters expect that a decrease in sugar maples will negatively affect the lumber industry, since sugar maple trees are a top lumber product. Maple syrup is one of many commodities produced on a farm, which helps diversify farm income: an additional source of income many farmers have come to depend upon.

**“... maple syrup production in Connecticut may be impossible by 2080, particularly at lower elevations, due to predicted increases in temperature, especially increases in late winter/early spring nighttime temperatures ...”**

#### Dairy

The threat to Connecticut dairy operations (animal husbandry and feed production) from climate change is expected to be imminent and high. Workshop participants would like to see adaptation action sooner than 2020. The primary climate driver for dairy animal husbandry is temperature;

more frequent, higher day-time temperatures and the absence of nighttime cooling will cause more stress to dairy cows, which will depress appetite and reduce lactation (i.e., reduced milk production) and calving. The stress of increased temperature will lead to long-term, poor animal health, reduced herd size and lower income potential. There also will be increased energy demands from fans and water cooling required to keep dairy cows cool during hotter temperatures. Increased precipitation will lead to difficulty with managing the herd indoors by increasing the cleaning requirement, and will lead to difficulty with managing the herd outdoors due to wet fields, especially in spring and early summer if more winter precipitation does occur. This increase will also make manure management and water management (runoff) from dairy infrastructure more difficult. Decreased precipitation during the hottest summer months and subsequent water restrictions will further stress dairy cows and dairy farming operations.

### *Warm Weather Crops*

Warm weather crops, or crops that mature from late June to early September (e.g., tomatoes), were primarily seen as being affected by climate uncertainties. Warm weather crops account for the larger share of revenue for produce farmers, making it increasingly important for a consistent crop yield. Temperature and precipitation will affect crops the most. Increased temperature and precipitation would increase crop disease, pests and pathogens, and decrease fruit set (e.g., peppers don't set above 90° F). Additionally, changes in air quality, in particular carbon dioxide, could increase weed growth, surpassing any benefit achieved from slightly increased crop growth. Ozone also is expected to affect warm weather crops by decreasing plant growth and negatively affecting warm weather crop pollinators.

**“...farmers are already seeing an increase in the colonial worm on sweet corn crops. Traditionally found in corn after Labor Day, now the colonial worm is able to overwinter and has been found on corn earlier than Labor Day.”—Agriculture Workgroup Report**

### *Shellfish*

Temperature was considered the primary climate driver influencing shellfish aquaculture in Connecticut. The major species commercially grown in Connecticut (i.e., Eastern oyster, hard clam) are also found in southern waters and should adapt to predicted temperature increases; in fact, increased temperatures could lead to faster growth. However, increased water temperature could also lead to increased disease prevalence. This could include epizootic parasites that affect shellfish survival directly, as well as naturally occurring pathogens that additionally pose a human health risk. Shellfish exposure to pathogenic organisms could be further exacerbated by increased climate change-induced storm events resulting in increased turbidity runoff and partially treated or untreated sewage overflows. In addition, preliminary research of ocean acidification, due to increased carbon dioxide, indicates that shellfish larvae and juveniles may be especially susceptible, which would negatively affect recruitment, jeopardizing future populations. However, pH impacts upon locally cultured species is not fully understood, and research is currently underway to further identify these risks.

### *Apple and Pear Production*

Precipitation variability was seen as the biggest threat to the high value apple and pear production crops in Connecticut. Too much precipitation, especially in the spring could lead to increased fungus infections, and reduced pollen production. Projected drier summers will be better for apple and pear production. However, insect damage due to increased temperatures could be worse, leading to decreased fruit yield. Increased spring precipitation could lead to poor bee pollination, which also would decrease apple and pear production. Extreme weather events, such as hail and ice storms, could be especially devastating to these long-lived perennials or may simply damage fruit, making it undesirable for consumers. Furthermore, apples and pears will mature earlier, potentially negatively impacting the success of pick-your-own operations, whose customers currently equate apples and pears with the fall season.

### *Opportunities*

Despite its challenges, climate change will present some agricultural opportunities. Biofuel crops, witch hazel and grape production could increase with climate change in Connecticut.

#### *biofuel*

Biofuel crops (e.g., switchgrass, hybrid poplars) could increase due to climate change projections of increased temperature, precipitation and ambient carbon dioxide levels. This could present an opportunity for Connecticut farmers looking to diversify or convert to more climate-change friendly crops. Biofuel crops are likely to play an important and increasing role in efforts to reduce greenhouse gas emissions by displacing a portion of our fossil fuel use.

#### *witch hazel*

Witch hazel is a shade-tolerant shrub that grows in upland forests. It is an economically important forestry crop that is used as an astringent, a component of cosmetics and to treat bruises, insect bites and other ailments. Witch hazel is usually just a supplemental source of income for foresters/farmers, but the crop could be expected to increase due to climate change. The largest witch hazel processing facility in the country is located in East Hampton, Connecticut, not only making witch hazel an important agricultural commodity, but also an important industrial commodity.

#### *grapes*

Grape production in Connecticut will greatly benefit from warmer, drier summers. Grapes will have a longer time to mature, making more varieties a viable option in Connecticut (especially red varieties), and the sugar content will increase, making Connecticut grapes more desirable for wine production. Mold, fungus and diseases also may decrease with drier summers. An increasing market for eating/table grapes could fill the void from climate change impacts to other berries.

Ultimately, a longer growing season, warmer winters and a relative abundance of precipitation may trigger positive impacts from climate change, in spite of the increased threat from pests, pathogens and disease. Therefore, climate change may enhance Connecticut in its value as an agricultural area. The working conditions of agricultural workers may need to be evaluated in the context of climate change, but the longer growing season would provide the benefit of extended work terms. Pick-your-own operations and farmers that rely on the fresh market may

be impacted due to increased precipitation and heat that may discourage customers from frequenting their operations, but innovative strategies to attract customers are increasing.

## Infrastructure Workgroup

The infrastructure planning areas determined by the Infrastructure Workgroup to be the most impacted by climate change were coastal flood control and protection, dams and levees, stormwater, transportation and facilities and buildings. Infrastructure planning areas were most affected by changes in precipitation and sea level rise, which could cause substantial structural and economic damage.

### Land

The planning areas categorized as land planning areas – Transportation, Energy and Communications, Facilities and Buildings and Solid Waste Management (Table 4 located in Appendix C) – were most affected by the increases in precipitation, including extreme precipitation events (e.g., hurricanes, storm surges, ice storms, nor'easters), and, where applicable, sea level rise. More frequent precipitation and extreme precipitation events will create operation and maintenance challenges. Specifically, land planning areas will have to deal with increased runoff and drainage needs. For

example, many of Connecticut's culverts that pass runoff under roads or other infrastructure are undersized, which currently contributes to ponding on roadways, bridges, airports runways, railroads and parking lots during extreme precipitation events.

Land infrastructure features located along the coast will be most impacted by inundation from sea level rise, which also will contribute to drainage problems, as well as salt corrosion. Overall, land infrastructure was designed and built based upon current 25, 50 or 100-year storm specifications and with knowledge of existing flood plain and coastal area management designations. Thus, current design specifications may not be able to accommodate climate change conditions, which may lead to costly damage or destruction of infrastructure.

### The Top Five Most Impacted Infrastructure Planning Areas

1. Coastal Flood Control and Protection
2. Dams and Levees
3. Stormwater
4. Transportation
5. Facilities and Buildings

### Select Land Based Planning Areas of Infrastructure in CT

- Transportation
  - 56 public and private airports
  - 3 deep water ports and 275 marinas
  - 628.5 miles of active railroads
  - approximately 21,295 miles of public roadway and 5,424 bridges, tunnels and buildings over roadways
- Energy and Communications
  - approximately 1,558 existing and proposed telecommunications sites
  - Electric generation infrastructure is comprised of 92 electric generators, including nuclear and hydroelectric generators, 1,818 miles of high voltage conductors, and 130 substations and/or switching stations
  - 3 interstate gas pipelines that extend 592 miles across the state, including 16 miles in Long Island Sound
- Solid Waste Management
  - approximately 200 solid waste handling and disposal facilities
  - 81 recycling facilities

### *Water*

As with the land planning areas, the Water planning areas – Water Supply, Wastewater, Stormwater, Coastal Flood Control and Protection and Dams and Levees (Table 4 located in Appendix C) – will be most affected by increases in, and changed patterns of, precipitation and sea level rise.

More frequent and intense droughts will decrease the quantity of available water. Increased precipitation and extreme precipitation events will increase stormwater and wastewater volumes, and thus decrease water quality from related pollutant loads. Sea level rise also can impact Connecticut's water supply and stormwater. Salt intrusion will decrease the quality of the water supply, and sea level rise, coupled with increased precipitation leading to higher groundwater levels, will limit the usefulness of infiltration galleries and other BMPs used to offset peak runoff impacts from stormwater.

Dams, levees and coastal flood control and protection infrastructure may be at risk of overtopping from increased precipitation and sea level rise, and aging flood management infrastructure may be unable to withstand the strain of increased water loads. Furthermore, in many areas development has complicated the impact from climate change by impeding the retreat or re-creation of tidal wetlands and flood plains, limiting the protection provided by these natural barriers against floods.

### *Economic Impacts to Connecticut Infrastructure*

In terms of economic effects, a FEMA HAZUS<sup>1</sup> loss estimation methodology software analysis of a 100-year flood scenario predicted that Connecticut could incur up to \$18.684 billion in property losses and business interruptions (Table 1 located in Appendix C). In addition, the loss estimation from the FEMA HAZUS gives a broad estimation of the value of Connecticut Facilities and Buildings that could be at risk due to other climate change impacts. However, the FEMA HAZUS analysis also does not take into account the climate change-induced, synergistic effects of increased groundwater tables and sea level rise on future flooding, which could increase the 100-year flood property losses and business interruptions.

#### **Select Water Based Planning Areas of Infrastructure in CT**

- Water Supply
  - 151 public water supply reservoirs, serving 70% of the population
  - approximately 6,600 public water supply wells, serving 14 % of the population
  - 250,000 estimated privately owned wells, serving 16 % of the population
- Wastewater
  - 87 large, permitted wastewater treatment facilities, with a number of private, community systems
- Dams and Levees
  - 5,500 dams
- Coastal Flood Control and Protection
  - 75 permitted locations for flood control tide gates
  - 2,360 permitted locations for passive armoring structures, such as bulkheads, seawalls and groins

<sup>1</sup> The FEMA HAZUS software uses historic flood data, coupled with the latest geographic information system (GIS) technology and datasets to determine the economic losses incurred during a 100-year flood. See <http://www.fema.gov/plan/prevent/hazus/> for more information.

## Natural Resources

The collective response from the Natural Resources Workgroup (NRWG) suggests that certain habitat types within the state are at relatively increased risk to projected changes in climate. Those habitats suggested to be at highest risk are Cold Water Streams, Tidal Marsh, Open Water

### Habitats at the Highest Risk from Climate Change

1. Cold Water Streams
2. Tidal Marsh
3. Open Water Marine
4. Beaches and Dunes
5. Freshwater Wetlands
6. Offshore Islands
7. Major Rivers
8. Forested Swamps

Marine, Beaches and Dunes, Freshwater Wetlands, Offshore Islands, Major Rivers, and Forested Swamps (Table 2 located in Appendix D). These habitat types are broadly distributed from Long Island Sound and the coast to the upper watersheds and forests across our State. The degree of impact will vary but, likely changes include conversion of rare habitat types (e.g., cold water to warm water streams, tidal marsh and offshore islands to submerged lands), loss and/or replacement of critical species dependent on select habitats, and the increased susceptibility of habitats to other on-going threats (e.g., fragmentation, degradation and loss due to irresponsible land use management, establishment of invasive species) in addition to climate

change. The additive stress of climate change will certainly have implications on the overall ecosystems supported and maintained by not only the high risk habitats mentioned above, but also all the other habitats and species within the State.

Several other habitats with low risk scores are worthy of further consideration because of their limited distribution and unique contributions to overall biodiversity in the State. These include: Rocky Outcrops and Summits, Bogs and Fens, and Sand Barrens and Warm Season Grasslands (Table 2 located in Appendix D). These habitats in particular are restricted in distribution by the limited availability of suitable geologic formations at elevation, specific hydrologic conditions and select glacial deposits, respectively. As with many of our unique or spatially limited habitats, the principal option is to assume these habitats will accommodate the projected changes in temperature, precipitation and sea level rise or be converted to other habitats. This is currently occurring along our coast where Fens at sea level are converting to brackish wetlands.

### *Dominant Climate Drivers*

All the primary climate drivers are likely to impact natural resources across the State. Extreme events such as more intense and frequent storms and extensive droughts will play a critical role in defining impacts to natural resources. The emphasis below is on three dominant climate drivers.

**“As with many of our unique or spatially limited habitats, the principal option is to assume these habitats will accommodate the projected changes in temperature, precipitation and sea level rise or be converted to other habitats.”**

Temperature was identified as a dominate driver amongst a variety of terrestrial and aquatic habitat types ranging from Upland Forest Complexes and Talus Slopes to Cold Water Streams and Lakes, Ponds and Impoundments and Shorelines. The dominate driver for the Open Water

Marine systems in Long Island Sound was increased water temperature. Alterations in precipitation will drive changes in not only aquatic habitats such as Freshwater Wetlands, Major Rivers, Warm Water Streams and Bogs and Fens, but also in terrestrial habitats like Rocky Outcrops and Summits and Early Successional Shrublands and Forests. For coastal habitat types such as Tidal Marsh, Beaches and Dunes, Offshore Islands, and Intertidal Flats and Shores, the dominant driver is sea level rise. Several habitats were identified as likely to be influenced by both expected precipitation and temperature changes: Forested Swamps and Sand Barrens and Warm Season Grasslands.

#### *Timing of Risk and Urgency for Action*

The pace at which change will occur within habitat types is identified by assignment of urgency for action categories by decade (i.e., 2020, 2050, or 2080). The habitats with the highest risk are, in most cases, assigned to the most urgent action category – 2020. This result implies that the necessary action to increase the capacity to accommodate change for at risk habitats such as Cold Water Streams, Tidal Marsh, Beaches and Dunes and Freshwater Wetlands, is required during this and the next decade. Habitats with high risk scores in the 2050 category include Major Rivers, Forested Swamps, Subtidal Aquatic Beds, and Warm Water Streams. The majority of the remaining habitats were in the 2080 category. Note that these assignments are intended to provide an initial assessment and are not prescriptive or authoritative. Tangible manifestations of changes in climate may in fact be realized much sooner or later than suggested by these responses.

#### *Select Habitats at Risk*

During the breakout sessions at the NRWG workshop, participants provided additional critical information concerning the likely impacts on habitats. A summary of the responses for several high risk habitats follows. The NRWG participants' ratings on likelihood and severity of impact were all rated high for these habitats, (for more specifics on the habitat ratings see Appendix D).

##### *Cold Water Streams and Associated Riparian Zones*

The limited distribution and quantity of this habitat in the State makes it particularly fragile and susceptible to projected changes in climate. As air temperatures increase, the suitability of cold water streams for critical species such as brook trout and burbot will decline. In many locations the critical water temperature threshold is already being exceeded, particularly during the late summer months in shallow reaches. This has important ramifications on the abundance of not only top predators like brook trout and brown trout, but also on many important aquatic organisms that support a dynamic food web within the streams and the adjoining terrestrial ecosystems. The continued viability of this habitat is certainly an important consideration given the revenue generated through active and passive recreation in the State.

##### *Tidal Marsh*

Tidal marshes along the coast have been and will continue to be impacted by both sea level rise and storm events. The pace of sea rise will likely outpace accretion and inundate existing coastal marshes resulting in rapid loss and conversion (from high to low marsh to mudflat) with concurrent impacts on dependent plant and wildlife species. In addition, the supportive nursery function of these coastal marshes for ecologically and recreationally important finfish will be impaired by changes in condition and availability of this habitat. Further upstream on major

rivers like the Connecticut River, freshwater tidal marshes will be lost or converted. This will be the result of increases in salinity as the estuaries move upstream, lack of suitable adjoining areas to accommodate upland migration, and alteration in the amplitude and timing of the annual spring freshets and lower summer flows. The reduction in extent and complexity of these highly productive interfaces between land and water will have impacts on ecological function (storm buffering, flood storage, fish nurseries, water filtering) and biodiversity within the state.

#### *Open Water Marine*

Changes have already been observed in the Open Water Marine habitat in Long Island Sound. The projected changes in water temperature will result in an increase in the occurrence of warm-water species from the south and a retreat of coldwater species to northern marine systems. Rebuilding commercially harvested species like American lobster and winter flounder through fishery management actions will be more difficult and alteration of migratory patterns and timing in anadromous fish species are likely. The potential alteration of plankton dynamics from temperature and salinity gradient shifts, coupled with continued nutrient loading may result in sustained changes to the entire food web of Long Island Sound. Seventy-nine percent of the 19 Natural Resources Workgroup respondents indicated that the likelihood of impacts from climate change was virtually certain and already happening.

#### *Beaches and Dunes*

The Beaches and Dunes habitat is highly susceptible to impacts from sea level rise and storm events given the limited distribution and position of this habitat along our coastal fringe. The ongoing erosion and transport of sediment along the coast will likely increase with projected future climatic conditions resulting in further loss of this habitat and conversion of supportive dunes to beaches. Important beach-and-dune dependent species such as horseshoe crabs, piping plovers, other migratory shorebirds, and terns will be impacted with the loss of this critical habitat. In addition, a decline in recreational opportunities and property values for the citizens of Connecticut will occur without substantial investment to mitigate these projected losses.

#### *Herbaceous Freshwater Wetlands*

Herbaceous Freshwater Wetlands represent a diversity of ecosystems that are highly dependent on, and susceptible to, alterations in hydrology, both in surface water runoff and groundwater discharge. Relatively small changes in the timing and amount of annual precipitation will influence the suitability and distribution of wetlands systems, particularly vernal pools and wet meadows, for many wetland-dependent amphibians, birds and plant species. These changes will require that wetland dependent species relocate via available corridors to other wetland systems if able or perish if not. Extended droughts that occur earlier in the breeding season along with elevated temperatures and lower groundwater table may reduce the distribution and condition of wetlands throughout the state.

## Public Health

### *Public Health Infrastructure*

Climate change associated with the NPCC projections would impact the public health infrastructure including hospitals, health departments, emergency medical services, and private practices. Increases in extreme weather events can take an economic toll on Connecticut public health infrastructure due to damage and increased use of resources. For example, according to the American Hospital Directory (AHD), there are about 8,373 staffed beds in Connecticut and approximately 2,423,215 patients daily (AHD 2010). Hartford and New Haven are the two areas with the highest numbers. However, there have been no studies to conclude if the number of current hospital beds would be sufficient during an extreme weather event in Connecticut.

**“Hurricanes and floods may lead to evacuations, which will stress Connecticut’s sheltering assets.”**

According to the Public Health Workgroup, public health infrastructure has a medium degree of sensitivity due to climate change. DPH will address public health infrastructure as the department modifies its emergency response plans under the Centers for Disease Control (CDC) Public Health Preparedness Grant. These plans assist with statewide preparedness. Local Health Departments and Districts are also required to have preparedness plans in place. It will be important for these plans to include sections for disasters due to extreme weather events.

### *Sheltering*

Sheltering issues may arise due to extreme weather events. Hurricanes and floods may lead to evacuations, which will stress Connecticut’s sheltering assets. The American Red Cross has been working with the Department of Emergency Management and Homeland Security (DEMHS) and with Emergency Management Directors (EMDs) from towns and cities within the state, to compare sheltering data. The goal is to compile one complete database for the National Shelter System (NSS). The NSS is a comprehensive web-based, data system created to support agencies (government and non-governmental) responsible for elements of shelter management.

### *Environmental Justice Communities*

The most impacted populations by climate change will likely be communities of color and low-income communities that are socially disadvantaged, disproportionately burdened by poor environmental quality, and the least able to adapt, otherwise known as environmental justice (EJ) communities. These EJ communities may disproportionately experience effects extreme heat events, and see increases in cardio-respiratory illness (including asthma), vector associated infectious diseases, food insecurity, and natural disasters.

Air quality changes related to climate change may increase the incidence of asthma in Connecticut EJ communities, which is already higher than non-EJ communities. A number of coastal EJ communities could also be vulnerable to storm surges and flooding, which can cause health impacts including direct injuries, death, infectious disease, and mental health problems. Furthermore, during extreme weather events, EJ communities may lack adequate shelter or access to protective resources such as air conditioning and transportation, and these events may lead to population migration out of the affected areas.

*Air Quality and Extreme Heat*

Human health in Connecticut will be impacted by climate change primarily by increasing extreme heat events, and its potential exacerbation of existing air quality problems. Connecticut residents may also experience a reduction in extreme cold events due to climate change, a potentially positive benefit to public health from climate change during the winter months.

*Ozone levels*

Exposure to ozone has been linked to a number of respiratory health effects, including significant decreases in lung function and inflammation of airways. Ozone exposure also has been shown to cause new-onset asthma and increased sensitivities to allergens (Shea et al. 2008). Children are among the most at risk from ozone exposure because their respiratory systems are still developing and they breathe more air per pound of body weight than adults. Furthermore, children often spend significant time outdoors during the summer, when ozone levels are at their highest. The elderly and individuals with existing respiratory diseases, such as chronic obstructive pulmonary disorder (COPD) and asthma, also are at risk from ozone exposure because their lung function is already impaired. Aggravation of existing respiratory disease impacts public health infrastructure because it can result in increased medication use, as well as increased hospital admissions and emergency room visits.

The Connecticut Department of Environmental Protection (CTDEP) has been measuring ambient ozone levels since the 1970's. Typically, measured ozone levels in Connecticut exceed the

**“Connecticut air quality experts believe that ongoing efforts to reduce ozone precursor emissions (oxides of nitrogen and volatile organic compounds) through 2020 coupled with the issuance of more stringent NAAQS for ozone, will largely reduce ozone concentrations before the effect from higher temperatures outpaces mitigation efforts by mid- to late-century.”**

National Ambient Air Quality Standards (NAAQS) on several days each summer, depending on weather conditions. Although the state is classified as “nonattainment,” peak ozone levels and the number of days on which air quality in Connecticut exceeds the standard have steadily decreased since 1974 as a result of numerous local, regional and national emission control strategies (CEQ 2008; CTDEP 2009).

Assuming no additional control measures are adopted in Connecticut, increases of ozone production due solely to temperature increases could undo much of what has been accomplished in Connecticut since 1983 in terms of ozone abatement.

The risk to Connecticut’s air quality due to the climate driver of higher temperatures was rated as medium by air quality experts during the risk assessment process conducted by the workgroup. Connecticut air quality experts believe that ongoing efforts to reduce ozone precursor emissions (oxides of nitrogen and volatile organic compounds) through 2020 coupled with the

issuance of more stringent NAAQS for ozone, will largely reduce ozone concentrations before the effect from higher temperatures outpaces mitigation efforts by mid- to late-century. This means that any potential increases in ozone formation due solely to the climate change driver of

higher temperatures will likely be of concern only in the mid to later years of this century (2050/2080).

### *Extreme Heat Events*

Extreme heat can cause heat cramps, heat exhaustion, heat stroke and death. Heat cramps are muscular pains and spasms due to heavy exertion. Although heat cramps are the least severe, they are often the first signal that the body is having difficulty cooling itself. Heat exhaustion occurs when blood flow to the skin increases, causing blood flow to decrease to the vital organs, which results in a form of mild shock. If heat exhaustion is not treated, the victim's condition will worsen; body temperature will keep rising and the victim may suffer heat stroke. Heat stroke is a life-threatening condition that occurs when the victim's temperature control system, which produces sweating to cool the body, stops working. Body temperature can rise so high that brain damage and death may result if the victim is not cooled quickly. Most heat disorders occur because the victim has been overexposed to heat or has over-exercised for his or her age and physical condition. Extreme heat vulnerability can be compounded if a person is overweight or sick.

Although Connecticut Light and Power determined that eighty percent of homes in their service territory had some form of air conditioning (e.g., central, window, room) in 2005, certain populations, such as the elderly and economically disadvantaged, are less likely to have air conditioning in their residences. In addition, those that work outdoors also will be at increased risk during extreme heat events. Employees who work outside could account for slightly over five percent<sup>2</sup> or more of the workforces, however, statistics are only kept by industry category and not by job specification, so the number of employees who work outside for all or part of their job could be much higher (Connecticut Department of Labor 2009).

### *Vector-Associated diseases*

Vector-associated diseases will likely be impacted by climate change. These diseases can be transmitted from ticks (e.g., Lyme disease) and mosquitoes (e.g., West Nile Virus). According to the public health workgroup, ticks and mosquitoes are very likely to increase due to climate change, and their associated diseases may pose a greater risk in Connecticut. Temperature, precipitation, soil moisture, and water runoff are all drivers of vector-associated diseases. Climate change alters ecosystems that will increase vector survival, replication, biting frequency, and geographic range.

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<sup>2</sup> Employment for the industries of agriculture, mining, construction and arts, entertainment and recreation (museums, historical sites, zoos and parks and amusement, gambling and recreation) covered by unemployment insurance for the 3<sup>rd</sup> quart 2008 (September).

## IV. Workgroup Intersections

During the impacts assessment phase it became apparent that there were intersections among a number of common planning areas across workgroups. These workgroup intersections included water quality and quantity, transportation, education, ecosystem services and buildings, and each workgroup discussed these intersections at length. During the adaptation strategies development phase, representatives from each workgroup will meet to discuss adaptation strategies for these intersections, so that the process will benefit from each workgroup's insight and the adaptation strategies will not impede the goals and outcomes of another workgroup.

### Water Quality and Quantity

The importance of having abundant and clean water was determined to be essential to each workgroup, and the potential variability in water quality and quantity due to climate change was determined to have a high impact on the core functions of agriculture, infrastructure, natural resources and public health. The Infrastructure Workgroup determined that more frequent and intense droughts will decrease the quantity of available water, while increased precipitation and extreme precipitation events will increase stormwater and wastewater volumes, and thus decrease water quality from related pollutant loads. Sea level rise also can impact Connecticut's water supply by increasing salt intrusion in fresh water resources, including the numerous private wells along the shoreline. The projected combination of sea level rise and increased precipitation could lead to higher groundwater levels, which would limit the usefulness of infiltration galleries and other best management practices (BMPs) used to offset peak runoff impacts from stormwater. Increased precipitation will increase stormwater and wastewater, which could overwhelm existing stormwater and wastewater infrastructure, including sewers, combined sewer systems, sump pumps and pump stations, and thus decrease water quality. In addition, higher groundwater tables may contribute to contaminant leaching from landfills, further decreasing water quality.

Abundant and clean water are important for Connecticut agriculture for crop irrigation and animal husbandry. Furthermore, the timing of precipitation events was also determined to be critical by the Agriculture Workgroup. . Too much precipitation during planting and harvesting periods could lead to decreased crop yields. Decreased crop yields, especially for economically important warm weather produce, would negatively impact Connecticut's agriculture industry. Too much precipitation also could lead to increased fungus infections and reduced pollen production in fruit trees. In addition, the resulting runoff from increased winter precipitation will decrease the water quality for shellfish breeding, which will increase shellfish contaminants and bed closures.

A number of the Natural Resources Workgroup habitats would be negatively affected by a change in the quality and quantity of Connecticut's water supply. In particular, effects of climate change on water supplies in Connecticut would likely exacerbate the threats to riverine resources already stressed by summer low flow conditions. This would result from increased societal

#### Top 5 Workgroup Intersections

1. Water Quality and Quantity
2. Education
3. Ecosystem Services
4. Buildings
5. Transportation

demand for water during periods of extended warming and drought. Effects would be magnified in water supply systems reliant upon groundwater sources and on surface water sources without sufficient storage capacity. Changes in stream flow could result in population reductions or localized extinctions of biota in small headwater streams, and the changes in the timing of high flows could conceivably effect spawning-related migration and the survival of early life history phases (i.e., eggs and larvae) of some fishes. Like the Agriculture Workgroup, the Natural Resources Workgroup is concerned with the affect of climate change-induced, poor water quality on shellfish. Shellfish in Long Island Sound provide an important ecosystem service, removing excess nutrients from the water. This water filtration is essential to supporting commercial and recreational fishing, since many valuable fish and shellfish species depend on clean water to survive. Water quality also affects swimming, since poor water quality can lead to beach closures and decrease desire to visit beaches due to increased public health concerns. This would limit recreational opportunities and could lead to decreased tourism revenues for state businesses. In addition, Connecticut's water supply may affect the distribution and viability of herbaceous freshwater wetlands, forested swamps and bogs and fens.

Decreased water quality and quantity also can directly affect public health. Increased stormwater runoff can compromise drinking water supplies with contaminants, such as pesticides, salts, metals, organic chemicals, viruses and bacteria. Short-term exposure to these contaminants can result in temporary ailments, such as gastroenteritis, while long-term exposure to high levels of some contaminants can result in kidney failure, cancer and reproductive deficiencies.

## Education

All of the workgroups saw the need to educate not only the public on the impacts of climate change on Connecticut agriculture, infrastructure, natural resources and public health, but also their own stakeholders. For example, Connecticut agriculture will need to educate both consumers on the changing food supply and prices, and farmers on how to productively adapt.

**“Research has shown that coastal marsh in United States provides approximately \$23 billion annually in hurricane protection services. In Connecticut, reduction in storm damage costs by coastal wetlands is estimated at \$13,000 per acre annually”**  
(Costanza et al. 2008).

## Ecosystem Services

Multiple workgroups recognized the benefit of ecosystem services, which refer to the many ways in which ecosystems support and fulfill peoples' lives. These services include production of goods (food, timber), life-support processes (maintaining soil fertility, purifying water, mitigating floods, stabilizing climate), and life-fulfilling conditions (providing aesthetic beauty, biodiversity and cultural stimulation). Ecosystem services also provide protection for man-made structures. For example, tidal marshes often buffer the effects of coastal inundation and flooding as a result of increasing sea levels and intense storms. Research has shown that coastal marsh in United States provides approximately \$23 billion annually in hurricane protection services. In Connecticut, reduction in storm damage costs by coastal wetlands is

estimated at \$13,000 per acre annually (Costanza et al. 2008). As sea level rises, these coastal

wetlands may migrate inland, if able, and allowed access to undeveloped and deconstructed shoreline. However, if hard protection measures are implemented to protect private property from rising sea level, wetland migration may be prevented. In these cases, coastal wetlands are likely to be inundated by rising sea level and ultimately converted to open water, thus forfeiting the flood control and storage services and associated cost reductions. If these tidal marshes are further degraded by climate change, large increases in federal, state and municipal funding will be needed to control coastal flooding, install additional infrastructure to protect property and human life, and repair repetitive flood damage.

Unfortunately, the ability of Connecticut's natural resources to deliver ecosystem services is already being altered by habitat degradation, land and water conversion and pollution, and now the likely impacts from climate change will further habitat degradation and conversion. Given the importance of the ecosystem services provided by natural resources, the Natural Resources Workgroup recommended that careful consideration of both the benefits and true costs of degradation and loss should be standard practice in the assessment of the impacts to climate change across multiple sectors and locations within the State.

### **Buildings**

All of the workgroups were concerned, to some extent, with the future structural integrity and location of buildings in Connecticut in light of climate change impacts. Specifically, the Agriculture, Infrastructure and Public Health workgroups were concerned with the structural integrity of buildings, particularly historic structures, strained from increased precipitation and sea level rise, while the Natural Resources workgroup expressed concern with the impact of increased building run-off on natural habitats. Furthermore, the Natural Resources workgroup has already expressed concern about the impact of the relocation of buildings as an adaptation strategy, which could further habitat fragmentation, thus reducing the resiliency of habitats to adapt to climate change.

### **Transportation**

Transportation, an Infrastructure Workgroup planning area, was determined to be critical for the core functions of agriculture and public health in Connecticut, as well as other infrastructure planning areas. Delayed agriculture inputs, such as seeds, animal feed and labor, will hinder or even halt the production of agricultural goods, while goods that are delayed from processing or direct sale may spoil. Obstructed transportation would impede the treatment of patients during extreme weather events, and could complicate evacuation and sheltering, especially in EJ communities. As with buildings, the Natural Resources workgroup has already expressed concern about the impact of the relocation of transportation avenues as an adaptation strategy, which could further habitat fragmentation, thus reducing the resiliency of habitats to adapt to climate change.

### **Intersections Beyond State Borders**

Although this report addresses the impacts of climate change on Connecticut only, the workgroups acknowledged the importance of understanding the interconnections between climate impacts, risks, and opportunities on the regional, national, and global levels. For example, decisions about what foods are grown where in the U.S. are based on many factors and interrelationships, including climate suitability, land quality and availability, local economies, and infrastructure. As climate change impacts influence food growing decisions in Connecticut,

changing climates in other regions will influence food production decisions there as well. Whereas there may not be adequate land, economic, or infrastructure conditions to feasibly grow certain crops in Connecticut today compared to other regions, as climate and other factors change, Connecticut might become better suited to grow those same crops in the future, as other regions of the country face severe decreases in water availability. While it is difficult to accurately predict the many changes that will affect agricultural productivity in the next few decades, and even more difficult to imagine how changing productivity in one region will influence food growing decisions in other regions, it will be critical to seek to understand these interconnections to build resilient food systems and food security. As such, it is very important to develop strong regional, national, and global dialogues on climate change impacts on agriculture and food production.

## V. Recommendations

The primary focus of this report has been on assessing the impacts of a changing climate on Connecticut's infrastructure, natural resources and ecological habitats, public health, and agriculture resources. Along the way each workgroup began making some early connections to the adaptive measures that will be more fully explored in the second phase of this effort. What follows is an introduction to some of the critical adaptations and needs for future research that have already been identified.

### **Agriculture**

Additional research and monitoring programs can help determine when risk of crop damage is elevated. Monitoring long-term changes in temperature, precipitation and sea level, is needed to more closely define trends in climate change. More specifically, expansion of monitoring systems for emerging insect pest and plant disease pathogens in integrated pest management programs is needed to identify imminent threats to crop systems and to mitigate economic losses. New crops need to be evaluated for their ability to survive warmer and wetter conditions. Moreover, research on sustainable agriculture is needed to develop more efficient growing practices and resilient food production systems. More attention is needed on proper land management practices to maintain soil health, prevent soil erosion, conserve water supplies, and protect water quality. Water is critically needed for irrigation, especially during prolonged periods of drought. Protecting Prime, Statewide and Locally Important Farmland Soils from competing land use changes will ensure a land base most resilient to the impacts of climate change. Further research is necessary on shellfish aquaculture to select disease-resistant shellfish strains for culture in Connecticut waters, identify pH thresholds for locally grown species, and determine adaptive strategies to mitigate the effects of increased disease prevalence and ocean acidification (if deemed necessary). These findings should be disseminated to Connecticut aquaculturists so that they may be implemented by the industry.

### **Infrastructure**

Research and detailed assessment is needed to improve our understanding of changing climate effects on infrastructure and our ability to adapt. Mapping of exact location and elevation of public and private infrastructure in Connecticut, its value and condition, for example the planning area of Buildings and Facilities, are key to more accurate and useful risk assessments. New flood and sea level maps, and engineering assessments of risk factors will allow a more exact assessment of risk with projected climate change, and the potential for site-specific adaptation. The location and elevation data could then be used to model the impact of future climate conditions. Finally, future monitoring of climatic conditions and sea level and associated research on the effects of climate change on Connecticut infrastructure are a continuing need.

### **Natural Resources**

The Natural Resources Workgroup identified the need to address the following topics: 1) habitats within the larger context of Connecticut's overall landscape; 2) specific threats to habitats at risk that may be amplified by climate change; and 3) areas where additional information (i.e., data gaps) is needed through research, surveys or monitoring. In addition, the habitat types evaluated

in this report should be revisited to assess their size (acreage), distribution, and/or connectivity within the state of Connecticut and generally within the southern New England region. Information on local and regional distribution, along with the habitat-at-risk assessment done in this report, provides a valuable context for making subsequent climate adaptation decisions on implementation.

### **Public Health**

During the climate change impacts assessment planning and reporting period, the members of the Public Health Workgroup and the rest of the public health community in Connecticut were required to reprioritize limited resources due to the pandemic H1N1 influenza virus. Due to this more pressing priority, the Public Health Workgroup's efforts were more limited in scope and, thus, this report entails a more limited review of the potential impacts of climate change on public health. The Public Health Workgroup believes a more thorough assessment, particularly in the area of public health infrastructure, is warranted and that it will be a worthwhile endeavor to revisit this element of Connecticut's Climate Change Adaptation Plan at a later date.

## VI. Public Comment

In developing this assessment report, the Adaptation Subcommittee involved stakeholders and experts across a wide range of topics. Workgroup members included scientists, engineers, farmers, local and state policy makers, public health officials, planners and small-business owners. Most had many years of practical experience in their field of expertise.

Following the drafting of the workgroup assessments, the Adaptation Subcommittee conducted two public outreach meetings to present the initial findings of the workgroups and solicit comment. In addition to the formal public information meetings, the draft reports were posted on the state's climate change website<sup>3</sup>, where comments were accepted electronically.

In total, 13 different people commented at one of the public forums or through the website. All comments were shared with the co-chairs of the workgroups and were considered in the drafting of this final assessment report. A brief table summarizing the comments is provided in Appendix C of this report. Many comments applied to the overall process, and fell into a few common categories that are addressed below. Some of the other comments directly related to the subject matter of the workgroups will be considered in the subsequent development of adaptation strategies.

### *Mitigation*

A few commenters focused on the need to continue efforts to mitigate greenhouse gas emissions, and in some cases provided specific commercial solutions to mitigating emissions. Since this assessment is focused on the impacts associated with climate change rather than mitigation, this category of comments is not addressed in this report. However, these comments will be brought to the attention of the Governor's Steering Committee on Climate Change (GSC), the state entity that directs migration efforts, for their future consideration.

### *Is climate change really happening?*

A number of commenters used these forums to express their skepticism of the underlying science of climate change. All good scientific debate must be undertaken with some level of skepticism, and that debate has taken place in other national and international forums and the conclusion has been that it is "unequivocal" that the climate is warming (IPCC 2007). Due to the overwhelming supporting evidence, and guidance from the federal government, academia, non-profits and the business community, we have chosen not to revisit the validity of climate change debate in conducting this assessment. Furthermore, the Adaptation Subcommittee was charged by the General Assembly with conducting an assessment of the *impacts* of climate change, and not with the evaluations of degree of change, therefore, we have used peer-reviewed, published projections from experts in the field of climate change modeling.

While the exact degree of change is still dependent on future mitigation actions, this assessment takes a precautionary approach. Caution dictates that we accept the position that change is

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<sup>3</sup> [www.ctclimatechange.com](http://www.ctclimatechange.com)

already underway. In fact, projections show that global mean temperatures are projected to increase over the next several decades even if emissions are drastically cut today. Risk management and planning is an iterative process so these projections will continue to be evaluated. Furthermore, it is important to recognize that most, if not all, of the areas of impact assessed in this report are also at risk from other ongoing threats, which may be ameliorated through the co-benefits derived from adaptation strategies.

*Why were the NPCC and NECIA projections chosen to guide the impacts assessment?*

As stated earlier in this report, some have questioned the data used to project change in Connecticut, claiming there is more current or site-specific information. The constraints on both time and resources have dictated that we rely on the information that is currently available, and has been widely vetted. However, we also recognize the need to consider both updated and more localized data. In fact, all of the workgroups expressed the need for, and recommended continuous climate change monitoring. The work that will be undertaken over the next few months will identify future areas where additional information is appropriate and the workgroups will craft adaptive recommendations that include the necessary site specific or temporal data needs.

Finally, we received a few sets of detailed comments on agriculture, infrastructure, natural resources and public health that have been shared with the appropriate workgroups and have, to some extent, been incorporated into this report. The rest of the comments were more appropriate for the upcoming strategy development phase, and the workgroups will consider them at this time. The Adaptation Subcommittee appreciates the time and effort of all the commenters, and will continue to solicit public dialogue throughout the next phase of this effort.

## VII. Next Steps

With the conclusion of the climate change impacts assessment phase, the Adaptation Subcommittee will now develop recommended adaptation strategies for the most impacted features of Connecticut agriculture, infrastructure, natural resources and public health. Adaptation strategies and related implementation plans will be detailed in a report due to the Connecticut Legislature in mid-2010.

The development of the adaptation strategies will be again led by the Adaptation Subcommittee workgroups. The workgroups will engage in a process determined by the Adaptation Subcommittee to prioritize and plan the implementation of the strategies. In addition to the workgroups, a small group made up of representatives from each workgroup also will be formed to discuss adaptation strategies for workgroup intersections. Again, public comment will be integral to this phase of the adaptation process.

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# Appendix A: Risk Assessment Questions

*These questions were located on the first and second pages of the risk worksheet, given to participants at the Adaptation Subcommittee workgroup workshops, and are adapted from Snover et al. 2007. Responses from these questions were used to direct the risk assessment question and to provide guidance to the participant when determining the risk assessment matrix score.*

## Sensitivity of the Feature to Climate Change:

1. What are the known climate conditions relevant to features (direct and indirect; e.g., summer temperature, winter precipitation)?
2. How do known climate conditions currently affect the feature?
3. How exposed is the feature to the impacts of climate change?
4. Is the feature subject to existing stress, not caused by climate change?
5. How are known climate conditions projected to change?
6. What are the projected impacts of changes to feature in this planning area without preparedness action?
7. Will climate change cause the demand for a resource to exceed its supply?
8. Does the feature have limiting factors that may be affected by climate change?
9. What is the 'impact threshold', or the level at which sensitivity to climate conditions increase, associated with the feature?
10. What is the degree of feature sensitivity to climate change (Low, Medium, High)?

## Adaptive Capacity of Feature:

1. Is the feature associated with the planning area already able to accommodate changes in climate?
2. Are there barriers to a feature's ability to accommodate changes in climate?
3. Are the features already stressed in ways that will limit their ability to accommodate changes in climate?
4. Is the rate of projected climate change likely to be faster than the adaptability of the feature in this planning area?
5. Are there efforts under way to address impacts of climate change related to features in this planning area?
6. What is the adaptive capacity of feature (Low, Medium, High)?

# Appendix B: Agriculture



A Report by the Agriculture Workgroup  
of the Adaptation Subcommittee

*January 2010*



Connecticut Climate Change

Connecticut's 4,916 farms, comprising 405,616 acres (13.1% of state's total area), contribute to the quality of life and rural character that state residents have come to expect. Total sales of Connecticut's agricultural products exceed \$551 million (2007), with an overall effect of contributing billions to the Connecticut economy annually. The Connecticut agricultural industry provides a diverse, high quality harvest to Connecticut residents (Figure 1) and to markets around the world, including oysters, fruits, vegetables, meat, milk, eggs, witch hazel, tobacco and horticultural products.

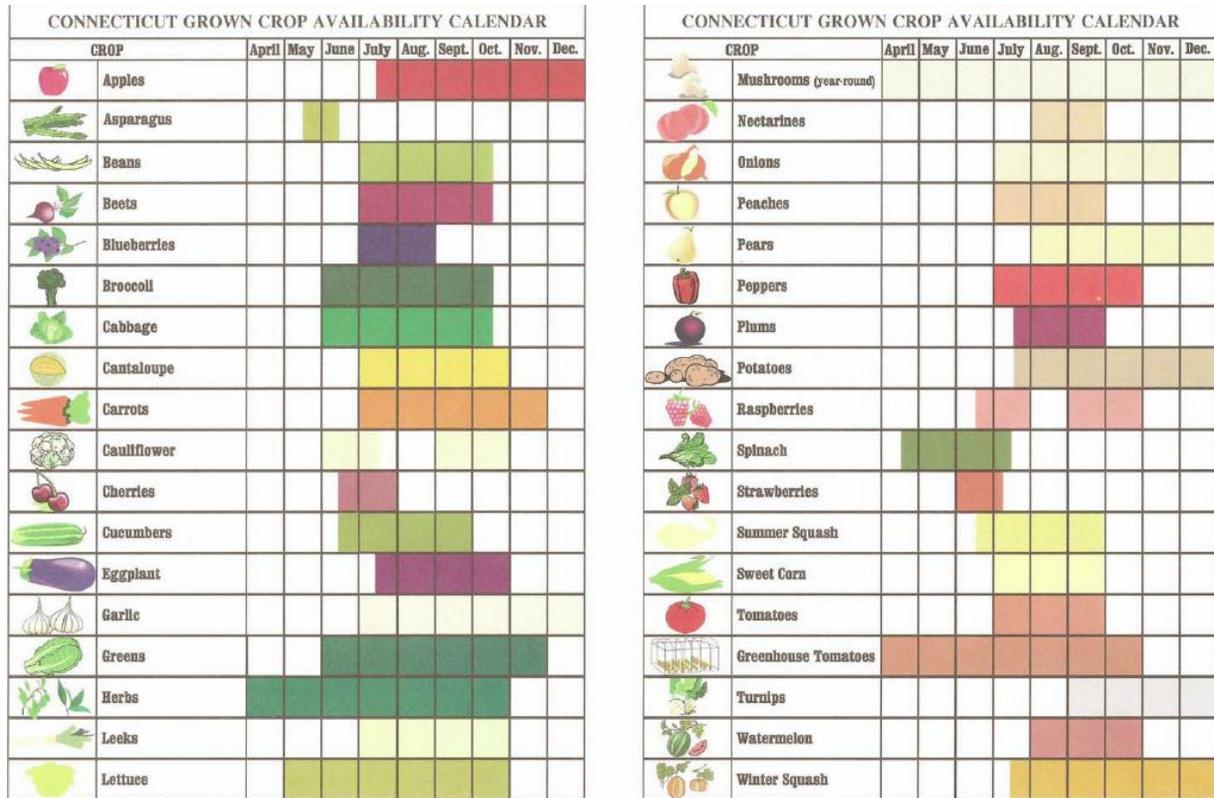
Connecticut agriculture has numerous strengths to sustain this thriving agricultural industry. Located in southern New England, Connecticut has areas of excellent agricultural soil, and enough water to sustain its needs. Every Connecticut town contains agricultural lands, and the diversity of agricultural commodities grown in the state is of tremendous benefit to its residents. Connecticut also has over 30 million customers within the state and neighboring states, which are increasingly demanding fresh, local products.

#### Connecticut Agricultural Achievements Include:

- The most valuable oyster crop in the country;
- New England leader in the production of pears (ranked ninth in the country) and peaches;
- Top producer of black currants in North America;
- Largest New England producer in the production of tomatoes, tobacco, green beans and asparagus;
- Largest producer and processor of witch hazel in the country;
- Horticultural leader, and largest rhododendron grower, in the Northeast;
- One of highest ranking states based on density of horses per square mile, with the value of horses in state estimated at over \$300 million;
- Home of the fifth largest egg production farm in the country, and second highest chicken inventory and total eggs produced in New England (223 table eggs per capita produced per year); and
- One of the highest producers of milk on a per cow basis east of Michigan.

Despite its strengths, Connecticut agriculture is currently stressed by a number of non-climate change related factors. Connecticut is a very expensive state for agricultural business; costs of labor, land and other inputs can exceed revenue based on nationally-set agriculture prices (e.g., milk) or what consumers are willing to spend. High quality agricultural land is diminishing, and existing farm land is often fragmented and at odds with the surrounding land uses. Agricultural activities can be heavily regulated in Connecticut, further challenging economic viability. Additionally, multiple use conflicts in Long Island Sound (i.e., access to harbors and recreational use of the water) negatively impact shellfish aquaculture.

Public Act 08-98 tasked the Governor's Steering Committee on Climate Change (GSC) to assess the impacts of climate change to Connecticut agricultural industry. The Adaptation Subcommittee of the GSC established an Agriculture Workgroup to specifically address this threat. The Agriculture Workgroup is co-chaired by F. Philip Prelli, Commissioner of the Connecticut Department of Agriculture (CT DoAG), President of Food Export USA- Northeast and Executive Committee Secretary of the National Grange, and Steven K. Reviczky, Executive Director of the Connecticut Farm Bureau Association (CFBA), and comprised of agricultural leaders from academia, government, and the farm community.



**Figure 1:** This table illustrates just some of the agricultural crops grown in Connecticut, and the timeframes when these crops are available for consumption. Connecticut agriculture grows both crops that require cool temperatures, such as asparagus and turnips, and warm temperatures, such as tomatoes and peaches.

The Agriculture Workgroup held its first organizational meeting on April 6, 2009 and began a collaborative climate change risk assessment process, involving several meetings, of compiling the existing strengths, weaknesses, opportunities and threats, including threats posed by climate change, of Connecticut agriculture (i.e., SWOT analysis; Appendix A). The Agricultural workgroup then developed a list of agricultural planning areas and associated features, based on U.S. Department of Agriculture (USDA) commodities (See Table 1), and specifically discussed the impacts from critical climate drivers of precipitation, temperature, sea level rise and air quality (ozone and carbon dioxide). On August 24, 2009, the Agriculture Workgroup held a risk assessment workshop at University of Connecticut (UConn) specifically to survey Connecticut agriculture stakeholders on climate change impacts to agriculture. The CT Department of Environmental Protection compiled the responses collected at the risk assessment workshop (See Table 2), which are discussed further in the “Findings” section below.

Some limiting factors in the agriculture risk assessment process were inevitable. The Agriculture Workgroup limited the scope of the risk assessment geographically to agriculture within the state of Connecticut. The Workgroup invited participants to the risk assessment workshop for a good cross section of expertise representing the 10 top agricultural commodities in Connecticut. The risk assessment workshop was held in late August at UConn, prior to the start of the school season and fall harvest. A workshop at a different time of year and open to the public may have

led to similar results, or some additional information not considered by the Agriculture Workgroup. However, the Agriculture Workgroup will have another opportunity for agriculture stakeholder input during the public informational meetings and comment period in December 2009. Furthermore, the Agriculture Workgroup hopes to periodically review the status of climate change conditions and agricultural adaptation in Connecticut, and adjust findings and strategies, as necessary.

**Table 1:** *Agriculture planning areas and associated features used in the climate change risk assessment process. These planning areas are based on the agricultural commodity categories in the 2008 U.S. Department of Agriculture Agricultural Census of Connecticut because it provided complete demographic and economic data on Connecticut agriculture. The associated features helped to separate the many complexities of the sometimes broad agricultural commodities, and were determined to be uniquely affected by climate change.*

<b>Planning Areas</b>	<b>Features</b>
Nursery, Greenhouse, and Sod	greenhouse production
	outside production (trees, shrubs, non-vegetable herbaceous plants)
	sod
Dairy	animal husbandry
	feed production
Poultry	egg production
	meat production
Fruit orchards	apple and pear production
	peach, nectarine and plum production
	cherry production
Small fruits	berry production
	grape production
Produce	warm weather crops (e.g., tomatoes)
	cool weather crops (e.g., spinach)
Forestry production	maple syrup
	witch hazel
	cut Christmas trees
	wood production (e.g., lumber, saw logs)
	biofuel crops
Aquaculture	shellfish
	finfish
Non-Poultry Animal Livestock	animal husbandry (beef cows, sheep and goats, pigs and horses)
	feed production
	bees
Tobacco	

**Table 2:** This table displays the risk assessment data, in order of risk, for the agriculture planning areas and associated features. The data was compiled from agriculture stakeholders who attended the Agriculture Risk Assessment Workshop in August 2009.

Planning Area	Feature	Average Likelihood	Average Magnitude	Most Often Risk Category Answer	Average Risk Score	Most Often Climate Driver 1 Answer	Most Often Climate Driver 2 Answer	Most Often Time Answer	Groups
Forestry Production	<a href="#">maple syrup</a>	3	3	High	-9	Temperature	Air Quality	2020	3
Dairy	<a href="#">feed production</a>	2.83	2.75	High	-7.83	Precipitation	Temperature	2020	4
Non-poultry Animal Livestock	<a href="#">feed production</a>	2.73	2.36	High	-6.36	Precipitation	Temperature	2020	4
Dairy	<a href="#">animal husbandry</a>	2.73	2.27	High	-6.00	Temperature	Precipitation	2020	4
Produce	<a href="#">warm weather crops</a>	2.89	2.56	High	-6.00	Precipitation	Temperature	2020	2
Aquaculture	<a href="#">shellfish</a>	3.25	1.75	High	-5.86	Temperature	Air Quality	2020	5
Non-poultry Animal Livestock	<a href="#">animal husbandry</a>	2.64	1.91	high	-5.36	Temperature	Temperature	2020	4
Non-poultry Animal Livestock	<a href="#">bees</a>	2.83	2.00	High	-5.17	Temperature	Precipitation	2020	1
Fruit Orchard	<a href="#">apple and pear production</a>	2.53	2.12	High	-4.78	Precipitation	Temperature	2020	1, 4
Forestry Production	<a href="#">wood production</a>	2.90	2.20	High	-3.80	Temperature	Precipitation	2020	3
Nursery, Greenhouse, and Sod	<a href="#">outside production</a>	2.73	2.55	High	-3.55	Precipitation	Precipitation and Temperature	2020	3
Forestry Production	<a href="#">cut Christmas trees</a>	2.55	2.36	High	-2.18	Precipitation and Temperature	Precipitation	2020	3
Nursery, Greenhouse, and Sod	<a href="#">greenhouse production</a>	2.55	2.36	High	-1.18	Temperature	Temperature	2020	3
<b>Tobacco</b>		2.50	2.25	high	0.00	Precipitation	Temperature	2020	2
Produce	<a href="#">cold weather crops</a>	2.50	1.63	High	1.11	Temperature	Precipitation	2020	2
Aquaculture	<a href="#">finfish</a>	3.00	1.00	Medium	-2.71	Temperature	Precipitation	2050, 2080	5
Nursery, Greenhouse, and Sod	<a href="#">sod</a>	2.64	2.09	Medium	-2.27	Precipitation	Temperature	2020	3
Fruit Orchard	<a href="#">peach, nectarine and plum production</a>	1.86	2.00	Medium	1.29	Temperature	Precipitation	2020	1
Forestry Production	<a href="#">witch hazel</a>	2	2	Medium	4	Precipitation	Temperature	2020	3
Forestry Production	<a href="#">biofuel crops</a>	2.45	2.36	High and Medi	4.27	Precipitation	Temperature	2020	3
Small Fruit	<a href="#">berry production</a>	2.20	1.60	Low	-0.60	Temperature	Precipitation, Temperature and Air Quality	2050	1,2
Poultry	<a href="#">Egg production</a>	2.00	1.20	Low	0.00	Precipitation	Precipitation and Temperature	2080	5
Poultry	<a href="#">meat production</a>	1.75	1	Low	0.6	Precipitation and Temperature	Precipitation	2080	5
Small Fruit	<a href="#">grape production</a>	1.88	1.63	Low	2.50	Temperature	Precipitation	2020	1,2

### Key Climate Drivers

The Adaptation Subcommittee adopted climate change projections from the New York Panel on Climate Change (NPCC 2009) as a basis for risk assessment analysis for all workgroups. Based on these projections, participants in the agriculture risk assessment workshop identified that the key climate drivers for Connecticut agriculture will be temperature and precipitation, with air quality a distant third. Sea level rise would have a localized effect mostly on the small number of shoreline farms (e.g., salt hay), and low-lying coastal and south central river valleys,

and the location of aquaculture activities (i.e., sea level rise may impact associated land-based infrastructure or lead to the relocation of shellfish beds in Long Island Sound).

Higher average annual temperatures are expected, especially in summer, and there will be more incidences of extreme heat. Rising temperatures will have both positive and negative impacts on Connecticut agriculture. Higher temperatures will lengthen the growing season, resulting in increased crop yields and the ability to grow new crop varieties, and warmer winters will decrease the heating need, especially in greenhouse production. However, a longer growing season and warmer winters may increase the quantity and variety of agricultural pests, pathogens and diseases (e.g., Fuhrer 2003; Ziska, Teasdale and Bunce 1999; Rose et al. 2001), which could necessitate changes in crops or crop varieties, changes in farming practices, or changes in pest control methods. Warmer winters may not meet the winter chill requirement for some fruit varieties, and the absence of the dichotomy of warm late-winter days and cold nights will lead to the decline of the Connecticut maple syrup industry. Higher summer temperatures, especially when coupled with increased incidences of summer drought, could have a dramatic effect on Connecticut agriculture. Greater water evaporation will require more irrigation/watering and/or changes in farming practices and/or changes to the types of crops and livestock produced in Connecticut. Water for irrigation may already be in short supply due to inadequate water supply infrastructure and increasing competition from non-agricultural uses. Heat stress will decrease livestock production, especially milk production, and crop yields or call for large-scale changes in livestock and crop varieties and methods. In addition, heat stress may hinder the productivity of farm employees. Heat stress will require changes in cooling systems, or crop and livestock varieties and growing methods, possibly including more expensive cooling measures, such as greenhouse misters, barn fans and air conditioning and a change to labor practices. Warmer water temperatures may change the species composition and impact the quantity and quality of shellfish (Hofmann et al. 2001) and finfish.

An increase in the total annual precipitation in Connecticut is likely. However, most of the precipitation towards the end of the century is projected to come in the winter and be in the form of rain rather than snow. In contrast, more frequent and longer droughts are expected during the summer due to increased evaporation. More intense storms may also increase in frequency, which will increase the intensity and frequency of flooding. Thus, Connecticut agriculture will have more available precipitation than is projected for other parts of the country, but the variability in precipitation (i.e., timing and intensity) may cause problems. Rising groundwater levels and soil saturation and flooding could cause delayed planting and harvesting, and may diminish crop yields or lead to crop failures. The additional precipitation and intense storm events will require costly additional conservation practices to prevent erosion and water quality impairments. More pesticides and fertilizers may be needed due to increased leaching and runoff, which will decrease the state's water quality and threaten shellfish beds in Long Island Sound. Farmland located on well drained soils will be in more demand for both development and farming because moderately well drained and poorly drained soils will become even wetter. Droughts may increase the need for crop irrigation and livestock watering, which would necessitate extensive changes in what is grown and how it is grown and/or expensive upgrades in water infrastructure and conservation practices on the farms. Some crops, such as silage corn, may become too expensive to cultivate if droughts increase. Extreme weather events will lead to crop failures and farm infrastructure damage from high winds, flooding, hail or ice damage.

Changes in air quality due to climate change will affect plant, livestock and agricultural employees' health. The Agriculture workgroup discussed two components of air quality, ozone and carbon dioxide, which will be increased by climate change and impact Connecticut agriculture. Ground level or tropospheric ozone, a secondary pollutant and major component of smog, is found at a higher concentration in rural areas due, in part, to a lack of urban haze which can obstruct sunlight, a key ozone-producing component. Crop studies have shown that exposure to chronic levels of ozone resulted in decreased photosynthesis, dry matter and yield. However, the impact of ozone on crops also has been shown to be mitigated under elevated carbon dioxide (Hatfield et al. 2008). Livestock is indirectly affected by ozone when their forage crops and pasture yield is decreased due to ozone. Human exposure to ozone has been linked to a number of respiratory health effects, including significant decreases in lung function and inflammation of airways. Ozone exposure also has been shown to cause new-onset asthma and increased sensitivities to allergens (Shea et al. 2008). These ozone-induced ailments may limit the number of hours or shift the time when agricultural employees can work outside during high ozone summer days.

The rise in carbon dioxide may have mixed effects on agriculture in Connecticut. Increasing carbon dioxide will increase ocean acidity (an increase of 0.3-0.5 pH units by 2100 is projected; Caldeira and Wickett, 2005) which may negatively impact the survival rate of shellfish (Fabry et al. 2008; Green et al., 2004; Watson et al., 2009) and the marine food chain. Research has shown that C<sub>3</sub> crops<sup>4</sup>, which are most of the plants grown as crops in Connecticut, will respond favorably to increased carbon dioxide. An increase of carbon dioxide from 380 ppm to 440 ppm is projected to increase crop yield, decrease irrigation needs and reduce ozone toxicity (Hatfield et al. 2008; Fuhrer 2003). However, an increase in temperature of just 1.2° C (projected increase by 2020), will negate all of the carbon dioxide-induced benefits to agricultural crops (Hatfield et al. 2008). The net effect of increased carbon dioxide and warmer temperatures also may increase the biomass and competitiveness of C<sub>4</sub> agricultural weeds and the development rate of many agricultural insect pests may be increased (Fuhrer 2003). Farmers also may lose the ability to combat common agricultural C<sub>3</sub> weeds, such as lambsquarters (*Chenopodium album*), due to increased glyphosate (i.e., the active ingredient in Roundup®) resistance from increased carbon dioxide (Ziska, Teasdale and Bunce 1999).

### **Risk Assessment Process**

The Agriculture Workgroup examined the risk of climate change-induced changes (i.e., climate drivers) to temperature, precipitation, sea level rise and air quality (ozone and carbon dioxide) to the planning areas and associated features (Table 2) of:

- Nursery, Greenhouse and Sod (greenhouse production, outside production and sod);
- Dairy (animal husbandry and feed production);
- Poultry (egg production and meat production);

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<sup>4</sup> C<sub>3</sub> and C<sub>4</sub> plants have slightly different photosynthesis pathways that allow C<sub>4</sub> plants to more efficiently capture and use ambient carbon dioxide. Therefore, increasing carbon dioxide makes it more easily available for the C<sub>3</sub> plants. Most of the crops that are grown as crops in Connecticut have a C<sub>3</sub> photosynthetic pathway, while C<sub>4</sub> crops account for relatively few Connecticut crops, such as corn.

- Fruit orchard (apple and pear production, peach, nectarine and plum production, and cherry production);
- Small fruits (berry production and grape production);
- Produce (warm weather crops and cool weather crops);
- Forestry production (maple syrup, witch hazel, cut Christmas trees, wood production and biofuel crops);
- Aquaculture (shellfish and finfish);
- Non-poultry animal livestock (animal husbandry, feed production, bees); and
- Tobacco.

These planning areas are based on the agricultural commodity categories in the 2008 USDA Agricultural Census of Connecticut because it provided complete demographic and economic data on Connecticut agriculture. The associated features helped to separate the many complexities of the sometimes broad agricultural commodities, and were determined to be uniquely affected by climate change.

To obtain input from agricultural stakeholders in Connecticut, the Agriculture Workgroup decided to conduct a risk assessment workshop focused on impacts to Connecticut agriculture posed by climate change. The workshop included farmers from every planning area listed above, as well as representatives from academia (e.g., UConn and Yale University), government (e.g., The Connecticut Agricultural Experiment Station, and National Oceanographic and Atmospheric Association) and agricultural non-profits (e.g., Connecticut Northeast Organic Farming Association and American Farmland Trust; See Appendix B for a complete list of participants). Among the participants were published experts in Connecticut agriculture and individuals that represented generations of farming experience.

Due to competing priorities for agriculture stakeholders, a number of experts were unavailable, leaving a knowledge gap in some planning areas, in particular Fruit Orchards. Experts in large-scale fruit production were the most lacking. However most of the features in Fruit Orchards were still assessed by a small number of growers at the workshop, and this assessment was supported by research noted in the Key Climate Drivers section above. The feature cherry production was not assessed using the risk matrix, however, general knowledge from the CT DoAG was used to assess the impact of climate change on this feature (see Appendix C for more information).

The agriculture risk assessment workshop started with a presentation on climate change projections, the SWOT analysis, and the risk assessment process, and was followed by an informative presentation by Dr. Lewis Ziska, researcher at the USDA–Agricultural Research Service (ARS), Crop Systems and Global Change Lab, entitled, “Carbon Dioxide, Climate Change and Invasive Plants: Changing of the Guard.” Participants were then separated into groups, where they engaged in a risk assessment process of at least two planning areas. The risk assessment process was facilitated by trained team leaders, and consisted of a group discussion and individual responses to sensitivity and adaptation questions listed on a questionnaire form (Appendix D; adapted from Snover et al. 2007), as well as a risk matrix (Figure 2) for each feature. Each box in the risk matrix has an associated risk category (Low, Medium or High) and risk scores, which were determined by multiplying the likelihood of occurrence by the magnitude of impact (Figure 3).

Name \_\_\_\_\_ Planning Area \_\_\_\_\_ Feature \_\_\_\_\_  
 Expertise Low 1 2 3 4 5 High

**Risk Matrix\*** Mark a "+" (positive impact) or "-" (negative impact) in **one** box for the risk assessment of the feature listed above.

		Likelihood of Occurrence			
		Low	Moderate	High	Virtually Certain/Already Occurring
Magnitude of Impact	High				
	Medium				
	Low				

\*Risk equals the likelihood of occurrence multiplied by the magnitude of the impact, and is categorized as low (L), Medium (M) or High (H).

Climate Driver	
<small>(Rank the below climate drivers from 1 to 4, with 1 having the most impact, or "N" if the climate driver does not have an impact on the feature.)</small>	
Precipitation	
Temperature	
Sea Level Rise	
Air Quality (CO <sub>2</sub> and ozone)	

Time Urgency	
<small>(Mark an "X" next to the timeframe when the climate change impact to the feature will need to be addressed)</small>	
2020	
2050	
2080	

Other Comments (space available on the back):

**Figure 2:** The third page of the risk assessment worksheet that was filled out by participants in the August 2009 agriculture risk assessment workshop. Participants noted if the impending impact from climate change was positive (“+”) or negative (“-“), and the degree that the impact was likely to happen and the magnitude of that impact in the risk matrix. Participants also were asked to rank the climate drivers, precipitation, temperature, sea level rise and air quality, from one to four (one having the most impact), and mark the timeframe when the climate change impact to the feature would need to be addressed (i.e., 2020, 2050 or 2080).

Risk Matrix					
		Likelihood of Occurrence			
		Low (1)	Moderate (2)	High (3)	Virtually Certain/Already Occurring (4)
Magnitude of Impact	High (3)	Medium (3)	High (6)	High (9)	High (12)
	Medium(2)	Low (2)	Medium (4)	High (6)	High (8)
	Low (1)	Low (1)	Low (2)	Medium (3)	Medium (4)

**Figure 3:** Risk matrix with associated risk categories (Low, Medium, High) and risk scores, which were determined by multiplying the likelihood of occurrence by the magnitude of impact. The final score for each feature, displayed in Table 2 above, was determined by the most often given answer for the risk category and the average of all of the risk scores (the risk scores could be positive or negative based on the impact).

Each feature in Table 2 was ranked first by the most often given answer for the risk category then by the average of all of the risk scores (the risk scores could be positive or negative based on the impact) and finally by the time urgency most often given answer (2020, 2050 or 2080; with an answer of 2020 being the most at risk). The top two most often given climate drivers also were recorded in the risk data table. This methodology employed by the CT Department of Environmental Protection to provide consistency across the four Adaptation Subcommittee workgroups (i.e., Agriculture, Infrastructure, Natural Resources and Public Health).

## Findings

(The findings in this section are the best professional judgments of the agriculture risk assessment workshop participants.)

Most of the agricultural features were determined to be highly impacted by climate change, and most of these impacts were negative. The top five most imperiled agricultural planning areas or features<sup>5</sup> in Connecticut were maple syrup (Forestry), dairy (animal husbandry-includes a lot of the same aspects as non-poultry animal husbandry-and feed), warm weather produce (Produce), shellfish (Aquaculture) and apple and pear production<sup>6</sup> (Fruit orchard). There were opportunities for production expansion, including biofuel crops and witch hazel (Forestry) and grapes (Small Fruits), with the future climate, as well as benefits identified for all agricultural planning areas. The discussions also identified a few relatively easy solutions for some climate change-induced problems with Connecticut agriculture, as well as problems that will be common to all agricultural planning areas. (See Appendix E for more information on the agriculture planning areas not discussed in this section.)

### Top 5 Most Imperiled Agriculture Planning Areas or Features:

1. Maple Syrup
2. Dairy
3. Warm Weather Produce
4. Shellfish
5. Apple and Pear Production

### *Maple Syrup*

Maple Syrup production in Connecticut will be the most impacted agricultural feature (risk and urgency are high; Table 2). In fact, maple syrup production in Connecticut may be impossible by 2080, particularly at lower elevations, due to predicted increases in temperature, especially increases in late winter/early spring nighttime temperatures (the dichotomy of warm days and freezing nights are needed to induce sap flows). Additional economic impacts of reduced maple syrup production and sugar maple trees include those communities, such as Hebron, that hold dedicated maple syrup festivals, and leaf-peeping tourism during the fall, since maple sugar trees are responsible for some of the most vibrant fall foliage colors. Furthermore, many foresters expect that a decrease in sugar maples will negatively affect the lumber industry, since sugar

<sup>5</sup> The Agriculture Workgroup did discuss all of the findings from all of the planning areas discussed at the agriculture risk workshop (Table 2), but the Adaptation Subcommittee asked each workgroup to focus on the five most imperiled agriculture areas or features in this risk assessment report.

<sup>6</sup> Bees were ranked higher than apple and pear production in the risk data table, but the Agriculture Workgroup, after reviewing the notes from the workshop, felt that this ranking could be largely attributed to non-climate change causes.

maple trees are a top lumber product. For many farmers, maple syrup is one of many commodities produced on a farm, which helps diversify farm income. However, some farmers have become dependent on this source of added income.

### *Dairy*

The threat to Connecticut dairy operations (animal husbandry and feed production) from climate change is imminent and high. Workshop participants would like to see adaptation action sooner than 2020 (risk and urgency are high; Table 2). The primary climate driver for dairy animal husbandry is temperature; more frequent, higher day-time temperatures and the absence of nighttime cooling will cause more stress to dairy cows, which will depress appetite and reduce lactation (i.e., reduced milk production) and calving. The stress of increased temperature will lead to long-term, poor animal health and reduced herd size and income potential. There also will be increased energy demands from fans and water cooling required to keep dairy cows cool during hotter temperatures. Increased precipitation will lead to difficulty with managing the herd indoors by increasing the cleaning requirement, and will lead to difficulty with managing the herd outdoors due to wet fields, especially in spring and early summer if more winter precipitation does occur. This increase will also make manure management and water management (runoff) from dairy infrastructure more difficult. Decreased precipitation during the hottest summer months and subsequent water restrictions will further stress dairy cows and dairy farming operations.

The current climate in Connecticut is optimal for dairy forage production, and thus Connecticut has a national competitive advantage. Feed production for dairy cows will be affected primarily by projected changes in precipitation. Increased rain could decrease the quality and quantity of production, especially for hay by impacting harvest timing. Land in corn silage may be subject to an increase in winter soil erosion. The cost associated with purchasing more fertilizer, due to increased run-off and leaching, and purchasing more feed would increase already inflated operational costs for the Connecticut dairy farmer. Increased fertilizer run-off/leaching also would negatively impact water quality and could increase regulatory compliance issues. Increased severe weather, such as tornadoes, hurricanes and hail, drought and increases in carbon dioxide concentration will further damage forage crops in Connecticut.

### *Warm Weather Crops*

Warm weather crops, or crops that mature from late June to early September (e.g., tomatoes), were primarily seen as being affected by climate uncertainties. Warm weather crops account for the larger share of revenue for produce farmers (i.e., over less valuable, cool-weather crops), making it increasingly important for a consistent crop yield (risk and urgency are high; Table 2). Temperature and precipitation will affect crops the most. Increased temperature and precipitation would increase crop disease, pests and pathogens, and decrease fruit set (e.g., peppers don't set above 90° F). Specifically, farmers are already seeing an increase in the colonial worm on sweet corn crops. Traditionally found in corn after Labor Day, now the colonial worm is able to overwinter and has been found on corn earlier than Labor Day. In addition, cucurbit (e.g., cucumber and squash) and solanaceae (e.g., tomato and peppers) crops (high value warm weather crops) are more affected by *Phytophthora* and water molds because of increased precipitation, an impact that is already occurring.

Additionally, impacts on warm weather crops include sea level rise, seen as a climate driver not only along the coast, but also along the Connecticut River and other major floodplain areas throughout the State, because as sea level rises, tidal rivers also will rise, raising ground water levels and ultimately flooding river valley farmland. Changes in air quality, in particular carbon dioxide, could increase weed growth, surpassing any benefit achieved from slightly increased crop growth. Ozone also is expected to affect warm weather crops by decreasing plant growth and negatively affecting warm weather crop pollinators.

Warm weather produce passed the threshold in 2003 for precipitation; since then increased and almost continuous precipitation has increased disease and rot in warm weather produce. A longer growing season could increase diseases, as well, but could allow farmers' markets to be able to stay open longer. Connecticut farmers are already seeing a decrease in the efficacy of glyphosate<sup>7</sup>, which is further expected to decrease due to increased carbon dioxide, thus preventing effective control of weeds. Fertilizers are already in a short supply due to the increasing demand from China and India and the increased price of petroleum, so run-off/leaching due to increasing precipitation will amplify synthetic fertilizer costs for farmers. Warmer temperatures will make it more difficult to maintain soil organic matter content which is critical to maintaining fertility and moisture retention.

### *Shellfish*

Temperature was considered the primary climate driver influencing shellfish aquaculture in Connecticut (risk and urgency are high; Table 2). The major species commercially grown in Connecticut (i.e. Eastern oyster, hard clam) are also found in southern waters and should adapt to predicted temperature increases; in fact, increased temperatures could lead to faster growth. However, increased water temperature could also lead to increased disease prevalence. This could include epizootic parasites that affect shellfish survival directly, as well as naturally occurring pathogens that impact shellfish survival as well as pose a human health risk. Shellfish exposure to pathogenic organisms could be further exacerbated by increased climate change-induced storm events resulting in increased turbidity runoff and partially treated or untreated sewage overflows. Other impacts of temperature on shellfish aquaculture could include changes in natural food assemblages and predator populations which could influence shellfish quality and survival.

Ocean acidification, due to increased carbon dioxide, was considered the second most influential climate driver. Aquatic pH levels are predicted to drop worldwide, and shellfish have shown susceptibility to increasingly acidic waters. Preliminary research indicates that shellfish larvae and juveniles may be especially susceptible, which would negatively affect recruitment, jeopardizing future populations. However, pH impacts upon locally cultured species is not fully understood, and research is currently underway to further identify these risks. If Connecticut-grown species are susceptible to ocean acidification, the impacts could severely impact the shellfish industry.

The shellfish industry in Connecticut is already stressed from sewage and land run-off driven harvesting closures, which may increase with increasing precipitation. Furthermore, sea level

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<sup>7</sup> Glyphosate is an important agricultural herbicide and the active ingredient in Roundup®.

rise could impact working waterfronts, which are already in short supply due to development pressure.

### *Apple and Pear Production*

Precipitation variability was seen as the biggest threat to the very valuable apple and pear production in Connecticut (risk and urgency are high; Table 2). Too much precipitation, especially in the spring could lead to increased fungus infections, and reduced pollen production. Projected drier summers will be better for apple and pear production. However, insect damage due to increased temperatures could be worse, leading to decreased fruit yield. Increased spring precipitation could lead to poor bee pollination, which also would decrease apple and pear production. Extreme weather events, such as hail and ice storms, could damage fruit, making it undesirable for consumers, or trees, which could be especially devastating to these long-lived perennials. Furthermore, apples and pears will mature earlier, potentially negatively impacting the success of pick-your-own operations, whose customers currently equate apples and pears with the fall season

### *Opportunities*

Despite its challenges, climate change will present some agricultural opportunities. Biofuel crops, witch hazel and grape production could increase with climate change in Connecticut.

#### *biofuel*

Biofuel crops (e.g., switchgrass, hybrid poplars) could increase due to climate change projections of increased temperature, precipitation and carbon dioxide, and represent an opportunity for Connecticut farmers looking to diversify or convert to more climate-change friendly crops. Biofuel crops also play an important role in energy conservation and reduce reliance on fossil fuels.

#### *witch hazel*

Witch hazel is a shade-tolerant shrub that grows in upland forests. It is an economically important forestry crop that is used as an astringent, a component of cosmetics and to treat bruises, insect bites and other ailments. Witch hazel is usually just a supplemental source of income for foresters/farmers, but the crop could be expected to increase due to climate change. The largest witch hazel processing facility in the country is located in East Hampton, Connecticut, not only making witch hazel an important agricultural commodity, but also an important industrial commodity.

Witch hazel grows in a wide variety of temperatures, from northern Canada to the southern United States. Therefore, temperature increases due to climate change should not have a negative effect on witch hazel distribution in Connecticut. Witch hazel is also tolerant of wet soils, but not as tolerant of dry soils, so an overall predicted increase in precipitation could have a positive effect on witch hazel. The effect of carbon dioxide on witch hazel growth is unknown, so more research may be needed.

#### *grapes*

Grape production in Connecticut will greatly benefit from warmer, drier summers. Grapes will have a longer time to mature, making more varieties a viable option in Connecticut (especially

red varieties), and the sugar content will increase, making Connecticut grapes more desirable for wine production. Mold, fungus and diseases also may decrease with drier summers. An increasing market for eating/table grapes could fill the void from climate change impacts to other berries. Plus, grapes do well on shallow, stony, and rocky soils which are more abundant in Connecticut than prime and important farmland soils, which are preferable for most other fruits.

Climate change may necessitate more care in grape site selection; vineyards will need better drainage/irrigation. Weed/invasive plant management due to increased, carbon dioxide-induced herbicide resistance also could be a problem, especially during the first few years of vine establishment.

Ultimately, a longer growing season, warmer winters and a relative abundance of precipitation may trigger positive impacts from climate change, in spite of the increased threat from pests, pathogens and disease. Therefore, climate change may enhance Connecticut in its value as an agricultural area. The work environment of agricultural workers may need to be evaluated in the context of climate change, but the longer growing season would provide the benefit of extended work terms. Pick-your-own operations and farmers that rely on the fresh market may be impacted due to increased precipitation and heat that may discourage customers from frequenting their operations, but innovative strategies to attract customers are increasing.

### Adaptation Strategies

Adaptation strategies will be the focus of the July 2010 report to the Connecticut Legislature, so just broad adaptation strategies are discussed at this time. The Agriculture Workgroup developed six major categories of adaptation response (Appendix F), and will elaborate on these categories during the adaptation strategies phase of the study.

Adaptation strategies for agriculture in Connecticut will require developing agricultural systems that are resilient and sustainable and can thrive under changing

conditions. *Change* is the most certain element of our future climate. The climate impacts used in this report are based on the best available information at this time, but these projections will certainly change, and possibly very dramatically, as we gain a better understanding of uncertainties in the climate system (e.g., timing of melting ice sheets, tipping points, feedback loops). Therefore adaptation strategies must continuously evolve and flexibility will be critical.

More specific adaptation strategies that were discussed by participants at the agriculture risk assessment workshop mostly centered on research that would recommend crop and livestock varieties already adapted to the climatic conditions projected for Connecticut, and consumer education to teach consumers about these new varieties. Additional agricultural adaptation strategies discussed included adaptation to agricultural infrastructure, such as increased drainage capacity, capture and storage of local runoff for use during dry periods, enhanced cooling systems, and new pest control plans and soil management. In general, adaptation will require more intensive and flexible management to address the greater variation in climatic inputs such as temperature and precipitation as well as threats and opportunities. Many agricultural

#### Major Categories of Adaptation Response for CT Agriculture

1. Regulation Changes
2. Research and Technology
3. Infrastructure Changes
4. Increased Management of Resources
5. Land Use
6. Education/Outreach

operations may require more “systems” approaches in order to minimize risks. Continuing research and education are key factors in helping producers assess their individual operations for risk and opportunities.

### **Intersections with Other Workgroups**

There are a number of facets of the agricultural industry impacted by climate change that intersect with the other workgroups’ purviews. Both the Natural Resources Workgroup and the Agriculture Workgroup are concerned with the climate change impact on forestry products and shellfish health (see Findings Section above for more information on shellfish). The Agriculture Workgroup feels that climate change will bring more opportunities to forestry than threats because of the positive effects of higher temperatures and more carbon dioxide. Currently, poor forest management is the limiting factor in forest products production, and forests could play an important role in climate change mitigation by acting as a source of carbon sequestration, if managed correctly.

The Agriculture Workgroup along with the Public Health and Natural Resources Workgroups also are concerned with ecosystem services, or human benefits derived from nature. Ecosystem services include oxygen from trees, storm water storage from intact wetlands and water retention, ground water recharge and filtering. Climate change could reduce the number and quality of Connecticut’s ecosystem services by altering the conditions in these natural habitats.

The Public Health and Agriculture workgroups are concerned both with the climate change impact to food safety and the health of agricultural employees. Higher temperatures will increase fresh food spoilage and require increased refrigeration and shorter “sell by” time periods. Food safety of shellfish also will be more at risk with climate change from pathogens that affect shellfish, as well as human health, and contaminants from increased run-off and sewer overflows due to rising levels of precipitation or intense storm events.

The Infrastructure and Agriculture Workgroups are concerned with agricultural infrastructure. Agricultural buildings such as barns and greenhouses will be strained under heavy, wet snow. Connecticut agriculture also is heavily dependent on supply lines (i.e., transportation) to get their agricultural products to processing facilities and to the fresh market. Transportation infrastructure could be impacted by increased precipitation and sea level rise by the Connecticut shoreline.

### **Intersections Beyond State Borders**

Although this report addresses the impacts of climate change on Connecticut only, we acknowledge the importance of understanding the interconnections between climate impacts, risks, and opportunities on the regional, national, and global levels. Decisions about what foods are grown where in the U.S. are based on many factors and interrelationships, including climate suitability, land quality and availability, local economies, and infrastructure. As climate change impacts influence food growing decisions in Connecticut, changing climates in other regions will influence food production decisions there as well. Whereas there may not be adequate land, economic, or infrastructure conditions to feasibly grow certain crops in Connecticut today compared to other regions, as climate and other factors change, Connecticut might become better suited to grow those same crops in the future as other regions of the country face severe

decreases in water availability, increased fire risks, etc. While it is impossible to project the many changes that will affect agricultural productivity in the next few decades and even more difficult to imagine how changing productivity in one region will influence food growing decisions in other regions, it will be critical to seek to understand these interconnections to build resilient food systems and food security. As such, it is very important to develop strong regional, national, and global dialogues on climate change impacts on agriculture and food production now.

### **Conclusion**

Agriculture is one of the most weather-dependent of all human activities. Change in climate variability and extreme events will have a great effect. Drought, floods, hurricanes, and the frequency and severity of heat waves, remain an important uncertainty in future agricultural crop selections. Climate variability will expose food, fiber and forestry to the negative risk of new and unique pest and pathogen outbreaks. These outbreaks could be a high risk if known controls are unavailable or unlicensed for the target crops. The agricultural community is subject to consumer demands and preferences. Given the current economic pressure on the small farm community, varietal changes might become monetarily impossible to implement. The type of food we eat is as important as how and where we grow it. Adapting to the coming changes will require a comprehensive interface between the public, farmers and our public research institutions.

Clearly, rising temperatures, increased rainfall, more frequent extreme weather events and possible intermittent periods of drought associated with climate change over the next several decades will have impacts on the agricultural industry in Connecticut. Significant biotic changes could result in different ecosystems, and crop production will not be unaffected. Fifteen features in nine planning areas were determined to be at high risk by the risk assessment conducted with key stakeholders in Connecticut agriculture.

A goal of the Agriculture Workgroup will be to determine adaptation strategies that achieve positive results for multiple agricultural commodities at risk, as well as target individual high risk commodities. Building on strengths and capitalizing on opportunities unique to, or characteristic of, Connecticut agriculture currently and in years to come will be primary areas of adaptation response to the risk posed by climate change.

Agriculture is an industry that is one hundred percent weather-dependent already. Secondly, it is consumer dependent and market driven. A successful crop in a good year, must also play out the economics of supply and demand for profitability. Connecticut agriculture must capitalize on its strengths of diversity and proximity to a large customer base to help weather the impacts of climate change and adapt to a changing future. Marketing local source food systems is a key strategy for encouraging and enhancing agriculture in Connecticut as well as solving a host of security, environmental and transportation dilemmas. Education of the general public and legislators on the realities and mechanics of Connecticut agriculture, and regional, national, and worldwide food systems, is paramount.

Additional research and monitoring programs can help determine when risk of crop damage is elevated. Monitoring long-term changes in temperature, precipitation and sea level, is needed to

more closely define trends in climate change. More specifically, expansion of monitoring systems for emerging insect pest and plant disease pathogens in integrated pest management programs is needed to identify imminent threats to crop systems and to mitigate economic losses. New crops need to be evaluated for their ability to survive warmer and wetter conditions. Moreover, research on sustainable agriculture is needed to develop more efficient growing practices and resilient food production systems. For example, the use of biochar, a fine-grained charcoal resulting from pyrolysis of plant wastes, as a soil amendment in agriculture may serve to reduce atmospheric carbon dioxide<sup>8</sup>, which contributes to climate change, and might enhance plant health by increasing nutrient retention in soil. Similarly, further research on low carbon biofuels could help reduce dependency on fossil fuels. Finally, more attention is needed on proper land management practices to maintain soil health, prevent soil erosion, conserve water supplies, and protect water quality. Water is critically needed for irrigation, especially during prolonged periods of drought. Protecting Prime, Statewide and Locally Important Farmland Soils from competing land use changes will ensure a land base most resilient to the impacts of climate change. Further research is necessary on shellfish aquaculture to select disease-resistant shellfish strains for culture in Connecticut waters, identify pH thresholds for locally grown species, and determine adaptive strategies to mitigate the effects of increased disease prevalence and ocean acidification (if deemed necessary). These findings should be disseminated to Connecticut aquaculturists so that they may be implemented by the industry.

Many current agricultural operations will need to be altered to adapt to climate change to remain economically viable. With continued rising costs and use of fossil fuels, greater carbon dioxide emissions, increased consumer demands for locally produced fruits and vegetables, and more public interest in preserving farmland, it is important to protect agriculture in Connecticut and to apply research findings to implement more efficient, resilient and sustainable-agricultural practices that address changing climatic and associated economic conditions.

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<sup>8</sup> Biochar can sequester carbon and release oxygen by the pyrolysis of trees and agricultural biomass which would otherwise be burned, releasing stored carbon that would further contribute to climate change. Biochar can be used as a soil amendment, making soil a carbon sink.

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**Appendix A**  
**Connecticut Agriculture Strengths, Weaknesses, Opportunities and Threats (SWOT) and**  
**Connecticut's Agricultural Impacts from Changing Climate**

**Strengths**

- Fertile farmland, especially the Connecticut River Valley, with excellent, highly fertile and productive agricultural soils with low erosion potential
- Excellent academic and research institutions and educated citizenry
  - Developed more productive hybrid corn and ongoing research for the production of new specialty crops
- Generally more water available in Eastern region of the country than western; adequate water and abundant rainfall in CT with fairly uniform precipitation at moderate intensity throughout the year
- CT has 4,916 farms in 405,616 acres of farmland of which 254 farms in 34,500 acres have been protected, or approved for protection, through the acquisition of development rights by CT Farmland Preservation Program (the nation's second oldest PDR program)
- Contributes billions to CT's economy each year
  - Environmental horticulture (production - nurseries/greenhouses/herbs/cut flowers/turfgrass, retail, landscape services) alone contributes \$1.022 billion to CT economy yearly; total sales of CT nursery/greenhouse/ floriculture/sod was \$269,221,000 in 2007; plant sales generate over \$583 million
  - Total sales of CT's agricultural products was \$551,553,000 in 2007
  - Some of region's finest crops with \$350 million annually generated
  - Economic impact of CT dairy industry (including processing) is estimated to be between \$832 million and \$1.1 billion in new output (sales) generating up to 4,242 jobs and \$208 million in additional personal income; total sales of CT's milk and dairy products was \$72,338,000 in 2007
  - Total sales of CT's cut Christmas trees and short rotation woody crops was \$3,840,000 in 2007
  - CT has 173 farms in maple syrup production with 11,732 gallons produced in 2007 (decrease from 2002)
- CT leads New England in the production of: pears (CT ranked ninth in country) and peaches
- CT is highest producer in New England of tomatoes, tobacco, green beans and asparagus
- CT is top in North America in the production of black currants
- CT's oyster crop is the most valuable in the nation and is second only to Louisiana in quantity
  - Total sales of CT's aquaculture products in 2007 was \$15,142,000
  - Over 300 jobs provided directly by industry
  - Annual shellfish harvest exceeds 450K bushels in more than 70K acres of shellfish farms
- CT leads the East in horticultural and floricultural sales and is home to the largest rhododendron grower in the Northeast
- CT is home to the largest producer and processor of witch hazel in the country

- CT contains the fifth largest egg producing farm in the country, and is second to Maine for highest chicken inventory and total eggs produced in New England
- Connecticut produces 223 table eggs per capita in state each year
- Value of horses in CT estimated at over \$300 million, and one of the highest ranking states based on density of horses per square mile
- CT is one of the highest producing states east of Michigan for milk on a per cow basis
- CT has the largest average dairy herd size of any New England state
- CT boasts high agricultural diversity for a small state
- Over 33 million customers consuming agricultural products within two hours radius in Connecticut

### Weaknesses

- Farm supplies and inputs more expensive in CT than other regions of the country such as higher costs of energy, raw land, transportation
- More regulated environment in Connecticut
- High cost of labor, health costs and immigration/labor issues
- Nationally set milk prices lower than cost to dairy industry in Connecticut
- Fragmented small fields make it hard to move equipment in and out of and spray outside of buffer areas (from surrounding development and wetland resources)
- High development pressure from incompatible, non-agricultural uses
- Urban sprawl and suburbanization discourages farming and creates incentive for farmers to sell for residential development
- Proximity of non-agricultural uses to agricultural operations
- Lack of knowledge of agriculture by municipalities
- Some local rules and regulations not supportive of agriculture
- Some agricultural infrastructure and supply sources being lost, e.g. Cargill closing mill in Franklin
- Lack of processing facilities in CT for CT-grown products
- CT farmers' dependence on fresh market
- Lack of farmer legislators and knowledge of agricultural processes and business models
- Some counties in Connecticut still losing tillable acreage (e.g. Litchfield)

### Opportunities

- Longer growing season allows farmers to invest in warmer-weather crops and compete with mid-Atlantic states (?change corn to soybeans, nursery industry)
- Growing organic farming movement
- Consumers seeking local foods
- 2007 agricultural census for CT indicates an increased number of farms, farmers markets, acres of farmland in CT, and small farms (although some of the increase in farmland is due to changes in accounting methodology, e.g. aquaculture now included; some areas of CT are still losing tillable acreage)
- Potential to sustainably grow woody/perennial plant-based biofuels, examples in poplars, willows, switch grass
- Potential to increase biofuel production (may also be a threat to local food crop production and food prices)

- Networks in place to communicate better with agriculture industry about best management practices, and SWOTs, adaptation efficiencies
- More people can grow their own food b/c of soils, climate and water availability than some other parts of nation
- Excellent academic institutions and educated citizenry should be receptive to outreach efforts promoting conservation (water usage, energy usage, best management practices)
- Business development = job development = economic development
- Most crops in CT are not tied into commodity price supports
- As cost of shipping from west or outside the country increases, CT will benefit from close proximity of agricultural production to consumers in state
- New England census shows 12,000-15,000 unfilled jobs in the nursery/greenhouse industry in New England region
- Jobs in agriculture help build small local economies
- Legislature willingness to be educated and informed about agriculture industry in CT
- High agricultural diversity in CT should be of benefit in adapting to climate change

### Threats

- Energy prices and availability
- Development pressure
- Invasive species
- Loss of biodiversity
- Labor cost and supply
- Climate Change (*see below*)

## Connecticut's Agricultural Impacts from Changing Climate

### Precipitation

This climate change driver has multiple anticipated agricultural impacts and has been divided into three subcategories: (1) Changes in Precipitation, (2) Drought, and (3) Timing and Intensity of Storms. There will most likely be an increase in the total annual precipitation in Connecticut. However, most of the precipitation towards the end of the century will come in the winter and will be in the form of rain rather than snow. Connecticut will experience more frequent and longer droughts during the summer due to increased evaporation due to higher temperatures. More intense storms may also increase in frequency, which will increase the intensity and frequency of flooding.

- More Precipitation
  - Increased heavy soil saturation and a higher groundwater table
    - delayed planting
    - delayed harvesting
    - diminished yields or crop failure (e.g., root rot)
  - Existing agricultural infrastructure, such as barns, may be subject to roof collapse from heavy wet snow
  - Changes in the type and number of pests, pathogens and diseases
  - More pesticides needed because leached, diluted or washed off in the rain (increased cost to farmers)
  - Increased nutrient run-off/leaching from the soil necessitating more fertilizer applications
  - Increased manure run-off/leaching which could pollute surface and ground water
  - Diminished quality of shellfish beds due to pollution from runoff (nitrogen loading or other) into Long Island Sound

- Drought
  - Increased water needs for animals and crop or greenhouse irrigation
    - Without water yields will decrease or crops will fail
    - Aquaculture and terrestrial animal production will also experience a decrease in high quality water
  - Inability for existing agricultural infrastructure to meet increased irrigation requirements
    - E.g., Insufficient storage mechanisms for greenhouse watering
  - Increased cost to farmers from:
    - Competition for water resources with other users
    - Increased need for more water/irrigation
    - Some crops may become too expensive to grow (e.g., silage corn)
    - Changes in infrastructure, such as increasing culvert size
  - Increased water requirements for animal husbandry
  - Drier soils
    - Loss of topsoil as dry soils are susceptible to wind blow
    - Decreased soil health due to less microbes in the soil, altered nitrogen cycle, and less organic carbon in the soil
    - Tillage systems are not adapted for drier soils
    - Dust will increase which will decrease air quality
- Timing and Intensity of Storms
  - More difficult risk management- leading to more dependence on crop insurance, now used primarily for specialized crops in CT
  - Flooding would lead to immediate and total crop loss, especially in the CT River Valley, one of the most fertile places in CT
  - Hurricanes- damage from high wind and flooding
    - crop losses
    - damage to trees harming fruit and maple sugar industries
    - infrastructure damage
  - Hailstorms
    - Lots of cosmetic damage to fruit and vegetables, which have to be processed instead of sold whole
    - Damage to plants making them susceptible to fungal and bacterial infections
  - Ice storms
    - Damage to plants and trees allowing disease and pests to enter
    - Late storm would lead to bud loss for fruit orchards

## Temperature

Higher average temperatures are expected, especially in summer, and there will be more incidences of extreme heat. Higher temperatures may be an overall positive climate driver in Connecticut because it will lengthen the growing season. However, higher temperatures coupled with low precipitation will negatively affect agriculture.

- Warmer winters
  - Winter chill requirement for fruit-set for some varieties may not be met.
  - Immature bud set leading to flower failure (e.g., Chrysanthemums, a major Connecticut nursery crop)
  - Maple syrup will not “run” leading to a collapse in the Connecticut maple syrup industry.
  - New and more pests, pathogens and diseases (e.g., equine encephalitis, kudzu).
  - Less greenhouse heating requirements

- Longer growing season
  - Increased crop yields
  - New crop varieties (e.g., rapeseed, grapes)
  - New nursery crops—Connecticut would be better able to compete with warmer states
  - More pesticide use or more labor-intensive weed/pest control for organic farms
- Warmer summers
  - Composting occurs more quickly
  - Greater water evaporation
  - Change to plant varieties
  - More soil organic matter required
  - More irrigation and animal watering needed
    - Misters needed in greenhouses potentially requiring expensive upgrades to existing infrastructure
  - Heat stress
    - animals (e.g. decreased milk production)
    - farm labor hindering productivity
    - Increased need for air conditioning, fans and misters (high cost)
  - More energy usage leading to increased costs and competition
- Warmer water
  - Aquaculture
    - Increased disease in shellfish due to warmer water temperature (e.g. MSX, Dermo, etc.)
    - The species composition and quantity may decrease for shellfish and finfish
  - Terrestrial animals operations may require water cooling

### Sea-level Rise

This climate driver results from ocean waters expanding when warmed, as well as melting of land-based ice. Accelerated melting of ice sheets may increase the higher emissions scenario projections by releasing stored carbon dioxide. Connecticut's extensive shoreline along Long Island Sound, a tidal estuary, and its freshwater river tributaries could be directly affected by this climate driver.

- Aquaculture
  - Loss or relocation of shellfish beds and breeding grounds
  - High cost of modifying existing infrastructure involved in aquaculture operations (e.g. docks, buildings on shoreline that can't adapt or aren't available, etc.)
  - Loss of Wetland and eelgrass beds which are important to health of estuary for aquaculture
- Cropland
  - Direct loss of agricultural land at near the shoreline due to erosion/flooding
  - Decreased cropland and freshwater quality due to saltwater intrusion and rising groundwater

### Air Quality

- Ozone is projected to increase due to increasing temperatures
  - Increased crop damage directly from higher ozone and as a component of smog (Cucurbits and tobacco especially susceptible)

- Agricultural workers' health affected (e.g., greater susceptibility to asthma and can aggravate existing lung conditions)
- Higher carbon dioxide concentrations
  - Increased photosynthesis for all plants up to a certain peak temperature ( $\pm 85$  degrees Fahrenheit) changes growth rates and patterns
  - Greater growth of invasive plants
  - Decreased efficacy of glyphosate
  - Agricultural workers' health affected
    - Increased pollen leading to increased allergic rhinitis (i.e., hayfever)
    - Increased poison ivy growth with concentrated toxins
  - Acidification of the ocean leading to decreased shellfish harvest

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**Appendix B**  
**List of Participants in the Agriculture Workshop**

Dr. Sandra Anagnostakis, CT Agricultural Experiment Station  
Candace Benyei, Whimsy Brook Farm LTD  
Jude Boucher, University of Connecticut Cooperative Extension System  
Dr. Patricia Bresnehan, University of Connecticut  
David Carey, CT Department of Agriculture - Aquaculture  
Dr. Richard Cowles, CT Agricultural Experiment Station  
Javier Cruz, US Department of Agriculture - Natural Resources Conservation Service  
Marshall Duer-Balkind, CT Department of Environmental Protection  
Bill Duesing, CT Northeast Organic Farming Association  
Dr. Wade Elmer, CT Agricultural Experiment Station  
Douglas Emmerthal, CT Department of Environmental Protection - Division of Forestry  
Dr. Cameron Faustman, University of Connecticut  
Amanda Freund, CT Farm Bureau  
Joseph Geremia, Geremia Greenhouse  
Melissa Greenbacker, Greenbacker's Farm  
Bruce Gresczyk, Jr., Gresczyk Farm  
Rollie Hannan, Hannan Honey, LLC  
Penny Howell, CT Department of Environmental Protection - Marine Species Assessment  
Jean Jones, Jones Family Farms  
Terry Jones, Jones Family Farms  
Christian Joseph, Prides Corner Farms Inc.  
Kip Kolesinskis, US Department of Agriculture - Natural Resources Conservation Service  
Anita Kopchinski, Sokol Farm  
Dr. James LaMondia, CT Agricultural Experiment Station-Valley Lab  
Seth Lerman, US Department of Agriculture - Natural Resources Conservation Service  
Jen Locke, Central CT Co-Op Feeds  
Bob Maddox, Sun One Organic Farm  
Dr. Louis Magnarelli, CT Agricultural Experiment Station  
Jiff Martin, American Farmland Trust  
Dr. Abigail Maynard, CT Agricultural Experiment Station  
Dr. Richard McAvoy, University of Connecticut - Plant Science  
Joyce Meader, University of Connecticut Cooperative Extension System  
Richard Meinert, University of Connecticut Cooperative Extension System  
Dr. Lisa Milke, National Oceanographic & Atmospheric Administration - National Marine  
Fisheries Service  
Bill Nail, CT Agricultural Experiment Station  
Joan Nichols, CT Farm Bureau  
Peter Orr, Fort Hill Farms, LLC  
Ken Pauze, Kofkoff Egg Farms LLC  
Greg Peracchio, Hytone Farm  
Mark Polek, Polek Farm Enfield  
Commissioner F. Philip Prelli, CT Department of Agriculture  
Steve Rackliffe, University of Connecticut - Plant Science

Sherwood Raymond, CT Department of Environmental Protection - Division of Forestry  
Roslyn Reeps, CT Department of Environmental Protection  
Steve Reviczky, CT Farm Bureau  
Dr. Robert Rheault, East Coast Shellfish Growers Association  
David Richards, Clinton Nurseries Inc.  
Bill Sokol, Sokol Farm  
Matt Staebner, Blue Slope Farm  
Lynn Stoddard, CT Department of Environmental Protection  
Dr. Kimberly Stoner, CT Agricultural Experiment Station  
Kevin Sullivan, CT Nursery & Landscape Association  
Don Tuller, Tulmeadow Farm  
Rick Van Nostrand, CT Department of Environmental Protection  
Bob Wall, CT Clean Energy Fund  
Dr. Glenn Warner, University of Connecticut - College of Agriculture & Natural Resources  
Joe Wettelman, CT Department of Environmental Protection - Ag Permitting and Enforcement  
Norman Willard, US Environmental Protection Agency - Climate Change and Energy  
Katherine Winslow, CT Department of Agriculture - Farmland Preservation Program  
Thomas Worthley, University of Connecticut Cooperative Extension System  
Dr. Xiusheng Yang, University of Connecticut - College of Agriculture & Natural Resources  
Dr. Steve Zinn, University of Connecticut - College of Agriculture & Natural Resources

### **Appendix C Cherry Production**

Currently, there are only about seven to 10 acres of cherry orchards in commercial agricultural production in Connecticut. Only about five farms are producing cherries, and most are sold directly to the consumer from the farm in pick-your-own operations. Although very popular, cherries are a small crop with a very short season (two to three weeks maximum) in late June-early July. Connecticut is not able to compete in the wholesale market for cherries with other states such as Michigan, Idaho, Washington and Oregon. Heat generally affects cherries negatively to some extent. In addition, too much precipitation can cause cherries to split. Due to these environmental and economic factors, climate change is expected to have an overall slight negative effect on cherries, although, it is not considered at high risk. With emphasis on local food sourcing, there may be some opportunity for farmers to diversify into small-scale cherry production to supplement their overall agricultural operations, with the understanding that some risk is posed by climate drivers.

## **Appendix D**

### **Risk Assessment Questions**

*These questions were located on the first and second pages of the risk worksheet, given to participants at the agriculture risk assessment workshop, and are adapted from Snover et al. 2007. Responses from these questions were used in this report.*

#### Sensitivity of the Feature to Climate Change:

11. What are the known climate conditions relevant to features (direct and indirect; e.g., summer temperature, winter precipitation)?
12. How do known climate conditions currently affect the feature?
13. How exposed is the feature to the impacts of climate change?
14. Is the feature subject to existing stress, not caused by climate change?
15. How are known climate conditions projected to change?
16. What are the projected impacts of changes to feature in this planning area without preparedness action?
17. Will climate change cause the demand for a resource to exceed its supply?
18. Does the feature have limiting factors that may be affected by climate change?
19. What is the 'impact threshold', or the level at which sensitivity to climate conditions increase, associated with the feature?
20. What is the degree of feature sensitivity to climate change (Low, Medium, High)?

#### Adaptive Capacity of Feature:

7. Is the feature associated with the planning area already able to accommodate changes in climate?
8. Are there barriers to a feature's ability to accommodate changes in climate?
9. Are the features already stressed in ways that will limit their ability to accommodate changes in climate?
10. Is the rate of projected climate change likely to be faster than the adaptability of the feature in this planning area?
11. Are there efforts under way to address impacts of climate change related to features in this planning area?
12. What is the adaptive capacity of feature (Low, Medium, High)?

**Appendix E**  
**Agriculture Workgroup Climate Change Risk Workshop Group Notes**  
**August 24, 2009**

**Group 1 - Fruit Orchards and Small Fruits**

Seth Lerman – USDA NRCS - Facilitator  
 Terry Jones – Jones Family Farms  
 Kim Stoner – CT Agricultural Experiment Station  
 Bob Wall – CT Clean Energy Fund - Recorder  
 Bill Duesing – CT Northeast Organic Farming Association  
 Anita Kopchinski – Hidden Brook Gardens  
 Dr. Bill Nail - CT Agricultural Experiment Station  
 Javier Cruz – USDA NRCS District Conservationist  
 Rollie Hannan – Hannan Honey LLC  
 Bob Maddox – Sun One Organic Farm

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General reactions to the risk workshop methods– Participants felt uncomfortable, the questions were difficult for them to understand, the systems were ambiguous (agricultural or climate?), and matrices were not focused enough to address the variability of crops. Participants also felt that it was difficult to make recommendations (don't know what's going to happen with their answers), and were skeptical of decisions that could be made from their answers. They felt that their answers could be used to create greater awareness among public officials, so it was better to say, "I don't know," than to provide potentially misleading answers. They also felt that this workshop would have been better to have in the winter when farmers are more available.

General Information about Farms/Farming- Orchards have been in existence for generations. Fruit farmers are few but thriving at farmers' markets.

Participants questioned government involvement in climate change risk assessment to agriculture, especially because, "government officials don't automatically agree with data." Government involvement could impact production and operations. Improper regulation could hinder someone with a small farm who can't economically comply with them. This year a lot of pesticide spray was needed because of frequent rains, which have economic, environmental, human costs. Farmers need more technical assistance, not regulatory.

What is the cost/benefit if we have to start importing food from other parts of country? In CT, climate change is the #3 factor behind land cost and economic viability of business (local premium – 50% more; #1 challenge is invasives). Climate change will affect agriculture in the Pacific Northwest to a greater degree; this area will not have the water buffer necessary to withstand droughts brought on by climate change. So, Connecticut could become more of an agriculturally important state. However, Connecticut agriculture will need a way to adapt to damages to crops from storm events (e.g., apple not marketable because bruised) and there is a lack of processing facilities in the state, mostly due to the prohibitive cost of renting or putting a

certified kitchen in to a farm. Government help could be used to convert damaged crops in to useful produce.

Drainage on farms— Water management is an important topic. Intense storm events have been happening more frequently. This year we had three to four ten-year storms. Will there be cost sharing for water management (excess and too dry)? Farms are shifting away from drainage work (especially subsurface drainage) because it is so expensive, but crops are better in non-wetland areas where drainage was installed. Orchards are a longer term investment and have to have land “locked up” in order to make capital improvements (10 acre orchard – easy to spend \$250,000 on drainage). Surfaced drainage could be harvested for summer use especially during a drought. Run-off also is a big issue. Additional research needed on water management (e.g., what type of diversion will withstand a 10-year storm and where do you put outlets for diversions, 10 or 20 foot channel to drain water).

### Apple and Pear Production

Known climate conditions – Cold and wet weather leads to fungus problems. Projected drier summers will be better for apple and pear production, but insect pressures could be worse, which would decrease apple production. Hail storms, poor bee pollination (weather-related) and climate variability (e.g., this year 4 days of 90 degrees, then rainy & cold) before the apples are mature will also decrease apple production.

Trends in weather patterns were less predictable this year. The challenge is managing variability. Variability in spring weather (warming/cooling patterns) is the biggest factors. If weather is screwed up in the spring, won't recover for rest of year. Pollen will suffer and fungus will increase. In the last 5 years, springs are getting later and later. Maple syrup is supposed to be tapped around Valentine's Day and end early March, but now maple syrup is still being collected at the end of March. Apple trees flower for 20 days usually April 22<sup>nd</sup> to May 15<sup>th</sup>. Flowering has been starting later, but also ending later, resulting in the same number of flowering days.

Based on projections of warmer/drier weather there is a medium risk to apple and pear production in Connecticut. Different varieties of apples and pears can be grown, especially those with longer harvesting times. (The Bosc pear variety seems to be resistant to weather variability.) The climate change impact to water and increased heat is a major concern. Apples will come earlier than people want to pick in a pick-your-own operation. Rain will affect size and quality. Planning for new varieties can take 10-15 (9 years at least for pears) years to produce a good crop, and purchasing new land for these varieties, while the old ones are phased out, will be impossible due to the high cost of land in Connecticut.

### Peach, Nectarine and Plum Production

Extreme weather will be the biggest problem to peach, nectarine and plum production; people won't buy hail damaged fruit and peaches, nectarines and plums, which are more susceptible to hail damage than apples because they are a softer fruit. (This year Bethlehem orchards, Lyman's and Bishop's had profound damages due to hail leading to significantly decreased yields. Hail also devastated squash & tomatoes.) Heavy wind also can damage fruit trees. Cost of mitigation for extreme weather will be expensive.

### Cherry

The group felt that they lacked expertise to assess the climate change risk associated with cherry production.

### Bees- (honey bees and other pollinators)

The honey industry in the U.S. is already stressed; 75-80% of honey in the U.S. is imported. Most of the impact to bees and honey production has been non-climate change related. Bears (cub rates above national average), mites, invasive plants (some plants produce good nectar for bees), colony collapse disorder and lack of orchards have more of an impact than climate change. Hives are difficult to fence from bears because there are 3,000 hives in state. Controlling invasive plants has impacted beekeeping; a number of late and early-blooming invasive plants can be good for bees and spraying might affect the health of bees. There is less forage overall due to urbanization. Miticides are used in hives, but only one product can be used at a time and bees ultimately become resistant. There is controversy over the cause of colony collapses; there is a lot of stress to bees—chemicals in the environment (e.g., pesticides-- FL spraying citrus – really impacting bees and herbicides), disease, invasive bees, etc. Orchards have to spray pesticides, but neighboring homeowner spraying and resulting water contamination are bigger risks. The almond industry is one industry saving the bee industry in US, but when there is a water shortage the fruit won't set. Many almond farms are going out of business due to massive debt. There also is a fundamental lack of understanding among non-beekeepers. Most dairy farms aren't growing bee-beneficial clover; they're growing feed grass. Homeowners clear stone walls of plants and broadcast spray for invasive plants instead of spot spraying.

Species diversity is important to pollination. We know less about bumble bees than honey bees. Some bumble bees are close to disappearing, others are declining. Scientists don't know the cause but it might have a lot to do with habitat modification. There is evidence that changes in land use and management have big effect on bee populations. Keeping "weeds" and using no till agriculture (ground nesting bees are affected) have been shown to increase bees on farms. Pumpkin fields also are good for bees.

Bees are highly sensitive to changes, but the easiest to move. People manage bees in a wide variety of climates, so climate change won't directly kill bees in Connecticut. However, climate change-induced changes in Connecticut habitat may push already stressed bees over the edge. Furthermore, some climate conditions are more conducive to bee and honey production than others. This year, with the wet, cooler weather, the bees didn't leave the hive that much and therefore didn't make much honey. Mating is affected if the temperatures are not ideal, since mating is done away from the climate-controlled hive; if the temperature is over 90 degrees or if it is too wet, mating will be drastically affected. Bees will be active during warmer winters and eat up their stored honey too soon with no food available to replace it.

The climate change risk to bees is high. Climate will affect many things important for raising bees and producing honey, but there is some adaptability. Bees can be moved to different crops.

### Small Fruits – Berries

What is the impact of climate change? Berries are less affected than apples and pears. This is too broad of a category. Strawberries are more affected by changes in climate than blueberries and raspberries. Raspberries are the most resilient to changes in climate, once established. This June berries experienced 3-4 degrees lower than normal average temperatures, which was great for strawberry and blueberry growth, but the wet weather made it tough to harvest them.

There is a great market for berries in the state due to their good taste. There is a moderate likelihood of occurrence but low impact from climate change. It's an adaptable industry; for example, blueberries are now grown from Florida to Maine. Farmers could consider a modified greenhouse approach, high tunnels (more labor and cost; will avoid hail damage, bugs, fungus) or drip irrigation to combat changes in climate.

### Grapes

The difference between wine grapes and eating/table grapes are that wine grapes are not as resistant to cold winters. Most grapes in Connecticut are grown for wine production. Some small, grape farms even have a pick-your-own operation.

Climate change may necessitate more care in grape site selection; grape orchards will need better drainage/irrigation. Weed/invasive plant management due to increased, carbon dioxide-induced herbicide resistance also could be a problem, especially during the first few years of vine establishment. Furthermore, if deer food sources are impacted by climate change, there could be more deer-browse impact to grapes. However, warmer winters and drier summers will be beneficial to wine grapes. Drier weather increases sugar content of the grapes and decreases the threat from fungus and diseases, and farmers could compensate with irrigation during a drought.

### SUMMARY

Besides grape production, most crops would be adversely impacted by climate change. Bees have more immediate problems than climate change. The climate drivers for fruit production are precipitation and temperature, while air quality is distant third and sea level is not that important. Demand on Connecticut-grown fruit may increase due to climate change because other, good fruit producing areas may cease to be viable in the future.

Slow-growing, perennial crops, such as apple trees, may be less adaptable, so long-term planning is a necessity. Quality land/soil (good drainage, no till agriculture to prevent erosion), crop diversity (including native crops), technical inputs and supportive public policy (protecting farmland, improving food for schools, etc.) will help to counter some of the effects of climate change on crop production.

## Group 2 Produce and Tobacco

Participants: Norm Willard (Team Leader), Bruce Gresczyk, Jr., Jean Jones, Dr. Abbie Maynard, Dr. Jim LaMondia, Jiff Martin, Bill Sokol, Mark Polek, Dr. Wade Elmer, Kevin Sullivan, Dr. Jude Boucher, Roslyn Reeps (recorder)

### General-

Longer growing season will help agricultural workers obtain more work, but government needs to extend visas to allow for the longer growing season. The warmer weather should not really affect the health of agricultural workers because most agricultural workers in Connecticut are already acclimated to the warm climates of their country of origin (e.g., Jamaica). However, zoning regulations concerning lights and noise should be lessened for farms so that agricultural workers could pick produce during the cool very early morning. Pick-your-own operations and farmers' markets will be the most affect by heat. Farmers will need to plant easy-to-pick varieties and plant more shade trees in the fields, and supply no-cook recipes, such as gazpacho for farmers' market consumers.

There is a lack of farming and food education in Connecticut. VoAg schools need to supply better farming education to future farmers, including how to deal with the challenges of climate change, and home economics needs to teach students about produce and how to cook it. Schools also should teach the benefits of eating locally produced produce (e.g., way to decrease carbon footprint). Farming education in Connecticut colleges and universities needs to focus more on production and the crops that are important in Connecticut (e.g., tobacco). In-state tuition also needs to be less expensive. (It is less expensive to send a student out-of-state to Cornell than to go to UConn).

Connecticut needs more processing facilities so that farmers can take advantage of the longer growing season and to benefit from hail damaged and excess fruit not picked by consumers during pick-your-own times.

### Produce, Warm weather crops (went question by question as an example)

Known Climate Conditions: Temperature and precipitation were stated as the climate drivers that affected warm weather crops the most. Increased temperature and precipitation would increase crop disease and pests (more generations of insects) and pathogens, and decrease fruit set (e.g., peppers don't set above 90 degrees). Sea Level Rise was seen as an important climate driver not only along the coast, but also around the Connecticut River, because as sea level rises the river backs up and infiltrates the Connecticut River valley farmland. Air quality, in particular carbon dioxide, would positively contribute to crop and weed growth, but weed growth would surpass any benefit achieved from increased crop growth. Ozone also will affect warm weather crops by decreasing plant growth and affecting warm weather crop pollinators. Specifically, farmers are already seeing an increase in the colonial worm on sweet corn, which used to only be found in corn after Labor Day, but now the colonial worm is able to overwinter and has been found on corn earlier than Labor Day. The leaf hopper also is now a more frequent pest, and cucurbit and solanaceae crops (high value warm weather crops) are more affected by Phytophthora and water molds because of increased precipitation.

How exposed is feature- Warm weather crop production is very exposed to climate change

Existing stress- Warm weather crops are already stressed by diseases pressure and normal variation, politicians/regulation, the economy, energy cost, labor shortage and lack of buyers. Warm weather crops are high value, especially tomatoes which are worth more than sweet corn, so when warm weather crops fail, it really financially impacts farms.

How are known climate conditions projected to change- Erosion will affect farms because most of the fertile, low lying land has been developed, pushing farms to hillside where erosion, brought on by increased precipitation, will be a big problem for a lot of farms.

Projected impact if no adaptation strategies- Farms are likely to experience bankruptcy due to the stress of projected climate change. Farmland located on higher elevations will be in more demand for development because low lying-areas will be too wet. Areas with well-drained, sandy loam soil also will be in more demand, but short supply for both farming and development. Farmers will need more water sources, which may be partly accomplished by digging more water supply ponds on farms. Ultimately, farmers may shift preference to other warm weather crops that grow well under climate change conditions (consumer education will be needed to accommodate a change in consumer demand).

Will climate change cause the demand for a resource to exceed its supply?- Yes, climate change will affect rotation abilities and farms may not be able to produce a consistent crop every year. Consumers will have to be educated to encourage new warm weather crop buying habits. For example, consumers might have to be encouraged to buy alternative salad crops that can withstand projected increases in temperature such as purslane, which is currently consider a weed by some people. There also will be more pressure on seed companies to produce climate change-adapted seed varieties. Plant abilities to take up nutrients might be affected by climate change, so nutrient delivery mechanisms (e.g., coated fertilizers for increase in precipitation) will have to be adapted, and crops that are tolerant of nutrient strain will have to be identified. Fertilizers are already in a short supply due to the increasing demand from China and India and the increased price of petroleum. Furthermore, the current regulatory process is restricting delivery mechanisms of fertilizers, mostly because of the affect on ground water. Also, demand for good farmland will exceed the supply.

Does the system have limiting factors that may be affected by climate change?- See above. Land for farming in Connecticut is especially limiting.

What is the impact threshold?- Warm weather produce passed the threshold in 2003 for precipitation; continuous precipitation means crops can't dry, which increases disease and rot. A longer growing season could increase diseases, as well, but could allow farmers' markets to be able to stay open longer. Ultimately, there needs to be more research to determine the impact threshold for warm weather produce.

Degree of Feature Sensitivity- The degree of sensitivity of warm weather produce to climate change is high.

Able to accommodate changes in climate change?- Warm weather produce will be able to accommodate projected changes in climate because most are tropical crops. Farms' success will then depend on farmers' ability to adapt. New varieties and methods will have to be supported by research, which will most likely look to methods and varieties grown in the southern United States.

Are there barriers to feature's ability to accommodate change?- See all of the above. Consumers will be biggest barrier; if purple tomatoes were best adapted to climate change, but consumers wanted red tomatoes then consumers would look out of state for the tomatoes that they wanted. Consumers will need to be educated in order to change consumer demand to non-climate change affect crops. There also are not enough people doing research on climate change and agriculture due to a lack of political expectation and government funding. Research should be married with practice to break down the political barrier.

Is the feature already stressed?- Yes, for example there is wide-spread Phytophthora in soils that doesn't go away.

Is the rate of projected climate change likely to be faster than the adaptability of the feature?- Yes, the rate of projected climate change is likely to be faster than the adaptability of warm weather produce, but there is still hope for resistant varieties from the biotech industry. The ability to adapt also depends on research, which could be influenced by research conducted in the southern United States. Round-up concentrations already have increased due to resistance. The adaptability of warm weather produced will ultimately be compromised because of the lack of intact, large farmland in Connecticut. Currently, farmers cannot meet the demand for local produce and animal feed. So for now, Connecticut farmers can get more money for less crop (some farmers picking 1/3 the crop as they used to, but charging 3x more). There may be potential to increase available crop land, farmers will just need to be creative (e.g., indoors, brown fields).

Are there efforts currently under way to address climate change impacts?- This conference and the Connecticut Agricultural Experiment Station (CAES; growth trials on new crops) are currently addressing the impact of climate change on warm weather produce. There also are a number of farmers that are trying to grow new crops, especially tropical crops (e.g., personalized watermelon), but maybe now with the education behind this conference, farmers will be encouraged to try new crops that will be climate change-resistant. However, these efforts are uncoordinated so "industry needs to marry with research." Politicians also will need to realize that farmers are profitable and need to be allowed to make a profit (i.e., farming is a business and operates under rules of business).

Adaptive capacity of the feature?- The adaptive capacity of warm weather produce to climate change is medium to high.

Produce- Cool Weather Produce (defined as crops that mature from mid-September to mid-June) Cool weather crops will be impacted more than warm weather crops due to increased temperature and precipitation (too much winter/spring precipitation will limit planting time) during the traditional cool produce growing season in Connecticut, but a lot of the other impacts

are the same as warm weather produce. A climate change-induced longer growing season will not benefit cool weather produce because light/day length is the limiting factor in Connecticut for growth. Plus, a longer, warmer growing season may mean that traditional holiday cool weather produce, such as pumpkins, will not be available for Halloween and Thanksgiving. Pests and pathogens (e.g., flea beetle) will be able to affect cool weather crops more due to climate change-induced decrease in winter chill days. Diseases that affect cool weather crops will be largely the same as warm weather crops.

Cool weather produce, such as peas, spinach, brassicas, beets, Swiss chard and bok choy, is of a lesser value and costs less to produce than warm weather produce, so there will be less stress to farm operations caused by climate change. Asparagus is the only really profitable cool weather crop, but it is already stressed by a lack of labor and will be further stressed by climate change by asparagus blight caused by the increase in precipitation. The “buy local” movement has made it easier to sell cool weather crops (e.g., customer acceptance of “alternative” greens such as kale), but it has required a lot of training of customers to know when cool weather crops are in season (e.g., asparagus is offered in the supermarket year-round, but is a spring crop in the farmers’ market in Connecticut) and how to cook cool weather crops.

Farmers will need research to determine the best cool weather produce variety to grow with climate changes. Some cool weather crops will still do well, such as onions, which are currently grown in warmer climates. Cool weather crops also are cheaper and keep longer and thus are a better choice than warm weather produce in a bad economy and when dealing with issues of food security.

#### Tobacco (shade grown not different from field grown so assessed together)

Changes in precipitation will affect tobacco the most in Connecticut; too much water will negatively affect planting and curing (tobacco can rot) and will increase diseases, such as brown spot. Since tobacco is a tropical crop, increases in temperature will not affect the growth or curing tobacco, as long as there is enough water to irrigate during the dry summer. In fact, warmer temperatures, especially earlier in the season, may benefit the growth of tobacco, and warmer winters will allow tobacco farmers to grow profitable cover crops, such as rape seed (biofuel), that also decrease pests (nematodes). However, increased temperature will affect the tobacco worker because tobacco is a very labor-intensive crop (i.e., hand-picked and hand-hung in a hot barn) and tobacco farmers have found it difficult to find labor when there is a hot summer. Warmer winter weather also may allow diseases, such as potato viruses, blue mold and black shank disease, to overwinter and proliferate. Extreme weather storms, such as hail and high wind, will affect field tobacco (already seen an increase in hail), and increased snow load would increase infrastructure costs for the curing sheds.

Tobacco is mostly stressed by factors outside of climate change, such as regulations on pesticide spraying, increased taxes, lack of labor, high development pressure and export complications. Ultimately, Connecticut tobacco will persist. Connecticut tobacco is prized due to the soil that it is grown in, so weather changes will not necessitate a move of tobacco production out of the state.

#### Small Fruits- Berries and Grapes

Cooler weather blueberries can be easily phased out by the time they are affected by the temperature increase in 2080. Strawberries will be especially affected by temperature because it's an alpine crop. Blackberries will increase with increasing temperature, but it will be negatively affected by extreme weather.

Pick-your-own operations, which are most berry operations in Connecticut, will be affected by increased precipitation and temperature. Extreme wet weather and increased temperatures also will stress agricultural workers picking berries.

Grape production in Connecticut will greatly benefit from warmer, drier summers. Grapes will have a longer time to mature, making more varieties a viable option in Connecticut (especially red varieties- see Cornell research), and diseases, such as mold and fungus diseases, may decrease. An increasing market for eating/table grapes could fill the void from climate change impacts to berries. Plus, grapes do well on marginal, rocky soil which is more abundant in Connecticut than sandy loam, which is preferable for most other fruits.

**Group 3 – Nursery, greenhouse, sod, and forestry**Participants:

Kip Kolesinskas, USDA NRCS, Group facilitator  
David Richards, Clinton Nurseries Inc.  
Dr. Richard Cowles, CT Ag Experiment Station  
Tom Worthley, Haddam Cooperative Extension Center  
Joseph Geremia, Geremia Greenhouse  
Joan Nichols, CT Farm Bureau Association  
Steve Rackliffe, UCONN Plant Science  
Douglas Emmerthal, CT-DEP, Forestry Division  
Sherwood Raymond, CT-DEP, Forestry Division  
Dr. Sandra Anagnostakis, CT Ag Experiment Station  
Dr. Richard McAvoy, UCONN Plant Science  
Christian Joseph, Prides Corner Farm  
Notes by Marshall Duer-Balkind, Yale FES

NOTE: There were a number of complaints about the limitation of matrix. People were initially confused as to whether they were supposed to be putting just the most important driver or all drivers in aggregate into matrix.

Area: Nursery, Greenhouse, SodFeature: Greenhouse Production

Greenhouse production will be largely unaffected from climate change since plant production is sheltered inside. However, a lack of summer precipitation/drought could affect greenhouse irrigation and water bans could decrease sales to the public. Warmer summers could increase the cooling costs of greenhouses. Pests also may increase due to warmer winter temperatures, and disease could increase due to high temperatures and humidity. Furthermore, climate change will impact greenhouse infrastructure from decreased light penetration due to increased precipitation during late winter/early spring. (Hail wind and snow load weren't a big concern because the greenhouse is constructed to withstand these impacts.)

Higher temperatures could benefit greenhouse production by decreasing winter energy costs, and increased carbon dioxide could increase plant growth. There also may be an opportunity to grow field crops that have been displaced by climate change.

Area: Nursery, Greenhouse, SodFeature: Outside Production (trees, shrubs, non-vegetable herbaceous plants)

Change to precipitation was the biggest concern for outside nursery production of trees, shrubs and non-vegetable herbaceous plants. The prediction of more water will be a positive change, depending on the timing and amount of the rain; although nursery plants do not grow well in saturated soils and rain during harvest time will create problems. The lack of precipitation during hotter summers will have a negative impact on nursery production, especially if irrigation systems are not adapted to compensate for the lack of precipitation. (The current size of most irrigation ponds in Connecticut will be inadequate due to increased evapotranspiration caused by

increased temperatures.) Increased extreme weather, such as hail, will increase the superficial/cosmetic damage to plants, which will delay sales for at least a year after the damage.

More research and monitoring will be needed to overcome the impact of climate change on outside nursery production. Nurseries will have to phase-out water-intensive plants and replace them with drought-tolerant plants, which will help growers, as well as consumers, adapt to less summer precipitation. Irrigation ponds also will have to be increased to accommodate and capture precipitation when it is abundant in order to compensate for the lack of summer precipitation.

Area: Nursery, Greenhouse, Sod

Feature: Sod

Since most sod is grown along the Connecticut River, increased precipitation that results in flooding and subsequent erosion will have the biggest impact to sod production in Connecticut. Good drainage is required to grow sod so that there will not be an increase in fungal diseases and that there will not be a delay in planting.

New varieties of sod that are pest and fungal resistant may need to be grown in Connecticut. Drainage infrastructure also will need to be constructed on sod farms.

Forestry

Generally:

Climate change will bring more opportunities to forestry than threats because of the positive effects of higher temperatures and more carbon dioxide. However, since trees are long-lived perennials, short-term adaptation to climate change would be difficult. Poor forest management is the limiting factor in forest products production, and forests could play an important role in climate change mitigation by acting as a source of carbon sequestration, if managed correctly.

Area: Forestry

Feature: Maple Syrup

Note: We decided to have a consensus discussion; one sheet, representing the consensus of the group, was filled out.

Magnitude: high

Likelihood: high

Driver: temp 1, air quality 2

Time Urgency: 2020

Maple Syrup production in Connecticut will be highly impacted by climate change. Maple syrup production in Connecticut may be impossible by 2080, particularly in low elevation areas, due to predicted increases in temperature, especially increases in late winter/early spring nighttime temperatures (the dichotomy of warm days and freezing nights are needed to induce sap flows). The lack of Connecticut-produced maple syrup products will especially impact Connecticut communities, such as Hebron, that hold maple syrup festivals. A decrease in established sugar maple trees due to climate change (some debate if this will happen- the USDA distribution map shows sugar maples across the southeast) also may negatively affect leaf peeping tourism during the fall, since maple sugar trees are responsible for some of the best fall foliage colors.

Furthermore, a decrease in sugar maples will negatively affect the lumber industry, since sugar maple trees are a top lumber product.

Maple syrup producers may have to be re-trained since there does not seem to be any solutions for directly adapting sugar maples to climate change.

Area: Forestry

Feature: Witch Hazel

Note: There were only a few experts on witch hazel, so we had a discussion. One sheet, representing the consensus of the group, was filled out.

Witch hazel is a shade-tolerant shrub that grows in upland forests. It is an economically important forestry crop that used in as and astringent, in a wide variety of cosmetics and to treat bruises, insect bites and hemorrhoids. The wood of the witch hazel is harvested in winter and sold in the summer for distillation, after the wood has dried. Witch hazel is usually a supplemental source of income for foresters/farmers. The largest witch hazel processing facility is located in East Hampton, Connecticut, not only making witch hazel an important agricultural commodity, but also an important industrial commodity.

Witch hazel grows in a wide variety of temperatures, from northern Canada to the southern United States. Therefore, temperature increases due to climate change should have no effect on witch hazel distribution in Connecticut. Witch hazel is also tolerant of wet soils, but not as tolerant of dry soils, so an overall predicted increase in precipitation will have a positive effect on witch hazel. The effect of carbon dioxide on witch hazel growth is unknown, so more research will have to be done.

Harvesting witch hazel is very labor-intensive because it is done by hand with saws. Harvesters are often of an older generation, and are not being replaced by younger generations. Witch hazel benefits from forest management practices.

Area: Forestry

Feature: Christmas Trees:

The projected increase in temperature will cause major disease (e.g., needle diseases) and pest impacts (e.g., phytophthora, armored scales) to Christmas trees in Connecticut. The projected increase in precipitation will cause root rot, especially in the true firs, which account for the largest amount of Christmas trees in Connecticut. Increased winter precipitation also will impact Christmas tree harvesting, especially at pick-your-own operations. Increased temperatures and precipitation will also increase weed growth, so increased herbicide resistance due to increased carbon dioxide will greatly impact the Christmas tree industry in Connecticut.

Christmas tree production is more adaptable than other forestry items because the grower has the choice of which species to plant. However, Christmas trees have a long growing period of ten to fifteen years, so adaptation planning will need to begin soon. Growers currently are adapting by growing different varieties of Christmas trees such as the Canaan fir, Eastern red cedar, Virginia pine and spruce instead of more northern species like the balsam fir. However, growing new Christmas tree varieties will necessitate consumer education; consumers may not be able to get

the Christmas tree that they want. More research is needed to support Christmas tree growers in Connecticut because currently the only research institution working on Christmas tree growth is the Connecticut Agricultural Experiment Station (CAES).

Area: Forestry

Feature: Wood Production (e.g. lumber, saw logs)

There would be a number of trees at their southern-most distribution or displaced by climate change in Connecticut, particularly softwoods such as eastern white pine and eastern hemlock. Many smaller sawmills in Connecticut could close because they are dependent on white pine and hemlock sawing stock. Hemlocks also are an important riparian and steep slope species, so their loss would destabilize these habitats. Warmer winters will narrow harvested tree removal time because the ground needs to be frozen.

The Connecticut forestry industry is under a lot of non-climate change induced stress. Forestry in Connecticut is a heavily regulated industry that relies on permits, which can hold up harvesting time until it is unfeasible. Forests also are becoming more fragmented in Connecticut which makes harvesting difficult and increases invasive plant establishment.

Consumer education will be needed to market less popular wood products, such as red maple. Forestry equipment also will need to be changed, at a large cost, to accommodate climate change.

Area: Forestry

Feature: Biofuel Crops

Biofuel and biochar (charcoal created by heating woody biomass and used for carbon sequestration, animal feed, soil enhancement and fuel) crops (e.g., urban trees, switchgrass and hybrid poplars) and production could increase due to climate change projections of increased temperature, precipitation and carbon dioxide.

Connecticut should develop a Woody Biomass plan to plan for the opportunities in this industry, and government economic incentives should be provided to develop the Connecticut biofuel/biochar industry. Economic incentives also need to be provided to biofuel plants to be combined heat and power plants (heat homes locally with steam) instead of burning biofuels with coal technology.

**Group 4 – Dairy and Livestock**

Candace Benyei

Greg Peracchio

Lynn Stoddard, team leader

Dr. Steve Zinn

Joyce Meader

Peter Orr

Joe Wettemann

Matt Staebner

Dr. Cameron Faustman

Dr. Glenn Warner

Richard Meinert

Don Tuller

Melissa Greenbacker

Amanda Freund, recorder

Dairy, Animal Husbandry

The primary climate driver for dairy animal husbandry is temperature; more frequent, higher day-time temperatures and the absence of nighttime cooling will cause more stress to dairy cows, which will depress appetite and reduce lactation (i.e., reduced milk production for sale) and calving. The stress of temperature will lead to long-term, poor animal health and reduced herd size and income potential. There also will be increased energy demands for fans and water cooling to keep dairy cows cool during hotter temperatures. Increased precipitation will lead to difficulty with managing the herd indoors by increasing the cleaning requirement, and will lead to difficulty with managing the herd outdoors due to wet fields. Decreased precipitation during the hottest summer months and subsequent water restrictions will further stress dairy cows and dairy farming operations.

The threat to Connecticut dairy operations from climate change is imminent and high. Workshop participants would like to see adaptation action sooner than 2020. Suggested adaptation strategies are to raise heat resistant breeds, implement cooling technologies and renovate barns for optimal cooling.

Dairy, Feed Production

The current climate in Connecticut is optimal for forage production, and thus Connecticut has a national competitive advantage. Feed production for dairy cows will be affected primarily by projected changes in precipitation. Increased rain could decrease production, especially for hay, impact harvest timing and increase winter erosion. The cost associated with purchasing more fertilizer, due to increased run-off, and feed would increase operational costs for the dairy farmer. Increased fertilizer run-off also would increase regulation. Increased severe weather, such as tornadoes, hurricanes and hail, drought and carbon dioxide (especially impacts corn) will further damage forage crops in Connecticut.

Dairy forage preparedness for projected climatic changes is critical. Crop management will have to be flexible and more intense, and heat resistant/drought tolerant forage species will have to be planted. The carbon dioxide-induced decrease in corn yield will require increased acreage in

Connecticut, which will be difficult due to development pressure. Greater winter precipitation also will require better erosion control.

Animal Husbandry for non-dairy Livestock (The group decided to combine beef cows, sheep and goats, pigs and horses into one group, Non-Dairy Livestock, because they felt that these animals will be similarly affected by climate change projections.)

Temperature and precipitation were the primary climate drivers for non-dairy livestock animal husbandry. As with dairy cows, increased temperatures will stress non-dairy livestock, and too much rain will increase hoof health problems and the use of bedding and hay and decrease pasturing. Increased temperature and precipitation also increase disease resulting from an increase in disease vectors such as mosquitoes and flies.

Capital investments and farm decisions need to recognize climate change projections and adjust their management plans accordingly before 2010.

#### Feed Production for Non-dairy Livestock

Precipitation is the primary climate driver for non-dairy livestock feed production. Droughts will necessitate rotational grazing, which is difficult in Connecticut where land is expensive, and expensive irrigation. The increase in the length of the growing season will be positive for feed production.

Feed production for non-dairy livestock is already stressed due to the increased demand on cropland to crop fuel crops instead of feed crops. New crops species tolerant of hot/dry and cool/wet climate conditions and new technologies will have to be incorporated into management plans.

#### Fruit Orchards for Apple and Pear Production

Precipitation is the primary climate driver for apple and pear production in fruit orchards. Continuous and increased rainfall will limit pesticide spraying. Warmer and wetter winters could decrease the size of fruit, and extreme weather, such as hail, could severely damage fruit.

Apple and pear production is already stressed due to a decrease in pollinators (i.e., bees).

**Group 5 Aquaculture and Poultry**

Penny Howell, Marine Species Assessment

Dr. Lisa Milke, NOAA Fisheries Service

Dr. Bob Rheault, East Coast Shellfish Growers Association

Jen Locke, Central CT Co-Op Feeds

Ken Pauze, Kofkoff Egg Farms LLC

Katherine Winslow, CT DoAG, Farmland Preservation (recorder)

Dr. Patricia Bresnahan, Uconn, CT Institute of Water Resources (team leader)

Rick Van Nostrand, CT DEP, Freshwater Fish Health and Culture

Dave Carey, CT DoAg, Aquaculture

Planning Area: AquacultureFeature: Shellfish

Temperature is the primary climate driver for raising shellfish in Connecticut. Increased temperature could influence the species and amount of shellfish grown in Long Island Sound, with both positive and negative results. Increased temperatures may affect shellfish quality and influence the type and quantity of shellfish predators and diseases, as well as the disease organisms that affect humans who consume shellfish. Ocean acidification caused by increased carbon dioxide in the atmosphere also could influence the species and quantity of shellfish grown in Connecticut. In thirty to fifty years, the ocean acidification problem may have a substantial negative effect on the shellfish industry, primarily due to increased mortality of shellfish larvae, which are the most vulnerable developmental stage. Research is ongoing to determine the effect of acidification on all species and stages of shellfish as well as ways to counter the negative impacts of climate change.

However, the shellfish industry in Connecticut is already stressed from forces outside of climate change. Shellfish production often conflicts with the multiple uses of Long Island Sound, both commercial and recreational, especially in terms of waterfront access and water quality.

Discharge from urban sewage treatment plants has been a problem for decades and is the primary cause of eutrophication and hypoxia in the Sound. Twenty years of improvement in sewage treatment within the Sound's watershed have only been able to stave off further increase in the duration and severity of hypoxia in the western Sound. Some species of shellfish may need to be grown further east and/or in the deeper parts of Long Island Sound (e.g., to North Stonington from Milford) to compensate for the increase in temperature and hypoxia. Further research will be needed to develop shellfish strains which are resistant to these effects of climate change.

Land-based hatcheries may also become a viable alternative if the costs of energy and waterfront real estate decline as the demand for high quality Connecticut-grown shellfish increases.

Feature: Finfish

The primary climate drivers for the finfish hatchery industry in Connecticut are temperature and precipitation. Increases in temperature could dictate the species raised in Connecticut, since the current hatchery species are primarily cold-water trout and salmon. Increases in temperature also could increase aquatic invasives and finfish pathogens and diseases. Furthermore, Connecticut imports a large percentage of its recreational stock of trout from Pennsylvania as well as other states. If these states experienced a climate change-induced die-off of their recreational stock, Connecticut would suffer. Furthermore, Connecticut hatcheries produce and stock most if not all

of their own recreational stock in Connecticut and also would suffer from a climate-induced die-off. An increase in precipitation of three to four inches could cause problematic epizootic events and impact water quality due to increased runoff.

Finfish hatcheries in Connecticut, which are exclusively trout, are out competed in the food fish market by much larger hatcheries out west that can raise trout at a lower cost per pound. In addition, high energy costs and a low number of low maximum number of allowable units of water limit fish production in Connecticut.

The finfish hatchery industry is very adaptable. Hatcheries could re-circulate, filter, sterilize and cool water, but money for these changes is the limiting factor. More temperature tolerant finfish species also could be grown; the mid-Atlantic hatcheries already are having success with temperature tolerant finfish species.

#### Planning area: Poultry

##### Feature: egg production

Temperature and precipitation were seen as the primary climate drivers for poultry egg production in Connecticut. Poultry are sensitive to high temperatures and a lack of good quality water, which will lead to a decrease in egg production levels. Increased groundwater mineralization caused by a decrease in water recharge will impact the quality of egg shells. However, the effect is relatively minor, poultry is grown all around the world, and warmer winters will have a positive effect on poultry egg production.

Poultry egg production is currently stressed by the high price of corn and grain feed and energy. Avian flu and other diseases and unregulated “backyard” farm flocks also pose a threat to poultry egg production in Connecticut. Managing poultry manure is another current problem for poultry operations.

Poultry facilities could easily adapt to climate change by raising poultry in a climate-controlled environment. It would be economically infeasible if poultry operations were forced to buy water.

##### Feature: meat production

As with poultry egg production, poultry meat production will be mostly affected by temperature and precipitation, but the impact will be relative minor since poultry can be raised in many different climates. More precipitation may cause more diseases, but higher winter temperatures actually may be a positive effect due to the need for less energy.

Currently, the poultry meat production industry is stressed by disease, predation (e.g., fisher cats and coyotes), grain and energy cost and the lack of processing facilities in Connecticut.

## **Appendix F**

### **Major Categories of Adaptation Response**

- (1) Regulation Changes
- (2) Research and Technology
- (3) Infrastructure Changes
- (4) Increased Management of Resources
- (5) Land Use
- (6) Education/Outreach

# Appendix C: Infrastructure

# 2010

# CLIMATE CHANGE IMPACTS ON CONNECTICUT INFRASTRUCTURE



A Report by the Infrastructure Workgroup of the Adaptation Subcommittee

January 2010



## Introduction

In accordance with Public Act No. 08-98, *An Act Concerning Connecticut Global Warming Solutions*, Section 7 required the Governor's Steering Committee on Climate Change to establish an Adaptation Subcommittee. The Adaptation Subcommittee is charged with the task, among others, of assessing "...the impacts of climate change on state and local infrastructure...", developing "...recommendations and plans that, if adopted, would enable state and local governments to adapt to such impacts...", and providing "...technical assistance to implement such recommendations and plans." Furthermore, the subcommittee shall first report on climate change impacts on: "infrastructure, including, but not limited to, buildings, roads, railroads, airports, dams, reservoirs, and sewage treatment and water filtration facilities..." This assessment effort is to be followed by a report due in mid-2010 that also contains the results of the above infrastructure assessment and, "...recommendations for changes to existing state and municipal programs, laws or regulations to enable municipalities and natural habitats to adapt to harmful climate change impacts and to mitigate such impacts."

Given this charge, the Adaptation Subcommittee established four working groups, including one on infrastructure adaptation. It is the goal of the Infrastructure Workgroup to meet the infrastructure requirement of Section 7 of PA 08-98 by fulfilling the following objectives: 1) assessing the risk from climate change relative to infrastructure; 2) identifying the level of urgency surrounding infrastructure by type; and 3) providing preliminary recommendations for developing and implementing infrastructure adaptation plans.

To meet the first and second objectives, listed above, the Infrastructure Workgroup has:

- 1) Assembled a work group with broad understanding and knowledge of state and local infrastructure that may be at risk from climate change;
- 2) Identified infrastructure planning areas and associated features of relevance to Connecticut that includes, at a minimum, those required by PA 08-98 (Table 3);
- 3) Identified the climate change conditions (i.e., climate drivers) that will most likely impact infrastructure (i.e., precipitation, sea level rise and temperature) and the predicted timeframes (i.e., 2020, 2050 or 2080) over which their effects will require adaptive responses;
- 4) Developed a risk assessment protocol that could be used to establish levels of risk and urgency for action for each infrastructure planning area;
- 5) Applied the risk assessment protocol in a workshop setting to complete a Infrastructure Workgroup "consensus" analysis of risk and urgency for each infrastructure planning area; and
- 6) Identified shortcomings of the risk assessment process, including information and research gaps that could improve the assessment and better support the second, adaptation strategy development phase.

During the next adaptation strategy development phase, which will fulfill the third objective listed above, the Infrastructure Workgroup will:

- 1) Identify potential adaptation strategies (e.g., retreat, re-engineering, armoring); and
- 2) Complete a report to the Legislature on specific infrastructure adaptation priorities, and recommendations for short-, mid- and long-term adaptation strategies and implementation steps.

The Infrastructure Workgroup represented a broad spectrum of regulators and planners at the state, regional and local levels; infrastructure stakeholders; and experts from academia, industry and private consulting in the planning areas identified for review. Although nearly 40 people were officially listed as participants in the workgroup (Appendix 2) and attended the risk assessment workshop, several more volunteered their time in unofficial roles in the July 2009 workshop (Appendix 3) or provided comment and review for various categories of infrastructure within their areas of expertise.

### **Climate Impacts on Connecticut Infrastructure**

There have been a growing number of publications related to climate change and, more recently, to climate change adaptation as federal and state agencies begin to prepare for what appears to be an unavoidable change. Of particular relevance to the Infrastructure Workgroup have been: 1. research that has helped to identify the potential changes in Connecticut's climate that could threaten our infrastructure (e.g., NPCC 2009; Frumhoff et al. 2007); and 2. studies and analyses that have identified various adaptation strategies and how to assign priorities for action (e.g., Snover et al. 2007; The Heinz Center and Ceres 2009).

Frumhoff et al. (2007) summarized projected climate change for northeastern states, including Connecticut. The authors concluded that Connecticut's climate is growing warmer and that residents could expect dramatic changes in climate over the course of this century if global warming emissions are not reduced. Exploring two emissions scenarios, a higher-emissions scenario, which assumed continued heavy reliance on fossil fuels, and a lower-emissions scenario that assumed the use of more "clean energy" technologies, they predicted:

- Connecticut is getting warmer and average temperatures could rise between 8 to 12 F degrees in winter and 6 to 14 F degrees in summer. Hartford, for example, could experience 8 to 30 days exceeding 100 F every summer, and air quality will be poorer;
- Winter precipitation will be mostly in the form of rain, increasing by 20 to 30%;
- More heavy rainfall events will cause more frequent and extensive flooding conditions;
- Summer drought conditions will increase, occurring annually in the high emissions scenario;
- Sea levels will rise in the range of 7 to 24 inches by the end of the 21<sup>st</sup> century;
- Coastal flooding of the magnitude of today's 100-year event could occur as frequently as once every 17 years in the New London/Groton area under the high emissions scenario; and
- Other effects that may threaten infrastructure include permanent coastal inundation, floodplain and shoreline erosion, extreme heat, forest and vegetation species composition change, and severity and frequency of storm events may increase.

The Connecticut Department of Environmental Protection (CT DEP) developed a series of climate change adaptation summary factsheets entitled, “Facing our Future: Adapting to Connecticut’s Climate Change<sup>9</sup>.” While all of the fact sheets relate to infrastructure adaptation in many ways, three of them, *Infrastructure*, *Water Resources, Quality and Quantity* and *Natural Coastal Shoreline Environment* are of particular relevance to the Infrastructure Workgroup effort.

*Infrastructure* identified river and coastal flooding as primary environmental threats to the state’s infrastructure. Transportation, water supply and treatment, wastewater treatment and dams were identified as key infrastructure types that could be threatened by increased river or coastal flooding. Also identified, but not always acknowledged as “infrastructure,” was the category of “landscape infrastructure.” The factsheet pointed out the investment in land-based best management practices (BMP) that are essential to water quality and quantity control and also provide habitat for fish and wildlife. BMPs aimed at dampening the effects of impervious cover (e.g., rain gardens) also provide habitat and ecosystem services that mitigate the effects of climate change by decreasing runoff and reducing the pollutant load carried in pollutant-laden, stormwater runoff.

The *Water Resources* factsheet focused on the implications of climate change for both water quality and quantity, but from the perspective of water as a human resource rather than the impacts on infrastructure. Highlighted were some of the climate-driven changes such as alterations of rainfall and storm patterns that could lead to more frequent floods or exacerbate droughts. While more total annual rainfall is anticipated for the Northeastern United States under changed climate conditions, the distribution, form and pattern of that precipitation can have severe consequences for water supply. For example, more precipitation in the form of infrequent, but torrential rainfall events does not provide the steady supply of water necessary to meet human needs. The factsheet also pointed to patterns of urban and suburban development that can disrupt the buffering capacity of forested landscapes and wetland areas, emphasizing the need for BMPs similar to those that protect infrastructure in order to maintain adequate water supply of good quality for human uses. Attention towards managing water supply is growing as episodic, severe droughts have been experienced over the last few years, providing a warning that supplies may be inadequate to meet growing demand in some areas.

The *Natural Coastal Shoreline Environment* factsheet primarily addressed habitat and ecosystem needs along the coast, though many of those “natural resource” needs also provide important services for humans and their infrastructure. Sea level rise and shoreline erosion can destroy barrier beaches, wetlands and tidal habitats, and significant habitats unique to fish and wildlife species that inhabit Connecticut’s coastal areas along Long Island Sound’s shores. Often, by protecting those rare habitats, we are also protecting natural defenses against sea level rise and storm surges that can be buffered by barrier beaches and tidal wetlands, thus protecting human infrastructure just a short distance upland from the shore. However, since sea level rise pushes these habitats inland, where there is not always open space for retreat and stabilization, both habitat and ecosystem services that protect infrastructure may be lost or compromised over time. Climate change can also change the sensitivity of coastal resources to water quality and

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<sup>9</sup> Available online at: [http://www.ct.gov/dep/cwp/view.asp?a=2684&q=436600&depNav\\_GID=1619#Sections](http://www.ct.gov/dep/cwp/view.asp?a=2684&q=436600&depNav_GID=1619#Sections)

biological degradation, which can render BMP infrastructure ineffective in some cases. For example, Connecticut estimates it will spend \$700 million to manage nitrogen to alleviate hypoxia in Long Island Sound; however, as temperatures warm, the sensitivity to hypoxia increases requiring nitrogen management goals to become much more stringent, and costly (CT DEP 2009).

In terms of economic effects, a FEMA HAZUS<sup>10</sup> loss estimation methodology software analysis of a 100-year flood scenario predicted that Connecticut could incur up to \$18.684 billion in property losses and business interruptions (Table 1). The increased occurrence of the 100-year flood due to climate change could greatly magnify these costs state-wide, especially without adaptation. In addition, the loss estimation from the FEMA HAZUS gives a broad estimation of the value of Connecticut Facilities and Buildings that could be at risk due to other climate change impacts. However, the FEMA HAZUS analysis also does not take into account the climate change-induced, synergistic effects of increased groundwater tables and sea level rise on future flooding, which could increase the 100-year flood property losses and business interruptions.

**Table 1.** *The Connecticut economic loss prediction by county from a FEMA HAZUS analysis of a 100-year flood scenario.*

County	Residential Property (Capital Stock) Losses (\$Millions)	Total Property (Capital Stock) Losses (\$Millions)	Business Interruptions (Income) Losses (\$Millions)	Total (\$ Millions)
Fairfield	1,588.36	3,959.34	26.64	5,574.34
Hartford	889.6	2,705.83	24.94	3,620.37
Litchfield	268.71	751.21	6.04	1,025.96
Middlesex	421.06	789.48	5.71	1,216.25
New Haven	1,062.78	3,793.97	25.21	4,881.96
New London	499	1,003.33	7.86	1,510.19
Tolland	98.35	277.09	1.91	377.35
Windham	118.81	355.46	3.08	477.35
Total (\$ Millions)	4,946.67	13,635.71	101.39	18,683.77

## Risk Assessment Process

To provide consistency in evaluating impacts of climate change among the four work groups, the Adaptation Subcommittee and workgroup chairs agreed to focus on three climate drivers, temperature, precipitation and sea level rise, and primary temporal benchmarks, 2020, 2050 and 2080. Further, the work groups adopted projections used by the New York City Panel on Climate Change (NPCC 2009; Table 2).

<sup>10</sup> The FEMA HAZUS software uses historic flood data, coupled with the latest geographic information system (GIS) technology and datasets to determine the economic losses incurred during a 100-year flood. See <http://www.fema.gov/plan/prevent/hazus/> for more information.

<b>Table 2. Temperature, Precipitation and Sea Level Rise projections for three benchmarks periods attributed to climate change (NPCC 2009).</b>			
	2020	2050	2080
<b>Temperature (°F)</b>	1.5 – 3	3 – 5	4 – 7.5
<b>Precipitation (%)</b>	0 – 5	0 – 10	5 – 10
<b>Sea Level Rise (in)</b>	2 – 5	7 – 12	12 - 23
<b>Rapid Sea Level Rise (in)</b>	5-10	19-29	41-55

Within these three climate drivers across the temporal benchmarks, the Infrastructure Workgroup also considered the effects of extreme events that might become more prevalent over time, especially heat waves, ice storms, intense precipitation and inland flooding, storm surge and droughts.

The Infrastructure Workgroup also considered the sensitivity and ability to adapt risk assessment questions in the Climate Impacts Group of the University of Washington, King County, Washington and ICLEI (Snover et al. 2007) in their *Preparing for Climate Change, A Guidebook for Local, Regional, and State Governments* for the risk assessment process. A matrix scoring approach incorporating the information from the sensitivity and ability to adapt risk assessment questions also was used to assess the relative risk of climate change on infrastructure planning areas in Connecticut (Figure 1).

Habitat: _____		2080 Perspective			Name _____	
Likelihood Severity	LOW	MEDIUM	HIGH	Virtually Certain/ Already occurring		
HIGH						
MEDIUM						
LOW						

Climate Driver	
Precipitation	
Temperature	
Sea Level Rise	

Time – Urgency - Action	
2020	
2050	
2080	

**Figure 1.** Scoring matrix for infrastructure climate change adaptation in Connecticut.

At the organizational meeting of the Infrastructure Workgroup in May 2009, efforts were directed towards compiling a list of infrastructure types (features and sub-features) to be aggregated into planning areas that are of concern in Connecticut, and would be assessed under the objectives listed above. A long and detailed list of specific infrastructure types was generated by Infrastructure Workgroup members, which was ultimately aggregated into nine broader categories, or planning areas (Table 3). The features and sub-features associated with the planning areas provided the specificity necessary to conduct the risk assessment during the July 2009 risk assessment workshop.

**Table 3.** *Infrastructure planning areas and related features and sub-features identified by the Infrastructure Workgroup for risk assessment for climate change adaptation.*

	Planning area	Feature	Sub-Features
LAND	Energy (gas, electricity, oil) and Communications	Generation	
		Transmission	Electrical lines
			Communication lines
		Transportation	Natural Gas Pipes
	Over Land		
	Storage	Over Water	
		Marine Terminals	
	Facilities and Buildings	Land Tanks	
		Public (schools, hospitals, government buildings, emergency operations)	
		Private (Recreation, residential, industrial/commercial)	
	Solid Waste Management	Cultural Resources (graveyards, monuments, historic structures, lighthouses)	
		Landfills	
	Transportation	Resource Recovery Centers (e.g., recycling, transfer stations)	
Roads and Bridges			
Rail			
Ports			
WATER	Coastal Flood Control and Protection	Airports	
	Dams and Levees		
	Stormwater (Point and Non-point)	Hazards	
		Collection	
	Wastewater	Treatment and Storage	
		Collection	inc. Pump Stations
		Treatment	public/community on-site systems
	Water Supply	Sources	surface water ground water
		Treatment	
		Distribution	

Risk assessment of Connecticut infrastructure was conducted during a July 2009 workshop using a modified University of Washington/ICLEI approach, described above. Two teams were formed to work on two broader categories of Land and Water related planning areas.

### Risk Assessment Findings

What follows is a summary of the key findings of the risk assessment workshop held in July 2009. They focus on commonalities across the planning areas. A further discussion of the assessment for each planning area can be found in Appendix 1. The information and analysis discussed here represents primarily the views and opinions contributed by participants at the infrastructure risk assessment workshop. Subsequent to the workshop, materials were assembled and a summary constructed for the Energy and Communications planning area, which was not completed at the workshop. Further, CT DEP staff Solid Waste Division were consulted to complete the assessment for the Solid Waste Management planning area.

**Table 4.** Risk assessment results from the infrastructure risk assessment workshop.

Planning Area	Feature	Average Likelihood	Average Magnitude	Most Often Risk Category Answer	Average Risk Score	Climate Driver	Most Often Given Time Answer
<a href="#">Coastal Flood Control and Protection</a>		3.30	2.70	High	8.73	Sea Level Rise	2020
<a href="#">Dams and Levees</a>	Hazards	2.64	2.82	High	7.36	Precipitation	2020
<a href="#">Stormwater</a>	Collection, Storage and Treatment	2.84	2.42	High	7.29	Precipitation	2020
<a href="#">Transportation</a>	Airports, Ports, Rail, Roads and Bridges	2.79	2.41	High	6.90	Precipitation	2050
<a href="#">Facilities and Buildings</a>	Cultural Resources, Private and Public	2.62	2.38	High	6.48	Precipitation, Sea Level Rise	2020
<a href="#">Wastewater</a>	Collection, Treatment	2.58	1.92	High	5.15	Precipitation	2080
<a href="#">Water Supply</a>	Sources, Treatment, Distribution	2.40	1.67	Low and High	4.21	Precipitation	2080

### Land

The planning areas categorized as land planning areas – Transportation, Energy and Communications, Facilities and Buildings and Solid Waste Management (Tables 4 and 5)– were most affected by the increases in precipitation, including extreme precipitation events (e.g., hurricanes, storm surges, ice storms, nor’easters), and, where applicable, sea level rise. More frequent precipitation and extreme precipitation events will create operation and maintenance challenges. Specifically, land planning areas will have to deal with increased runoff and drainage needs. For example, many of Connecticut’s culverts that pass runoff under roads or other infrastructure are undersized, which currently contributes to ponding on roadways, bridges, airports, railroads and parking lots during extreme precipitation events.

Land infrastructure features located along the coast will be most impacted by inundation from sea level rise, which also will contribute to drainage problems, as well as salt corrosion. Overall, land infrastructure was designed and built based upon current 25, 50 or 100-year storm specifications and with knowledge of existing flood plain and coastal area management designations. Thus, current design specifications may not be able to accommodate climate change conditions, which may lead to costly damage or destruction of infrastructure.

### Water

As with the land planning areas, the Water planning areas – Water Supply, Wastewater, Stormwater, Coastal Flood Control and Protection and Dams and Levees (Tables 4 and 5) – will be most affected by increases in, and changed patterns of, precipitation and sea level rise.

More frequent and intense droughts will decrease the quantity of available water. Increased precipitation and extreme precipitation events will increase stormwater and wastewater volumes, and thus decrease water quality from related pollutant loads. Sea level rise also can impact Connecticut’s water supply and stormwater. Salt intrusion will decrease the quality of the water

supply, and sea level rise, coupled with increased precipitation leading to higher groundwater levels, will limit the usefulness of infiltration galleries and other BMPs used to offset peak runoff impacts from stormwater.

Dams, levees and coastal flood control and protection infrastructure may be at risk of overtopping from increased precipitation and sea level rise, and aging flood management infrastructure may be unable to withstand the strain of increased water loads. Furthermore, in many areas development has complicated the impact from climate change by impeding the retreat or re-creation of tidal wetlands and flood plains, limiting the protection provided by these natural barriers against floods.

Finally, temporal benchmarks set at 2020, 2050 and 2080 do not provide a useful framework for climate change planning as impacts run the range from currently occurring to beyond 2080. Risk and vulnerability depend on the proximity of the infrastructure to various risk factors, making impact time variable as the impacts of climate change increase.

#### *Future Needs*

Research and detailed assessment is needed to improve our understanding of changing climate effects on infrastructure and our ability to adapt. Mapping of exact location and elevation of public and private infrastructure in Connecticut, its value and condition, for example the planning area of Buildings and Facilities, are key to more accurate and useful risk assessments. New flood and sea level maps, and engineering assessments of risk factors will allow a more exact assessment of risk with projected climate change, and the potential for site-specific adaptation. The location and elevation data could then be used to model the impact of future climate conditions. Finally, future monitoring of climatic conditions and sea level and associated research on the effects of climate change on Connecticut infrastructure are a continuing need.

**Table 5.** A summary of the impacts and future research and monitoring needs of each planning area.

Planning Area	Feature	Risk	Time Urgency	Primary Climate Driver	Main Impact	Future Needs
<b>Transportation</b>	Airports, Ports, Rail, Roads and Bridges	High	2050	Precipitation	Increased precipitation will negatively impact transportation due to flooding.	A locational and operational analysis of transportation infrastructure, with a particular focus on local roads and small, private airports.
<b>Energy and Communications</b>	Transmission, Transportation and Storage	N/A	N/A	Precipitation	Extreme precipitation events, such as ice storms, can damage energy and communication transmission lines. Increased groundwater levels may erode underground structures.	Since energy and communication generation and transmission cross state boundaries, a regional study of the effect of climate change on this planning area is needed.
<b>Facilities and Buildings</b>	Cultural Resources, Private and Public	High	2020	Precipitation, Sea Level Rise	Structures that were designed for existing precipitation amounts and sea level will be inundated by increases. Historic, cultural structures may be most at risk, due to the likelihood of construction before building codes and planning and zoning requirements.	A locational study of historic, cultural infrastructure.
<b>Solid Waste Management</b>	Landfills, Solid Waste Facilities	N/A	N/A	Precipitation	Higher groundwater tables may contribute to contaminant leaching in landfills. Extreme weather events, including ice storms, may disrupt solid waste transportation and increase storm-related debris.	Continued monitoring of active and inactive landfills to determine if groundwater rise or the rise of a nearby body of water will impact the landfill.
<b>Water Supply</b>	Sources, Treatment, Distribution	Medium	2080	Precipitation	The lack of precipitation caused by more frequent and intense droughts will decrease the quantity of available water, while increased precipitation and extreme precipitation events will decrease water quality from increased runoff and related pollutant loads.	Research the affect of increasing evapotranspiration on water supply, and the affects of storm intensity, duration and seasonal occurrence on rising groundwater levels.
<b>Stormwater</b>	Collection, Storage and Treatment	High	2020	Precipitation	Increased precipitation will increase stormwater, which will overwhelm existing stormwater infrastructure.	Determine the new 25, 50 and 100-year storm specifications, and determine the threshold when higher groundwater tables will slow the absorption of increased stormwater.
<b>Wastewater</b>	Collection, Treatment	High	2080	Precipitation	More frequent and intense precipitation will overwhelm sewers and combined sewer systems, sump pumps and pump stations.	The efficacy of flood barriers that protect wastewater treatment plants will have to be evaluated with increasing precipitation and sea level rise.
<b>Dams and Levees</b>	Hazards	High	2020	Precipitation	Dams and levees will be stressed and overtopped by increased precipitation.	An inventory of non-regulated dams and increased monitoring on the structural integrity of dams and levees.
<b>Coastal Flood Control and Protection</b>		High	2020	Sea Level Rise	Coastal flooding will increase in frequency, duration and magnitude and the existing flood control and protection infrastructure may be damaged, overwhelmed or overtopped.	FEMA coastal flood mapping will need to be redrawn and new impact data will have to be recalculated.

## Adaptation

Adaptation strategies will be the focus of the July 2010 report to the Connecticut Legislature, so just broad adaptation strategies are discussed at this time.

In general, categories of adaptation discussed at the workshop that have applicability to Connecticut's infrastructure include: 1) relocation to lower risk areas; 2) re-engineering to new, more protective standards; and 3) implementing mitigation techniques such as watershed management to reduce flooding. Not every technique will be practicable or even applicable to all types of infrastructure, and, in many cases, the adaptation of existing infrastructure may be more problematic and expensive and less effective than incorporating adaptation strategies into future construction.

### Barriers to Adaptation

- Social
  - Public Acceptance
  - Water Usage
- Political
- Economic
  - High Cost of Relocation

Adaptation strategies for infrastructure in Connecticut will include research that determines the structural and operational thresholds for each planning area feature considering the impacts of climate change. The findings of this research could lead to further recommendations, including the institution of additional design standards and zoning regulations. Cost and social implications of adaptation activities will need to be considered, as well as the changes in law and regulation that might be required. A comprehensive adaptation plan needs to take into account the uncertainty inherent in the projection figures, and allow for changes as new data arise. . An evaluation of any adaptation strategy will need to consider all factors, environmental, social and economic, and prioritized accordingly.

## Intersecting Issues

During workshop discussions, several intersecting issues emerged both within and across the infrastructure planning areas and also as related to the other workgroup areas of public health, agriculture, and natural resources. In particular, there is heavy reliance on transportation and communication services that affect public health (e.g., emergency transportation, response to catastrophes) and agriculture (e.g., bringing products to market). More examples of intersecting issues can be found in Appendix 1.

## Conclusion

This report represents the first step in a comprehensive analysis of potential climate change impacts on Connecticut's infrastructure, and ways in which Connecticut's state and local authorities, and citizens might adapt to unavoidable change. It identifies the primary threats from climate change, which are caused by changes in precipitation patterns and storm intensity, increasing temperature, and sea level rise. It identifies nine planning areas related to infrastructure on land (transportation, energy and communications, facilities and buildings, and solid waste management) and water resources (water supply, wastewater treatment, stormwater, dams and levees, and coastal flood control and protection). Within each planning area, specific infrastructure types are identified, e.g., roads, rails, airports, etc. for transportation, and a

subjective determination of risk (high, medium and low) from the primary climate change factors is made.

The evaluation process comprised a consensus approach from a diverse work group assembled from knowledgeable representatives of state, local and federal government, industry and academia. The process did not involve extensive literature review, information gathering or technical evaluations at this point; it was the goal of this phase to identify the primary threats to infrastructure and their relevance and importance to Connecticut's setting. The work group fully acknowledges this limitation and recognizes the needs for more detailed inventory, assessment, planning, and cost analysis to better quantify, and locate, specific infrastructure at risk in Connecticut, and the economic consequences of climate change impacts. That more detailed assessment is also a key to effective planning for adaptation, including options for adaptation, the interplay of federal, state and local regulation, siting considerations, social consequences and economic ramifications that will follow this first phase analysis.

The work group recognized the information need as a major challenge moving forward. Full scale planning for climate adaptation not only involves basic information described in the preceding paragraph, but also a sense of more subtle considerations that may require an enormous data gathering process. For example, knowing the life cycle of infrastructure can help determine timing with respect to the immediacy of the threats, to answer questions about relocation or re-engineering infrastructure now, or later. There is also a large and rapidly growing number of climate change reports being developed at all levels of government and industry that provide ideas and new perspectives on options for adaptation that should be more thoroughly reviewed for applicability to Connecticut. Finally, because climate change occurs gradually, over decades rather than suddenly in most cases, and predictive tools are not precise, it will be difficult to ensure actions are taken at the appropriate time to both minimize risk, the primary concern, and to minimize unnecessary or premature action. In some respects, adaptation need is a moving target, and even the best plans may be upset by an extreme event driven by climate change that can have disastrous effects for susceptible infrastructure that is not climate ready.

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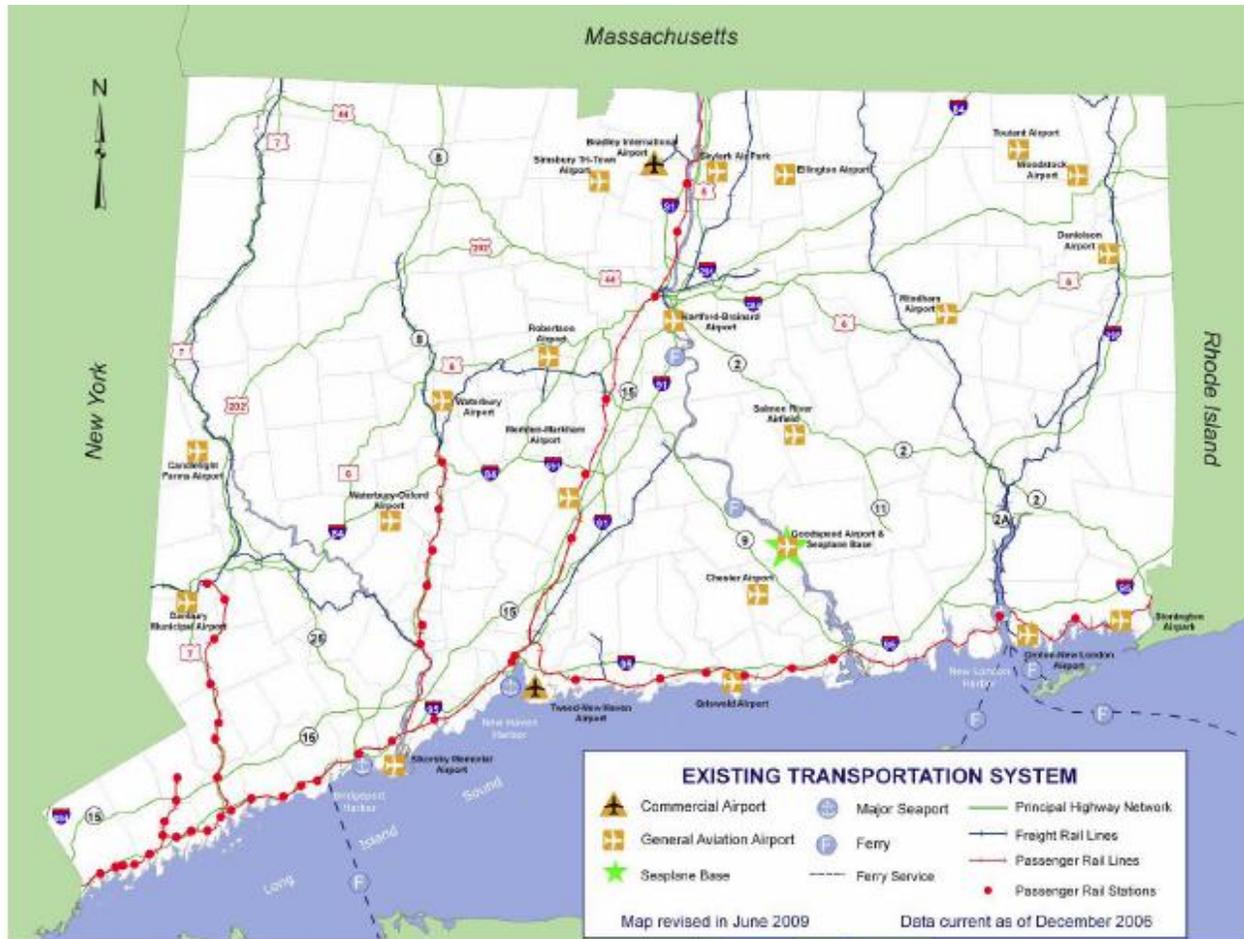
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## APPENDIX 1. Workshop Summaries by Planning Area

The following is a more detailed summary of the impact analysis performed by the experts who participated in the July 2009 risk assessment workshop. It also includes an early snapshot of level of resources that may be at risk.

### LAND

#### Planning Area: Transportation



*Connecticut's current transportation network, including airports, highways and rail lines (CT DOT 2009).*

Primary features considered in the climate change assessment of Transportation included roads and bridges, airports, railroads and ports and harbors. Of particular concern in all of the transportation planning areas are changes in storm intensity/flooding, precipitation, winter precipitation, especially potential increases in ice storms, and sea level rise inundation. Location is an important consideration for all transportation infrastructure, as features located in flood plains or along the coast are likely to be most susceptible to the impacts of climate change. Extreme events such as hurricanes and ice storms could have widespread and costly impacts. Sea level rise would rapidly increase if ice cap melting accelerates. There are also potential

secondary effects from climate change impacts such as increased use of chemical deicers that may degrade water quality.

### *Airports*



*Tweed New Haven airport and the surrounding area (left), and the same area with a 12 inch sea level rise scenario as a result of climate change (right; CT DEP).*

The Federal Aviation Administration (FAA) lists 56 public and private airports registered in Connecticut (FAA 2009). The Connecticut Department of Transportation (CT DOT) owns and operates Bradley International Airport in Windsor Locks and five general aviation airports in Hartford, Groton, Waterbury, Windham and Danielson (CT DOT 2009).

Increased precipitation, fog and storm intensity will affect airport operations, including usability of facilities, cancellations, clearing of debris and accessibility via municipal and state roads. Susceptibility of the airports may be mitigated to some extent because of their location in open areas where sources of debris may be limited, but plowing, use of salt and deicers and potential accelerated deterioration of paved areas may lead to increased maintenance and repair. With a lesser capacity to provide ongoing maintenance, smaller airports may be more susceptible and small changes could subsequently lead to problems. Furthermore, some airports may be threatened by flooding or sea level rise that could inundate runways, support facilities and access roads that may disrupt operations (e.g. Tweed – New Haven, Groton, and Sikorsky are located along the coast in low-lying areas).

Adaptation may require extraordinary resources to protect against climate change for the most vulnerable airports. Permanently closing or relocation of airports could shift supply and demand factors and alter cost and benefits. Also, if larger airports are closed more often due to climate change effects, even on a short-term basis, then demand may increase elsewhere, or diversions to other airports may put them over capacity and add to delays. Prospects for adaptation, especially relocation, are limited, can be costly, and may have regional impacts on other airports. Elevating airport infrastructure may be feasible, but would be costly. Overall, the adaptive capacity of airports, however, is considered low to medium, since it would be very difficult to move airports out of projected flood and storm surge zones.

### *Roads and Bridges*

Connecticut has approximately 21,295 miles of public roadway and 5,424 bridges, tunnels and buildings over roadways. CT DOT maintains approximately 3,731 miles of Connecticut roadways, 9,760 through-lane miles of state roadways and 3,875 roadway structures. Most of Connecticut's highways were constructed between 1920 and 1970, while Connecticut's interstate highways were constructed in the 1950s and 1960s (CT DOT 2009).

Similar to airports, roads and bridges, including winter passage, accident rates, clearing of debris and accessibility, especially for emergency vehicles will be most affected by increased precipitation, fog and storm intensity. Plowing and use of salt and deicers are costly and paved areas may deteriorate more quickly under projected climate conditions, leading to increased maintenance, and replacement. In addition, flooding can wash out roads and stream crossings and culverts may present potential erosion sites that can cause structural damage. Many culverts

(i.e., drainage and stream crossings) are already undersized, which contributes to backups in extreme weather events. In areas where sea level rise will impact stream levels, flooding will be exacerbated and due to higher frequency of extreme weather, neighborhood flooding will be more frequent due to backups caused by culverts. Local roads may be more susceptible than state roads or interstate highways because of age and design standards that may not accommodate more extreme weather events, or sea level rise.



*A flooded roadway in Connecticut (CT DEP).*

Low-lying coastal roads, which often already experience periodic tidal flooding, will be highly susceptible to inundation. Use intensity is also a factor that can compound the effects of climate change, especially in terms of maintenance costs and safety during storms. Extreme events of climate change are a major concern, especially when responding to disasters or providing emergency services that require safe and rapid transportation.

Adaptation may require extraordinary resources to protect against climate change for roads and bridges. Demand for roads and road improvements, including bridge replacements, already exceeds available resources, with estimates of \$10 billion for the total cumulative difference between anticipated revenue and projected needs in Connecticut over the next ten years (CT DOT 2009). Climate change will exacerbate these effects and our ability to adapt with fewer roads and viable routes due to sea level rise and flooding, closures due to extreme events, chronic reconstruction necessary to keep pace, peak hour under-capacity, and limited ability to retreat or relocate major corridors. These systems are already stressed and therefore have a high level of sensitivity to further effects related to climate change. However, as this continued investment to

upgrade our road systems is made, it is even more important to invest that money wisely, in a way that accounts for the changing climate.

Due to the enormous costs for reconstructing and relocating roads and bridges, the adaptive capacity is low. This is further complicated at the local road level, where adaptation options and budgets may be limited and pressure to maintain access, especially to valuable coastal properties, will be high. Some options may include alternative forms of transportation to free up capacity and reduce maintenance costs, and use of watershed management practices that might reduce flooding impacts on road and bridge infrastructure.

### *Railroads*

Connecticut has 628.5 miles of active railroads, which includes the transportation of passengers and cargo. Passenger rail service in Connecticut includes interstate service between New York and Massachusetts and commuter service along the shoreline (CT DOT 2009). Rail services for commuters, travelers and freight currently benefit highway overcrowding, which may suffer as a result of climate change. Demand could eventually exceed supply if economic or convenience forces continue to shift road commuters and freight to rail. Options for maintaining and expanding service are limited.

Railroads can be affected by precipitation events, sea level rise, and temperature. In many cases, railways are built upon much older infrastructure and along susceptible coastal areas or floodplains. Coastal spur tracks, especially those associated with ports, are likely to be in flood-prone areas where flooding will increase. Undersized culverts can lead to flooding of infrastructure upstream of rail bridges where stormwater flow is constricted. In general, railroads are less sensitive to snow events but more sensitive to ice storms, flooding and sea level rise along the coast. Both freight and passenger service could be susceptible to climate change-induced accidents, increased maintenance, and with limited redundancy of routes and options for relocation minimal, disruption of service may become more frequent and chronic. Though Connecticut's rail network is by and large in place, planning for new facilities such as stations, parking lots and structures, sidings, or maintenance facilities needs to account for and adapt to future changes in climate. The location of such facilities in flood-prone zones or in coastal areas may render them more vulnerable to damage than they historically would have been.

Adaptation for railroads is likely to be both logistically difficult and costly. Socio-political issues and regional economics impair the ability of railroads to adapt to climate change. Elevation of rail lines and bridges would be extremely difficult and costly and landward relocation of coastal rail lines is infeasible. While current sensitivity of railways to climate change is high, there is potential for adaptation if systems can be redesigned for future storms, flooding and sea level rise. However, adaptation will be very costly, such expenditures and require a renewed commitment and reliance on rails. There are some limited adaptation efforts underway; however, most are in response to crowded roadways and a desire to more economically move people and freight. Rehabilitation to current standards may or may not meet climate change needs, but could help with mitigation of greenhouse gases. In general, adaptive capacity of railroads to climate change is low.

### *Ports and Harbors*

CT DOT operates the port complex in New London, the only Connecticut seaport that has rail access directly through the Northeast states to Canada from a finger pier and easy access to I-95. CT DOT also operates two ferry services across the Connecticut River between Rocky Hill and Glastonbury and Chester and Hadlyme. Connecticut has three deep water ports in Bridgeport,



*Coastal fuel tanks at the port of New Haven (CT DOT).*

New Haven and New London, which are capable of accepting large industrial ships and cargo (CT DOT 2009). The New Haven port also includes a strategically important fuel oil terminal. Each year, private operators transport 19 million tons of cargo, 2.1 million people and approximately 850,000 vehicles (Yim 2002). In addition, Connecticut is home to a Naval Submarine base and associated General Dynamics Electric Boat Corporation submarine construction yard in New London/Groton. Furthermore, there are approximately 275 marinas in Connecticut.

Ports and Harbors are most susceptible to sea level rise and storm surges because of their location along the coast of Long Island Sound. More frequent storms could also affect maintenance dredging as sediments are both delivered to the Sound and relocated within the Sound during storms, especially extreme events. Consequently, needs for dredging will increase and any inability to keep ports and harbors functional could affect national security as well as commercial uses for freight transport and fishing, including aquaculture, and recreational boating uses. Breakwater structures, usually large stones, may deteriorate as wave heights and average depths increase. Loss of these breakwaters could have a devastating impact on some harbors. Land-side coastal infrastructure, including roads used for transporting goods, could be adversely impacted as they become impassable as a result of flooding. Secondary effects on the energy sector may occur if fuels such as home heating and power plant oil cannot be transported to ports and up rivers to storage terminals or power plants. Ports and harbors are also essential to the success of the fishing industry, primarily lobsters and shellfish.

New or expanding ranges of currently invasive species that negatively affect port functionality may become more prevalent due to warmer temperatures that could provide a competitive advantage over native species. Storm damage, additional dredging, more frequent/intense storms could compound negative consequences of storm surge and sea level rise for coastal habitats that currently provide natural buffers against storm damage.

Port and Harbor sensitivity to climate change is variable: facilities with features such as existing bulkheads with substantial freeboard, floating docks or the ability to move landward may be little affected by a one foot change in sea level rise, while others may be seriously impacted, especially if there is little room for land-side infrastructure to retreat. Adaptive capacity is medium depending on local conditions. While larger ports may be maintained to be more resilient to the effects of sea level rise and storm surge than local marinas, re-engineering of Connecticut's largest ports at New London, New Haven and Bridgeport as well as for the Submarine Base and other military installations may be necessary as climate change impacts continue to increase. While bulkheads can be raised, and strengthened to withstand tomorrow's 100-year storm, if upland space or affordability are constraints, some facilities may need to modify their capacity and make other adjustments in services. Elevation and intensity of land-side facilities are critical factors. For example, tank farms have low adaptive capacity, while bulk or container cargo lay down areas are more adaptable. While there may be local differences in the degree of impact, in general most of the coastal effects of climate change are likely to be Sound-wide.

Intersecting issues for transportation are many and varied since virtually all human commerce and services rely on transportation in one way or another, and natural resources can be impacted by transportation infrastructure. Further, mitigation of greenhouse gases may shift emphasis towards public transportation, perhaps exceeding demand and certainly requiring responsiveness to climate change to ensure functionality of existing systems. Human health relies on emergency transportation that can be affected by transportation failure. Agriculture needs to obtain delivery of supplies and equipment to maintain their operations, and bring their products to market before they spoil. Aquaculture relies on shoreline dockage and ports to bring their fish and shellfish to market. Natural Resources can be affected by transportation corridors through habitat disruption, and climate change may exacerbate impacts, e.g. more use of road salt, erosion from construction sites, and effects on stream flow caused by culvert sizing that may be inadequate to handle increased flows and effects. Similarly, all planning areas within the infrastructure category rely on transportation to bring goods and services to business and the public, maintain economic stability, and provide emergency services. Loss of transportation can have dire consequences in these and other areas.

## Planning Area: Facilities and Buildings



*The current Fairfield shoreline (left), and the same area after a 12 inch sea level rise inundation scenario, predicted in climate change models (right). Notice that a number of facilities and buildings, including private homes and schools, will be inundated due sea level rise (CT DEP).*

All climate drivers, temperature, sea level rise and precipitation, have the potential to affect all features of Facilities and Buildings to some degree. Vulnerability varies depending on location for sea level and precipitation threats, but all structures may be affected by socioeconomic effects of temperature that can impact heating and cooling needs and, thus, energy usage and public health. The facilities and buildings review considered all structural features within public, private and cultural categories. Although threats are similar for all facilities and structures, each has varied ability to respond and adapt, depending on a variety of social and economic considerations.

Higher temperatures will increase energy demand, primarily for cooling, which has both economic and public health ramifications. Cost of energy is increasing and can strain budgets for some socioeconomic classes. Inability to cool households adequately can lead to added stress for certain populations, especially those that suffer from chronic illnesses, including those exacerbated by poor air quality, such as asthma. Also, children and the elderly are less able to tolerate extreme of heat, and heat waves experienced throughout the world have led to illness and death. Coping with heat can also lead to excessive use of water, which also may be strained due to climate change conditions, especially during drought. Water may be used for cooling, but also landscape irrigation that may increase during drought and heat wave periods and contribute to decreased water quantity and quality. There is also an increased fire threat to structures, especially related to forest and brush fires, from high temperature and drought conditions. While Connecticut has not experienced the forest fires to the extent seen in more arid parts of the country, there are threats related to drought conditions that should not be overlooked.

Public, private and cultural structures have a medium to high susceptibility to temperature effects, though older structures with poor insulation and inferior structural integrity will be most susceptible. Extreme events, primarily heat waves, can be expected to occur more frequently under a changed climate.

Precipitation effects, especially flooding and extreme storm events, can threaten life and property to varying degrees depending on location. In particular, all categories of structures located in floodplains or along the coast can be impacted by floods and storm surges. In some cases, the unsafe effects of even moderate storms that contribute to erosive forces in streams, or wind and wave-driven shoreline erosion, can threaten vulnerable structures if the frequency increases over historical levels.

While most of the facilities and structures highly susceptible to the effects of precipitation are located in flood plains and along the coast, facilities throughout the state are moderately susceptible to damage from wind and rain forces likely during extreme events. Connecticut is more forested today than any time since Colonial conversion of forests to farmlands in the 18<sup>th</sup> and 19<sup>th</sup> centuries. Collateral storm damage from trees and other debris on structures is a likely scenario. Similarly, risk to structures from forest fires should be a planning and climate adaptation consideration. At the other extreme, snow and ice storms can have similar consequences to wind and rain events, including potentially collapsing roofs, energy outages, and collateral damage to property from falling tree limbs. Impacts on transportation, communication and emergency services will compound the consequences of precipitation effects and the ability to respond.

Sea level rise can be a serious threat to structures located along the coast. While the incremental rise in sea level directly threatens the viability and integrity of buildings and structures, the devastation of extreme events, such as a hurricane or major Nor'easter, is of more immediate concern. If sea level rise accelerates due to more rapid melting of polar ice caps than originally predicted, the effects of a major storm can be compounded, reaching to higher elevations than under current sea level conditions and predictions. Therefore, coastal buildings and facilities are generally highly susceptible to the effects of sea level rise, especially in combination with extreme event conditions. Sea level rise can also have more unsafe effects on structures, and their related infrastructure. Salts can corrode metals that are essential to the structural integrity of a building, and also contaminate potable ground water for public and private wells, and render subsurface sewage treatment systems ineffective from inundation.



*Intensive mixed-use coastal development will be at risk from climate change-induced sea level rise (CT DEP).*

Groundwater levels can rise due to added precipitation and due to localized impacts of sea level rise. This can cause:

- A limit to the usefulness of infiltration galleries and other BMPs used to offset peak runoff impacts from storm water;
- Impacts to existing foundations and basements and changes in pore pressure could impact soil bearing capacities and slope stabilities;
- An expansion in the aerial extent of development-prohibited areas (i.e., wetlands, vernal pools, surface waters); and
- An increase in the discharge from dewatering systems (i.e. sump pumps) that would result in an increase in surface water and/or sanitary flows.

In general, buildings and structures have a high ability to adapt to temperature increases. However, social and economic obstacles may limit adaptation. Adaptation strategies for temperature effects should focus on a range of energy conservation measures, including better insulation, weatherization, and use of more efficient heating and cooling systems. Use of alternative energy sources, such as solar energy, will also provide a measure of self reliance during periods of high energy demand. Certain best management practices that are effective for rainfall runoff controls, such as green roofs and landscaping practices, can also mitigate the effects of extreme weather conditions. For example, green roofs provide added insulation and contribute to vegetative cooling effects. Similarly, trees used for windbreaks and shading can reduce the effects of heat extremes, although plantings should be carefully planned to reduce risks from trees and branches falling on structures, as well as potential exposure to forest fire risks.

The capacity to adapt to the effects of precipitation, including extreme events, on buildings and structures is medium for most public and private structures as there are opportunities for reengineering to protect against floods or relocation, especially if worked into the life cycle of structures and urban renewal projects. However, for cultural structures, which often include a sense of “place”, opportunities for both reengineering and relocation are limited lest their cultural or historical value be destroyed. Careful landscaping and tree trimming practices can reduce risk from collateral damage to structures while also maintaining the cooling and rainfall runoff mitigative benefits of landscaping and related best management practices. Barriers to adaptation for all vulnerable structures are commonly related to economic, social or cultural situations that limit options for relocation or reconstruction. However, municipalities have opportunities to consider adaptation, particularly for new development or redevelopment, in their local plans of conservation and development, which are updated every 10 years.

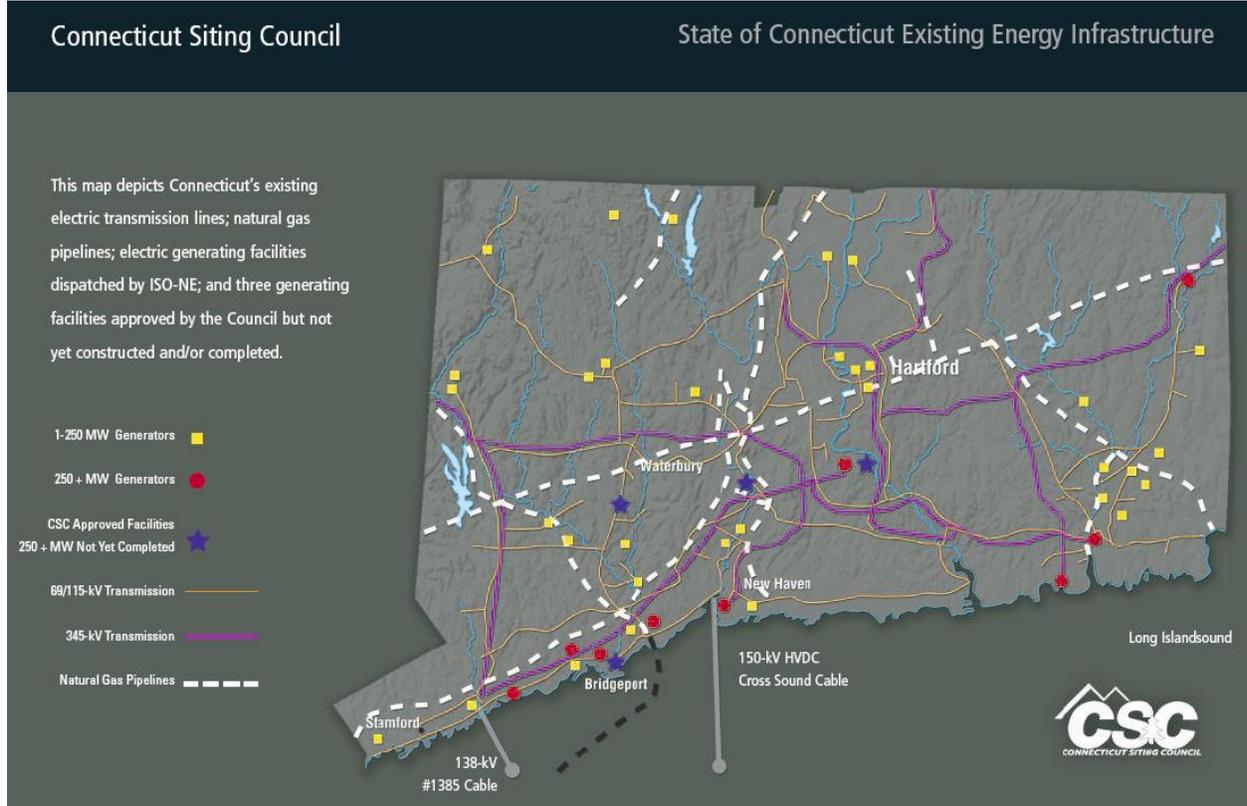
The adaptive capacity for coastal structures is low to medium, depending on the local situation. Often there is no room for retreat, and engineering solutions are often inimical to environmental management objectives and laws. These conflicts of use are primary barriers to adaptation along the coast along with the economic, cultural and social concerns and conflicts that impact all change. However, in some cases, management practices can help accommodate both environmental habitat needs and protect structures and buildings along the coast. For example, wetlands and barrier beaches provide buffering against waves and storm surge, reducing the force of water that may reach coastal structures. Proper design or modification of shoreline buildings, combined with the benefits of natural buffers may be enough to protect some buildings from destruction or damage. As discussed later in the *Flood Control and Protection in Coastal Areas* section below, protection of private property and associated property rights issues

(i.e., takings claims) will be a major point of debate during consideration of adaptive policy alternatives.

In many cases additional research, monitoring and assessment studies are needed to answer questions about building and structures at risk in all sectors, and how to best adapt to the effects of climate change – temperature, precipitation and sea level rise. The best opportunities for adaptation exist during revision of local plans of conservation and development, local regulation of new development, urban renewal and/or brownfield projects, and application of best management practices. However, most at risk are cultural and historical features that have limited options for relocation or rebuilding without losing the historical and cultural value for which they are preserved.

Building and structure adaptation intersects with most of the other subcommittee areas of study. Within the Infrastructure Workgroup, there is a strong link to flood control and protection in coastal areas, stormwater, transportation, and energy adaptation. Building and structure effects also intersects with human health effects, as heat and cold have direct health impacts, adding to stress of susceptible populations, and storm damage impacts emergency services and social well-being. Many of the mitigative techniques that will protect structures from flooding and coastal storm surges, and people from the extremes of hot and cold weather, also have environmental co-benefits. Best management practices related to landscaping or coastal buffering, for example, also provide habitat and natural resources sustainability benefits.

## Planning Area: Energy and Communications



There are approximately 1,558 existing and proposed telecommunications sites in Connecticut (CT Siting Council 2009). Electric generation infrastructure in Connecticut is comprised of 92 electric generators, including nuclear and hydroelectric generators, 1,818 miles of high voltage conductors, and 130 substations and/or switching stations (Connecticut Siting Council 2008). Connecticut Light and Power (CL&P), Connecticut's largest energy supplier, provides 1.2 million customers with electricity. CL&P electrical transmission and distribution infrastructure consists of 1,625 miles of overhead and 65 miles of underground transmission lines, 16,944 miles of overhead and 5,913 miles of underground distribution lines, 280,789 transformers, 712,885 poles, 235 substations and 1,222,728 meters (CL&P 2009). Connecticut's energy needs also are served by three interstate gas pipelines that extend 592 miles across the state, including 16 miles in Long Island Sound (DPUC 2008).

All climate drivers, temperature, sea level rise and precipitation, will variably affect energy generation, transmission, transportation and storage as well as related communication features. Electricity generation, transmission and distribution, as well as communication transmission and distribution features have similarities in their vulnerability to climate change. Of specific concern is the likelihood of more intense precipitation events, including hurricanes, icing and lightning strikes, and higher ambient temperatures that affect the cooling efficiencies of powerplants and substations (transformers), increasing operational requirements and reducing the lifespan of equipment. Fuel supplies for powerplants, such as natural gases and petroleum based fuels are generally transported by rail, truck, barge or pipeline and are, therefore, subject to some of the

same climate change effects as Transportation features. Storage is generally used to mean bulk storage at transportation terminals, but also storage at individual distributor or user sites as well. Structural facilities providing infrastructure support for energy and communications may be impacted in manners similar to those described for Buildings and Structures – each will have varied ability to respond and adapt, depending on a variety of locational and economic considerations.

Projected higher ambient temperatures and the potential for longer high heat events will increase energy demand, primarily for cooling purposes, which can strain energy supplies and the bulk power grid, particularly during extreme events. Escalated summer peak load demands may precipitate the need for new power generation or import capability in Connecticut. Climate change demands could contribute to fuel shortages and result in electrical blackouts or brownouts when peak demands cannot be met. As noted for buildings and structures, inability to heat or cool households adequately can lead to added stress for susceptible populations (e.g., children and the elderly and those that suffer from chronic illnesses) from temperature extremes and poor air quality that will exacerbate conditions such as asthma. Energy and communications infrastructure, and the operation thereof, will need to adapt to new temperature trends and the affect on system load demands.

Extreme events, primarily heat waves, although winter precipitation falling more frequently as ice and sleet, may contribute to increased power outages. Higher ambient temperatures will impact the efficiency of powerplant cooling systems and the lifespan of electrical transmission infrastructure, such as transformers.

Energy could easily adapt to climate changes related to temperature, provided fuel sources are plentiful. More power generation facilities could be constructed, transmission grids and pipelines updated and expanded, and transportation of fossil fuels stepped up. However, supply obstacles, including those that are politically driven (e.g., the Oil Cartel), , and the decade or more it takes to plan, obtain permits and construct energy infrastructure may limit adaptation. As with Buildings and Structures, adaptation strategies for temperature effects should focus on a range of energy conservation measures, including better insulation, weatherization, and use of more efficient heating and cooling systems. Use of alternative energy sources, including green sources such as solar and wind energy and fuel cells, but also nuclear and hydro-power, could present opportunities that provide a measure of energy independence from foreign fossil fuel sources. Furthermore, upgrades to cooling processes and changes in distribution transformer specifications may need to be investigated.

Communications adaptation can benefit from the trends towards more wireless communications, although telecommunication tower transmission sites may be susceptible to temperature effects and energy shortages as well. It also should be noted that many wireless communications facilities are still dependent on the wire line infrastructure. While wireless communication appears robust and invisible, it is still reliant on communication infrastructure, and likewise vulnerable.

Barriers to energy and communication adaptation are primarily economic and political, although social concerns over location for energy and communications infrastructure can forestall more rapid adaptation to climate change as the public approval process can be slow. Public concerns over exposure to electromagnetic fields and the aesthetics of wireless transmission towers often make facility siting difficult. Gas terminals and liquid fuel storage may also be viewed as fire and explosion threats to those in close proximity. Further, like transportation corridors, transmission corridors require long stretches of continuous land that often transverse human and wildlife habitats with negative consequences that are costly to mitigate when alternative routes are not practicable. These barriers to adaptation can lead to aging of infrastructure rendering it more susceptible to the effects of climate change.

Precipitation effects, especially flooding and extreme storm events, can threaten the integrity of energy and communications systems to varying degrees with concomitant effects of continuity of supply or service. In particular, electrical generation plants, transmission lines, pipelines, storage facilities and other energy and communication infrastructure located in floodplains or along the coast can be impacted by floods and tidal surge driven by storms. In some cases, storm-driven erosive forces in streams or along shorelines, can threaten vulnerable structures. Extreme events could be devastating, with long periods required to repair energy delivery systems, especially transmission lines. Lightning strikes and wind gusts associated with more intense precipitation events can cause severe damage to energy and communications structures leading to significant outages of service. Connecticut is more forested today than any time since Colonial conversion of forests to farmlands in the 18<sup>th</sup> and 19<sup>th</sup> centuries; falling trees and limbs during high winds and ice storms can cause collateral damage to transmission lines.

The best opportunities for precipitation adaptation are to maintain and reengineer infrastructure to protect against floods and storms, including relocation and other adaptive measures, when feasible. This would be most effective if worked into the life cycle of energy infrastructure upgrades and replacements. Careful landscaping and tree trimming practices can reduce risk from collateral damage to transmission and transportation systems and will maintain the heating, cooling and rainfall runoff benefits of landscaping and related best management practices. Barriers to adaptation for all energy and communications infrastructure are commonly related to economic, political and social forces that may limit options for relocation or reconstruction.

Sea level rise can also be a serious threat to energy infrastructure located along the coast in vulnerable positions, including transportation and storage systems, which are often related to ports for coal or liquid petroleum fuels. While the incremental rise in sea level directly threatens the viability and integrity of energy and communication systems, the devastation of storm surges from hurricanes or major Nor'easters, are of more immediate concern. Many power plants in Connecticut are located along the coast, both on harbors or on tidally influenced rivers, making them susceptible to sea level rise and storm surge. One facility in Bridgeport is already experiencing some site flooding during astronomical high tides when harbor water occasionally crests protective barriers at the site. If sea level rise were to accelerate due to more rapid melting of polar ice caps than originally predicted, the effects of a major storm would be compounded, reaching to higher elevations than under current sea level conditions. Therefore, coastal infrastructure related to energy and communications is generally highly susceptible to the effects of sea level rise, especially in combination with extreme event conditions. With sea level rise

also comes additional impacts on energy infrastructure associated with salts that can corrode metals, switches, pipelines, and storage tanks that are essential to the structure and function of energy and communication systems.

The adaptive capacity for coastal energy infrastructure is high as engineering can take into account the effects of sea level rise and corrosive properties of salt water. Pipelines and cables can be constructed under water, rendering sea level rise of little technical consequence, though costs and environmental concerns must be addressed. The environmental and social conflicts are the primary barriers to adaptation along the coast. With proper design or modification of shoreline and subsurface infrastructure, the natural habitats may be protected, or damage minimized.

Additional research, monitoring and assessment studies are needed to answer questions about potential impacts of climate change on energy and communications infrastructure, and how to best adapt to the effects of climate change. Of particular concern are the effects of transmission corridors both inland and under the surface of Long Island Sound. Studies of the landscape and seafloor are necessary to ensure the least damaging routes are identified, and the approaches used minimize the environmental and social impacts. Vulnerability studies of the powerplants, the bulk power grid, distribution lines, telecommunication towers and communication land lines will need to be performed by various entities, including infrastructure owners, operators and state/federal agencies. The adaptation of the energy and communications infrastructure to climate change, must be a coordinated effort and include Federal Energy Regulatory Commission (FERC), North American Energy Reliability Council (NERC), ISO New England, Federal Communications Commission (FCC), appropriate state agencies, public utility companies and telecommunications companies. Modifications to safety, engineering, planning and system reliability standards would need to be developed and implemented. Specific decisions would have to be made on load forecasting models, the need for new generation and transmission projects, and the need for renewable energy sources.

Energy and Communications infrastructure adaptation intersects with most of the other subcommittee areas of study. Within the Infrastructure Workgroup, there is a strong link to effects on buildings and structures and transportation. For generation facilities that need cooling water, competing uses and shortages driven by climate change, especially drought, may require prioritizing water use. Reuse of other wastewater sources is one adaptation option that would benefit both water supply infrastructure, and energy generation. Energy and communication effects also intersect with human health effects, as heat has direct health impacts, adding to stress of susceptible populations, and storm damage impacts communications and emergency services related to social well-being. Energy and Communications generation, transmission, transportation and storage all have potential impacts to natural resources if not carefully planned and sited. Best management practices related to landscaping or coastal buffering may not only benefit energy and communication systems infrastructure but also provide habitat and natural resource sustainability benefits. Further, conservation and alternative energy options will protect ecosystems and reduce the effects of air pollution on human health, and mitigate the discharge of greenhouse gases, thus mitigating a major contributor to climate change.

### **Planning Area: Solid Waste Management**

Primary features considered in the climate change assessment of Solid Waste Management included solid waste facilities and landfills, both operational and closed. Solid waste facilities include most aspects of solid waste handling under current practice, such as resource recovery facilities, recycling facilities and transfer stations, where solid waste may be transferred and processed for ultimate disposition. There are approximately 200 solid waste handling and disposal facilities under individual permits and 81 recycling facilities under general permits in Connecticut (CT DEP 2006).

As with Transportation planning area, of particular concern are changes in precipitation that could lead to more intense storms and flooding and affect winter precipitation, especially increases in ice storms that may disrupt solid waste transportation as well as contribute to surges of storm-related debris. Temperature and sea level rise effects were judged to be less of a concern, primarily affecting older, often closed Landfills that may have been located in susceptible coastal areas or floodplains.

Like most infrastructure planning area features, location is an important consideration for Solid Waste infrastructure, and CT DEP is currently working on a locational assessment of solid waste infrastructure. Unlike other planning areas, however, it is primarily the effects on the ability to collect and transport solid waste that is of concern, rather than the constructed facilities and landfills themselves. If key transportation routes or solid waste facilities are located in flood plains or along the coast, they are likely to be most affected by the manifestations of climate change. Extreme events such as hurricanes and ice storms could have widespread and costly impacts, not only disrupting transportation, but also creating storm debris that would have to be collected, transported and disposed of through the solid waste system, including out of state destinations. Secondary impacts of power failures may also result in additional food wastes and other material that will have to be disposed of promptly before decay and potential health or littering risks occur. Sea level rise would most likely impact any landfills along coastal areas, lowlands/wetlands, and floodways as sea level rise would rapidly increase if ice cap melting accelerates.

Solid waste facilities would be minimally affected by temperature changes related to climate change. Increased temperatures could have a positive effect on solid waste facilities in Connecticut by reducing some of the negative effects of cold weather, such as frozen solid waste and equipment failures. Contrarily, increased temperatures may also lead to increased putrefaction of waste, especially as it awaits collection during service disruptions due to weather events.

Sea level rise may have some effect on solid waste facilities located in Connecticut's coastal area (e.g., Bridgeport). The exact number would have to be determined by a GIS analysis. Similarly, extreme precipitation events resulting in flooding may negatively affect facilities located in flood zones, though today's siting standards generally preclude exposure to floods. The solid waste transportation network would be affected by both sea level rise and flooding, by blocking routes and creating surges of additional solid waste in the form of storm debris. Some solid waste facilities are capable of operating during flood events because newer facilities were built outside of the 100-year flood plains. Precipitation has a moderate direct effect on the efficacy of solid

waste incineration due to increased weight and moisture (BTU value lowered). There also could be more leakage of contaminants from solid waste during handling and transportation (e.g., leaking dumpsters, bins and trucks) with increased precipitation. Furthermore, extreme precipitation, such as ice storms, can impede solid waste transportation and solid waste incineration.

Landfills, whether operational or inactive, have a generally low sensitivity to climate change. Precipitation has the most impact on operational landfills. Landfills that have been located on rivers in the past or, more recently, in order to minimize the effect of accidental leakage, may be impacted by changes in water tables if not isolated from ground waters. Landfills were traditionally located in low-lying wetland areas, which were undesirable land and helped to control mosquitoes. Landfills located along the tidal rivers such as the Connecticut River, or along the coast, may be inundated from sea level rise associated with climate change. This location makes inactive landfills very susceptible to increases in ground water, which will occur due to climate change-induced increases in sea level rise and precipitation. In less extreme cases, higher water tables associated with sea level rise may contribute to contaminant leaching. The impact of increased salt intrusion due to climate change is unknown.

Temperature may increase the rate of gas generation in some landfills, but in general the temperature within a landfill isn't expected to fluctuate widely. Precipitation may affect newly closed landfills, like the Hartford landfill, that may be threatened by extremely high precipitation because the fresh earthen cap has not established a sturdy vegetative cover layer to effectively protect newly closed landfills from surface erosion. However, these caps are sufficient to repel most of the precipitation during normal precipitation events. Very few older landfills have leachate collection systems. Therefore, the long-term care of landfills may be particularly at risk, regardless of climate change impacts. The predicted more torrential downpours or higher levels of precipitation related to changed climate may exacerbate those effects.

There are some existing stressors that affect solid waste management, mostly limitations caused by the transportation network that brings solid waste to the facilities. Solid waste facilities used to be smaller and closer to the communities and businesses that they serviced. Today, facilities are fewer, larger and more spread-out across the state. Connecticut currently is at or has surpassed the capacity to manage its own solid waste, further increasing the transportation demand to out-of-state facilities. A number of publicly owned solid waste facilities also are stressed by the need to update aging infrastructure with little available capital. While the economic downturn has been positive for solid waste generation because people produce less solid waste per capita when the economy is poor, the eventual economic improvements will continue to strain capacity in future years. Both operational and inactive publicly owned landfills already are stressed by lack of funding, especially those landfills with closure and post-closure requirements.

Increasing demands for additional solid waste management infrastructure, including ultimate disposal needs for incinerator ash, may be constrained by the negative economic and social concerns that surround those needs. It is difficult to site transfer stations, incinerators and landfills in populated areas and few parts of the state can escape those concerns and provide the right transportation and environmental setting to be viable. The siting process is thorough for

new landfills and can, therefore, be expensive and time consuming. These costs and time constraints further limit the adaptive capacity of solid waste management systems.

Adaptation prospects for Solid Waste Infrastructure, including landfills, are limited, especially by the difficulties of relocating or siting new facilities with the social and political pressures that surround solid waste management. Although sensitivity of solid waste infrastructure to climate change is low, existing stressors and the prospects for storm debris management needs under emergency conditions coupled with the related transportation effects, raises solid waste concerns to a moderate level.

Transportation relationships have been described as a potential major intersecting issue. Others include potential public health effects from increased solid waste leachate into groundwater, prompt removal of decaying wastes during extended power outages, and emergency removal of debris. Natural Resources and agriculture may contribute to the solid waste stream if there is increased waste generation due to die-offs caused by increased disease and pestilence driven by a changed climate. Further, without prompt, efficient and economical disposal of solid waste, increased illegal disposal resulting from increased storm debris, and spoiled food wastes, could impact Connecticut habitats and wildlife and increase human health risks.

## **WATER**

### **Planning Area: Water Supply**

Connecticut has 151 public water supply reservoirs, serving 70% of the population, approximately 6,600 public water supply wells, serving 14 % of the population, and 250,000 estimated privately owned wells, serving 16 % of the population (CT DEP 2000).

All three primary climate change drivers can affect water supply sources, distribution and treatment infrastructure, but the impacts can be highly site specific and will be highly dependent on source water and location (e.g., surface water versus groundwater sources).

- 1) Increased temperature can increase demand, increase evaporation from surface supplies, and, in the case of surface reservoirs, temperatures can affect turnover and treatment.
- 2) Sea level rise can increase salt intrusion into groundwater sources near the coast, and can cause a change in local groundwater levels.
- 3) Precipitation patterns can lead to either drought conditions or more rapid replenishment depending upon the amount and timing of precipitation events.

Higher temperatures will not only increase demand, but will also decrease water quantity and quality. Extreme events, such as major storms and flooding, will affect water quality from increased runoff and related pollutant loads and damage the infrastructure itself. Precipitation amount and timing will likely have a continuing effect with the most severe consequences on supply, especially if change is abrupt.

Despite Connecticut's history of abundant, relatively clean water for human uses, recent shortages during drought periods have heightened awareness that some areas are already at risk. Connecticut is one of only two states nationally (Rhode Island being the other) that affords a

high level of protection in surface-water supply watersheds (Class AA – active water supply; Class A – potential water supply) by not allowing municipal or industrial wastewater discharges to Class AA and A waters. When planning for climate change, this differentiation in designated uses should be kept in mind as Class B waters, where treated industrial and municipal sewage are permitted to discharge, are not currently classified for potable water uses. One option, if conservation and water reuse measures fail to keep pace with human demand for potable waters stressed or depleted due to climate change, might be to modify Class B designated use to allow for potable water uses.

The quality of Connecticut's water supply will continue to remain high by maintaining these restrictions on uses of water supply streams and rivers, along with a strong aquifer protection program and watershed management practices that help diminish water supply treatment needs. Further, Connecticut is developing stream flow regulations<sup>11</sup> that will consider and account for current water supply demands, margins of safety, and mitigative activities in watershed management programs and conservation that will help assure adequate water supplies both for humans and fish and wildlife. As climate change effects become more prominent, especially drought effects, this balancing of needs will become more essential and perhaps controversial.

Water supply features can have considerable exposure to climate change effects, especially water supply sources. Overall, the exposure of water supply infrastructure to climate change will depend on the location, and the impact will depend on the number of features exposed at one time, both of which require additional assessment and evaluation. Sea level rise will increase vulnerability to salt water intrusion into numerous wells along the coast and tidal rivers, such as the Connecticut River. Some reservoirs along the coast are tidal to the base of the dam, rendering them potentially susceptible to salt water intrusion and sea level rise. Inland community water supply sources will be vulnerable to drought more than any other climate driver. Extreme events may disrupt water supply by impacting sources and damaging treatment and distribution infrastructure.

Although annual precipitation is expected to increase in our region, there will likely be a continuing trend towards water supply shortage, as decreased spring and summer precipitation reduce discharge during peak demand periods. Further, winter snow cover is expected to decline, which will reduce the spring freshet and potentially impact spring water storage and supply. Coincident increasing temperatures, especially when coupled with drought, will increase demand for human consumption, recreation, and landscape watering. In addition, increasing temperatures will increase evapotranspiration rates increasing landscape irrigation demands and reducing water supply reservoir yields due to increased evaporative losses.

There is also some evidence that longer growing seasons may mean increased water supply usage for crop irrigation, although other research suggests that increased carbon dioxide levels reduce stomatal conductance in vegetation, reducing evapotranspiration (Hatfield et al. 2008). Also, if nutrients, especially nitrogen, are limiting growth of forested areas, consequences may include both reduced evapotranspiration and increased runoff. Higher temperatures can affect

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<sup>11</sup> For more information about Connecticut stream flow regulations, see the CT DEP website <http://www.ct.gov/dep/cwp/view.asp?A=2586&Q=448406>.

both initial water quality and water treatment processes and can increase degradation of the quality of waters held in storage tanks.

The size of the drinking water source (i.e., the contributing watershed and/or aquifer) will affect the safe water quality yield. However, precipitation patterns, loss pathways (e.g., evapotranspiration and runoff), and both natural and engineered storage capacity are all considerations that could affect yield. Large interconnected water supply sources with multiple feeder sources will be in a better position to accommodate the increased demand, and whole smaller systems with fewer sources, may have a lower margin of safety.

Stress on potable water supplies is higher if the water is used for non-potable industrial or landscape or agricultural purposes, such as for cooling water in power plants. Stresses unrelated to climate change, like increases in population and related changes in land use, will magnify the demand brought on by climate change. While the potential increased growing season may not have a major impact on water supply sources because agriculture is largely irrigated with non-potable water, there are some operations that use potable water, and these diversions within water supply watersheds or aquifers may further reduce potable water availability.

Climate change is expected to produce swings in precipitation resulting in heavy rains and flooding, as well as drought conditions both which will directly affect water supply. Many wells are located close to major rivers and are highly susceptible to flooding and associated contamination. Sea level rise, along with precipitation-driven flooding can both negatively impact water supply by adding salt or contaminants to wells along the coast and tidal rivers, particularly the Connecticut River, which is tidal to north of Hartford.

Sea level rise was seen as the biggest threat to water supply distribution. Pipes in the inundated areas may have to be abandoned and salt water intrusion may corrode older pipes further inland. Rising temperatures could lead to more open hydrants in urban areas for recreational and cooling purposes and more water diversion for more frequent and intense forest fires, both causing a decrease in water pressure. Irrigation demand for residential and agricultural uses may also increase. Rising or falling water tables may impact older systems that leak water in or out of the pipelines. However, the group consensus was that water supply distribution is more significantly affected by infrastructure adjustments due to usage and age, not climate change.

The ability and capacity to treat drinking water will also be affected by climate change. For example, temperature may accelerate the effects of biological oxygen demand (BOD), which could result in low dissolved oxygen compromising water quality. Drought could concentrate contaminants in source waters, and more frequent flooding increases nonpoint and stormwater runoff pollution, which may require more intense treatment. Treatment plants are usually located in upland areas of higher elevation to allow gravity to assist feed, so sea level rise and flooding will not threaten most facilities. Water supply treatment demand will also increase as more people switch from wells to public water supplies due to both decreases in ground water quantity and quality, including the effects of salt water intrusion.

The sensitivity of water supply treatment plants to climate change was determined to be generally low, especially as compared to water supply source effects. However, it is also location

dependent and the sensitivity can range from low to high depending on local setting and conditions. Extreme storms and flooding may reduce or severely suspend the ability to effectively treat supply waters. The capacity for adaptation is high because the relatively small problems caused by climate change could be easily solved with existing technology, albeit at an increased expenditure. In general, some extreme storms and flooding may reduce, or temporarily suspend the ability to effectively treat water supply. Watershed management practices can help increase source water protection and quality and also help diminish water supply treatment needs.

In some areas, pharmaceuticals and other potentially toxic chemicals, which are difficult to treat and may affect aquatic life and human health at very low concentrations, are sometimes problematic for water treatment authorities. A strengthening of federal rules and a lack of agreement among water users about how to solve these emerging concerns are impediments to water supply treatment adaptation. As noted above, Connecticut prohibits industrial and municipal wastewater discharges to Class A and AA water supply streams and rivers, which precludes direct discharges of many toxic chemicals and pharmaceuticals that may be associated with industrial wastewater and sewage; however, urban stormwater runoff and subsurface disposal can contribute these contaminants to Class A and AA waters, further supporting the need for comprehensive approaches to stormwater management and aquifer protection. Furthermore, it is unknown what the affect of induced infiltration from a waste-receiving stream will be on groundwater supplies.

Without early planning and adaptation, climate change effects could seriously impact Water Supply Infrastructure (sources, treatment and distribution) in some high risk areas. The adaptive capacity of water supply sources and treatment and distribution systems can range widely, depending on local geographic setting and development conditions, and level of demand. The adaptive capacity depends on the geography (e.g., shoreline salt water intrusion), size of the water source, distributional distances, quality of water/level of treatment required and the amount of money available for adaptation. The adaptive capacity of the water supply itself is also limited if only Class AA and A waters are used, as currently required by state water law. Use of lower quality water sources (e.g., B class sources, which cannot be used for water supply uses per state water laws) for non-potable supply uses could provide a faster solution to non-potable water supply shortages than some other options. Reservoirs and aquifers cannot be moved and those subject to sea level rise and drought have few adaptation options. Therefore, effects of climate change will undoubtedly affect water supply, and have to some degree already. Climate change impacts can be mitigated on the supply side by increasing capacity and creating interconnections and redundancies to provide backup water supplies. Reduced demand is also a primary adaptation through conservation, water reuse, and non-potable supply substitution (but only for non-potable water uses). Water recycling, particularly in industry, and Drought Management Plans and a Wide-Area Response Network to respond to drought have helped ease pressure on water supplies and prepare for shortages. Changes in land management practices can also contribute to recharge instead of runoff and reduce demand for irrigation of landscapes.

Regulatory, social, economic and political roadblocks were cited as possible impediments to adaptation strategies related to water supply. Social barriers are potentially large issues since Connecticut residents are seldom denied water supply and it is provided very cheaply. It will be

increasingly important to educate Connecticut residents about water conservation needs, and protection of existing resources. Politics may also impair our ability to adapt to climate change, especially when a watershed or aquifer crosses political boundaries (e.g., Greenwich's watershed is mostly in New York). Politicians are often focused on the short-term, local interests and do not like to raise alarms about future conditions, and the high costs that may be associated with their management.

Adequate time to prepare and costs of implementation, however, are key considerations in providing adequate supplies of safe, drinking water at the lowest costs and planning for effects of climate change should begin now. Effective planning horizons could require seven to ten years to plan and implement new infrastructure that would ensure adequate water supply sources, treatment and distribution. Land acquisition and management would require the longest planning and management period. Emergency situations might be prevented or mitigated by proactive approaches with due attention to climate change effects by supporting proper water supply planning. Connecticut's Water Utility Coordinating Committees (WUCC) promote major regional interconnections. This regional approach would not only improve Connecticut's current infrastructure, public health and safety, and quality of life, but would put the state in a position to move water regionally as needed during emergency situations such as prolonged and sewer flooding, dam breaks and drought events.

In many cases additional research, monitoring and assessment studies are needed to answer questions about future drinking water availability, competing needs, effects of climate change, and options for adaptation and mitigation. Some of this information could become part of required water supply plans pursuant to CGS section 25-32d, and should include climate change vulnerability analyses and risk assessments for ground water, as well as surface supply from reservoirs and streams. Connecticut is also developing stream flow management regulations, which should consider future scenarios and the effect of climate change on water availability, water supply demand, margin of safety, and the cost and time to implement such scenarios. As a part of the planning process to develop stream flow management regulations, CT DEP will consider and account for current water supply demands, margins of safety, challenges in cost and resources, and the time it will take to address and implement current and future scenarios and the effect of climate change on water availability. While water supply was thought to have a low to medium sensitivity to climate change because of Connecticut's history of abundant, relatively clean water, recent shortages during drought periods have heightened awareness that at least some areas are already at risk. The quality of Connecticut's supply water can be a serious issue in spite of restrictive uses of water supply streams and rivers (e.g., no industrial or wastewater discharges are permitted) and a strong aquifer protection program along with the available technologies to filter and treat water.

The quality of Connecticut's water supply can continue to be at an optimal level by maintaining restrictive uses of water supply streams and rivers (e.g., no industrial or wastewater discharges are permitted) and a strong aquifer protection program and watershed management practices to help diminish water supply treatment needs. Adequate time for planning, preparation and implementation are key considerations in providing adequate supplies of safe, potable water at the lowest costs and planning for effects of climate change should begin now.

Intersecting areas for water supply include potential effects on human health if water is in short supply or is contaminated; and for natural resources if human demand for water supply leaves inadequate water for stream flow and other habitat needs essential to the health of the fish and wildlife populations.

### Planning Area: Wastewater

Connecticut has 87 large, permitted wastewater treatment facilities, with a number of private, community systems (Greci 2009). In areas not serviced by municipal or community systems, sub-surface disposal systems are generally used on an individual dwelling basis.



*Wastewater treatment plants located near Long Island Sound, like this one in Stamford, may be at risk from sea level rise (CT DEP).*

With many similarities to water supply with respect to climate change impacts, wastewater collection and treatment are the primary features of concern. Precipitation was seen as the biggest threat to wastewater collection, including effects related to combined sewer overflows (CSO) and sewer system overflows (SSO), treatment and, ultimately, the effluent

discharge itself. Industrial wastewater treatment can be similarly impacted by climate change but fewer large industrial treatment plants exist, they are not typically near coastal

water bodies and collection systems and subsurface disposal are not prominent features of industrial treatment.

More frequent and intense storms and flooding will overwhelm collection systems, increasing the frequency of CSOs and SSOs. This could reduce the benefit of very large expenditures in recent years by negatively impacting water quality in rivers and Long Island Sound. Systems with CSOs are most common in the larger Connecticut cities including portions of New Haven, Bridgeport, Hartford area (served by MDC) and Norwich. Added precipitation and sea level rise can also elevate groundwater, causing an increase in the infiltration and inflow into a sewer system through leaky pipes, legal and illegal foundation drains, sump pumps and roof leaders. This will increase the flows to the treatment plants, consume capacity of sewers, potentially overload pumping stations, increase electric usage in pumping stations and plant components, and in some cases reduce the treatment efficiency. Pump stations will need to operate for longer periods, and some will need to be increased in capacity. Close to Long Island Sound, salts and sulfates (converted to acids) may accelerate corrosion of concrete and equipment. Salty water may intrude into coastal collection systems. However, many of these impacts occur without climate change but the problems may increase or be exacerbated from climate change.

Since many sewer systems in Connecticut are at or beyond their useful life, adaptation planning strategies for wastewater collection systems should anticipate changes in ground water levels, sea levels, flood levels, and related impacts. Adaptive strategies and opportunities for low impact development (LID) measures that would mitigate some of the increased wastewater and infiltration and inflow (I/I), especially for illicit rainwater connections (e.g., roof leaders, sumps) that would better be diverted to infiltration practices or reuse should be considered.

For some wastewater treatment plants, a rise in sea level may trigger a need to install effluent pumping systems at a large capital and operating cost; for those already pumping effluent during higher tides, the duration of pumping will increase. For those adding effluent pumping, many of the emergency generator systems will also need to be enlarged due to the added electrical load to operate during extreme events.

The operations of treatment plants are modestly affected by increases in temperature. Bacteria favor higher temperatures, (especially the nitrifying bacteria) so increased temperatures with climate change modestly increased treatment efficiencies, especially in winter -- a benefit. If the swimming season also is lengthened due to increased temperature, there are implications for seasonal effluent disinfection periods, which may need to be extended.

If groundwater levels cause an increase in I/I, this will either need to be offset through more aggressive sewer system rehabilitation or CT DEP may have to renegotiate National Pollutant Discharge Elimination System (NPDES) permits for higher maximum flows. It has also been seen that higher flows (statewide) have led to higher nitrogen discharges to Long Island Sound, as opposed to dryer year conditions. If this trend persists, the statewide CT DEP permit for total nitrogen discharge to Long Island Sound could face a setback and require more aggressive nitrogen treatment, a costly and challenging proposition.

Since it is common to have treatment plants located near water (oceans and rivers), treatment plants must be protected from damage during floods and must operate and function during extreme events. As sea levels rise (and some rivers as well) wastewater sites may have to be further protected with berms, dikes or similar systems and some plant components may need to be raised. In extreme cases, wastewater treatment plants may have to re-located due to sea level rise or flood exposure.

Moving public/community wastewater treatment plants to higher ground as an adaptation measure to protect them from floods or other extreme events would be very costly and the relocation into new areas would be a difficult siting challenge. There would also be increased energy costs, and greenhouse gas emissions, associated with pumping more of the wastewater rather than relying on gravity. Armoring, such as dikes and sea walls, is likely to be more cost effective than relocation, but these are site specific and must be evaluated on a case-by-case basis. The adaptive capacity of wastewater collection systems is low because re-laying pipe and adding additional pumping stations is a substantial expense.

Climate change impacts should be a consideration when treatment plant upgrades are planned as well as when collection systems are reconstructed or new or replacement septic systems are planned and approved. CT DEP is in a position to add this planning requirement as part of their facility planning checklist.

On-site wastewater treatment (i.e. septic systems) may be affected by changing ground water levels which can be altered by long term precipitation changes and increased elevations of water bodies (Long Island Sound or adjacent rivers, streams and drainage features). An increase in groundwater levels will most often have a negative impact. A well-operating septic system must

have adequate separation distance between the leach fields and the ground water table. Where ground water tables rise, treatment in the soil will diminish and groundwater contamination can accelerate. While an increase in precipitation leads to more dilution of on-site wastewater, dilution of the same quantities of contaminants is rarely beneficial. If water table levels shift downward, a benefit for treatment will occur.

Sea level rise may necessitate the extension of sanitary sewer systems, require alternative on-site technologies or in the worst cases, cause abandonment of the property if sewerage is not an option because of location or sewer avoidance policies.

Projected increases in occupancy and use of geothermal heating and cooling, factors which, although not climate change effects, may result from mitigation activities to reduce greenhouse gases. These changes may affect the sensitivity and adaptive capacity of subsurface disposal by stressing the system (occupancy) or requiring ground space reserved for leach fields (geothermal).

One potential benefit of increased temperature is a longer growing season (and in the case of golf courses, a longer playing season) that may increase the utilization of wastewater for irrigation. Water reuse is not as large a component of water supply and wastewater treatment planning as in other parts of the country, but it should be encouraged as part of a sustainable environment, with or without global warming impacts.

In most cases, additional site specific monitoring and assessment studies will be needed to answer questions about future wastewater collection, transport, and treatment impacts of climate change, and options for adaptation and mitigation. Some of this information must become part of required treatment planning, both surface and subsurface, and should include ground water, flooding, storm frequency, and sea level rise considerations. Connecticut is also developing streamflow management regulations, which should consider future scenarios and the effect of climate change on water availability; effluent reuse for industry and irrigation may be a desirable response complementing plans for reducing reliance on potable water supply.

More emphasis on water conservation can also free up treatment capacity at wastewater facilities as well as community subsurface systems, thus increasing treatment efficiency and improving receiving water quality. While the process of wastewater treatment generally has a low sensitivity to climate change, the nexus of effluent reuse to water supply needs, and potable water treatment provides opportunities for rethinking comprehensive water supply and treatment trains. The quality of Connecticut's surface and ground waters would benefit from comprehensive planning as well, including watershed/development considerations that can reduce stormwater runoff and related effects on wastewater treatment. Extreme events may impact wastewater because of flooding, which can overwhelm treatment capacity and cause physical damage and power failure.

Intersecting areas for wastewater include potential effects on human health if water is not adequately treated and contaminates water supply or recreational waters; Agriculture if supplies are limited and infrastructure and policies for wastewater reuse become a primary adaptation

option; and for natural resources if wastewater cannot be effectively treated and diluted upon disposal to protect the health and well-being of fish and wildlife populations.

### **Planning Area: Stormwater**

Increased precipitation and sea level rise are the biggest impacts to stormwater systems in general. Increased precipitation associated with individual storm events will necessitate an increase in stormwater collection and stormwater treatment and storage capacities. A sea level rise of at least one foot would render some sump pumps and outlet pipes in shoreline towns (e.g., Stamford and Norwalk) ineffective and could inundate tidal wetlands and natural buffers thus reducing stormwater purification. Undersized stormwater collection systems could lead to water backing up behind undersized pipes and culverts, causing erosion and flooding and related infrastructure damage.

With changes in climate, stormwater return frequencies are also changing. Connecticut has recently seen a significant increase in the more extreme rain intensity events, leading many to predict this will be representative of a new definition of storm occurrences. Consequently, flood lines will need to be adjusted consistent with stormwater return frequencies. Historically, stormwater handling dealt only with quantity of water. More recently it is recognized that stormwater quality is an important aspect of stormwater handling, with a special focus on treating the first inch of runoff as required under several general stormwater permits issued under the NPDES program delegated to the CT DEP.

In many developed areas of Connecticut, especially highly urbanized areas, there is a shortage of stormwater storage and treatment infrastructure. BMPs are needed to increase retention and detention times (as required) and promote infiltration in areas where stormwater treatment is minimal. Stormwater is inherently difficult to treat because of the sudden and large influx of water into the environment, especially during extreme events, which are projected to increase under changed climate conditions. Landscape “softening” including reduction of impervious cover, preservation of features that promote runoff treatment (e.g., buffers and wetlands), and engineered BMPs can help resolve some quantity and quality problems, especially under exacerbations that may be caused by climate change. Additional study will be needed to determine if the management can keep pace with the negative consequences of climate change. Accelerated climate change would most likely affect coastal areas from sea level rise, as a symptom of accelerated ice cap melting.

Upgrading and enhancing stormwater storage and treatment to address increased stormwater volume is viewed as a priority and should become standard practices in all development and communities should take steps to incorporate storage and treatment into existing municipal systems whenever possible. Where possible storage in natural systems should be reclaimed from overly developed sites and restrictions (e.g., culverts, bridges, dams, etc.) may need to be removed.

Low impact development (LID), such as vegetative swales, rain gardens and pervious pavement, is a primary adaptation mechanism to improve performance of all stormwater system components. LID practices reduce volume by promoting infiltration, so enlarging stormwater

collection systems becomes less urgent, and provides ideal options for stormwater storage and treatment. Infiltration contributes to aquifer recharge and maintenance of base flows in streams, although consideration must be given to some pollutants associated with stormwater.

Temperature increases may change the way regulatory agencies treat stormwater; emphasizing wet ponds and BMPs that mimic natural features to reduce primary pollutants such as BOD and nutrients, which require increased treatment and storage time.

While LID strategies are a viable adaptation option to combat the effects of increased stormwater brought about by climate change, they are also good practices in any case to universally preserve habitat and hydrologic features of the landscape, and reduce pollutant loads from stormwater and nonpoint sources. Further research and assessment is needed to determine the exact vulnerability of stormwater systems in Connecticut, and the ultimate effects from climate change need to be evaluated. Connecticut should also review options for making better use of stormwater permitting authorities to promote LID practices and to better plan for the effects of climate change.

Lack of communication, collaboration and planning amongst watershed political entities and aging infrastructure make stormwater collection and transport infrastructure more sensitive to the impacts of climate change. Implementation of stormwater management efforts is most effective when conducted on a watershed-wide basis, which almost always crosses town boundaries and often state boundaries as well. Failure to consider downstream quantity and quality effects, and the projected changes brought about by climate change, would undoubtedly lead to losses in management efficiency, higher costs and ultimate failure to meet management goals and objectives in a comprehensive manner.

Intersecting areas for stormwater management include potential effects on human health if high levels of treatment can't be instituted and maintained and water supplies or recreational waters are contaminated; agriculture if recharge of groundwater is inadequate to provide surface and groundwater supplies for irrigation; natural resources if stormwater management cannot contribute to maintaining minimum streamflow and other habitat needs, and healthy water quality conditions essential to Connecticut's fish and wildlife populations.

### **Planning Area: Dams and Levees**

Connecticut contains an estimated 5,500 dams, of which 2,995 are regulated by CT DEP. The majority of dams are privately owned (72%) and used for recreation (50%). Other dam uses include hydroelectricity, drinking water, flood control and farm irrigation (Ruzicka 2009).

Levees are regulated in Connecticut as dams and are protective to at least the 100-yr storm. They are generally built to exceed FEMA standards, which are 100-year storm height plus three feet. Some levees, such as Hartford, are built to the flood of recent record, which exceeds the FEMA standards.

Dams are built to safely pass the design flood through adequate spillway capacity. A spillway is an area of the dam structure where water can flow downstream in a safe, confined manner without overtopping the rest of the dam. CT DEP maintains a 100-year return frequency storm

as a minimum basis for design and utilizes the US Army Corps of Engineers (ACOE's) spillway design criteria as a basis for the design of repairs and reconstruction of dams. The spillway design criteria utilized by CT DEP ranges from the probable maximum flood (PMF) – the runoff generated from the most severe meteorological and hydrologic conditions that are reasonably possible in our region, to the 100-year return frequency storm. The design flood varies dependent on the potential hazard classification of the dam structure. For instance, dams with high hazard potential have to meet a spillway design standard of a full PMF, and a dam with a low hazard potential has to meet the 100-year standard.

Projected precipitation, and especially extreme events, will have the most impact on Dams and Levees in Connecticut. Physical damage from floods and storms may breach or destroy dams and levees, and floodwaters may fill impoundments with sediments, reducing storage capacity and adding pollutants. As extreme precipitation events become more frequent, what is now considered a 100-year flood flow event. Under climate change 100-year flood events may be of higher magnitude and expand the flooded area that is actually impacted into unmapped floodplains or mapped 500-year floodplain areas putting more area and presumably more people at risk of flooding. These changes will have to be evaluated with due consideration for socio-economic conditions and public safety. Increased flooding may become more common in Connecticut and residents and government may have to adjust to that change since adaptation options may be limited.

Sea level rise might have positive environmental benefits if unnecessary dams and coastal levees and tide gates are removed, thus creating more natural systems that can retreat inland and opening of passage for fish and aquatic life migration. However, there will likely be more pressure from coastal property owners to increase the use of levees and tide gates (See Flood Control and Protection in Coastal Areas, below).

Since 72% of dams are privately owned in Connecticut, there are social and economic obstacles to overcome. The management of dams already creates a huge, and underfunded, regulatory and public safety burden. Adding considerations from climate change effects will require a large increase in resources to ensure public safety and environmental health. Strong outreach and education programs to make dam owners more aware of their responsibilities, and the possible adaptations to climate change, is essential.

Intersecting areas for dams and levees include potential effects on human health if dams and levees are breached and properties are flooded, or supply waters contaminated; agriculture if fields are flooded or eroded; and for natural resources if breached dams and levees alter, perhaps beneficially, habitats supporting the health of fish and wildlife populations.

#### **Planning Area: Flood Control and Protection in Coastal Areas**

Connecticut has 75 permitted locations for flood control tide gates, and 2,360 permitted locations for passive armoring structures, such as bulkheads, seawalls and groins.



*Undermining and collapse of a house caused by coastal flooding that was intensified by an undersized culvert (CT DEP).*

Sea level rise and extreme events such as hurricanes are likely to be driving factors. They will affect flood control and protection in coastal areas by increasing the frequency and intensity of flooding and erosion.

Historically, sea levels were considered to be fairly stable, with a predictable but slow rate of rise. However, climate change projections predict a rise in sea level that could be very dramatic. The combination of a rising sea level and more frequent high intensity storms can have a significant impact on stormwater impacts and flood impacts in low lying areas near Long Island Sound and its tributaries. Already it can be seen that the combination of inadequately sized storm drainage features and growth induced stormwater runoff is problematic in a great many communities, and storms over the past five years have resulted in more frequent and more significant impacts than historical records would predict, even without the added impacts from a sea level rise.

Rising ground water levels are usually problematic for flood control and protection in coastal areas. A great deal of coastal development was designed based on historical groundwater and sea level conditions, and a rise will potentially impact basement foundation and increase the amount of water entering storm sewers or being pumped illegally into sanitary sewers.

The Connecticut Coastal Management Act allows use of structural solutions (e.g., bulkheads, jetties, groins) only when necessary to protect infrastructural facilities, water dependent uses and pre-1980 inhabited structures when there is no feasible, less environmentally-damaging alternative. There has already been a significant amount of money invested in infrastructure adaptation along the coast, mostly reactive adaptation when property is threatened or storms damage or destroy infrastructure that must be replaced, or is allowed to be replaced under the law. Economics often plays a role since coastal real estate is expensive and many property owners can afford to install protective structures and implement other adaptive fixes. As rising sea level and increased storm intensity threaten coastal properties, there will be increased pressure from property owners to further harden shorelines and manipulate tidal impacts with

tide gates, not only to protect structures, but also to prevent loss of property from erosion and inundation. Whether or not investment in shoreline protection of private and public property should continue despite increasing risks, will continue to be debated, and ultimately tested in the courts.

Alternative adaptation measures, for example building setbacks, no-rebuild policies, and purchasing coastal land that is threatened by sea level rise and providing retreat areas for wetlands and coastal habitats, must be considered in adaptive management strategies. Much of the land at risk is under private ownership requiring foresight in regulation updates and strong enforcement, outreach and education to protect the public and their properties. Owners must be made aware of both their responsibilities, and their options for reducing risk.

Intersecting Areas for coastal area flood control and protection include potential effects on human health if protective barriers are breached and properties are flooded or damaged by storm surges, or supply waters contaminated with salt or other pollutants; agriculture if fields are flooded or eroded or rendered too salty for crops; and for natural resources if coastal structures are breached and altered, perhaps beneficially, habitats supporting the health of fish and wildlife populations, or adversely if policies are adopted that encourage further hardening of the shoreline or manipulation of tidal impacts.

**APPENDIX 2. Infrastructure Workgroup**

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**APPENDIX 3. Participants in the July 2009 Infrastructure Risk Assessment Workshop**

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# Appendix D: Natural Resources

# The Climate Change Impacts on Connecticut Natural Resources

A Report by the Natural Resources Workgroup  
of the Adaptation Subcommittee

January 2010



## Executive Summary

### Background

Climate change and the impacts on natural resources (forests, coastlines, rivers, estuaries, wildlife, inland and marine fisheries) will be an important issue for citizens within Connecticut and across the Northeast.

In April 2008, legislation (Public Act 08-98) was passed that established a subcommittee under the Governor's Steering Committee on Climate Change. This "Subcommittee on Climate Change Impacts" is specifically tasked with finalizing two legislatively mandated products that must be completed by July 2010: (1) an assessment of climate change impacts and (2) a set of actionable recommendations. This report represents the first of these products as it pertains to the projected impacts of climate change on the natural resources of the State of Connecticut.

### Approach:

- ◆ A Natural Resource Working Group (NRWG) was established via the Subcommittee. The NRWG is comprised of an assemblage of experts who can provide information on the impacts to the state's natural resources and represent the perspectives of the private sector, academic community, and resource managers.
- ◆ Information on the anticipated affects of climate change on natural resources was adapted from a series of Climate Adaptation Briefs prepared by the Department of Environmental Protection in 2008.
- ◆ Eighteen terrestrial and aquatic habitat types were identified as representative of the current diversity in Connecticut per the Comprehensive Wildlife Conservation Strategy.
- ◆ Climate change predictions for temperature, precipitation, sea level rise, and frequency of extreme weather events that were developed by the Columbia University/New York City Panel on Climate Change were used in this report.
- ◆ A facilitated risk assessment workshop of the NRWG was held to evaluate climate change impacts to the 18 habitats. Each habitat was evaluated to determine the (1) likelihood of its being impacted by climate change by the year 2080, (2) severity of impact by 2080, (3) primary climate driver and (4) likely time horizon for impacts to occur and urgency for action in 30-year steps – 2020, 2050, or 2080.
- ◆ An assessment of the impacts of climate change on Connecticut wildlife species was done via a web survey administered to all members of the NRWG, technical staff in the DEP Bureau of Natural Resources, and all members of DEP Taxonomic Committees.
- ◆ The species included in the survey were listed as "Species of Greatest Conservation Need" by the DEP or, in the case of plants, on the State's list of endangered, threatened or special concern species. Also included were invasive species and diseases in order to discern the potential impact of climate change on these threats to Connecticut's natural resources.

### Key Findings:

- ◆ Certain habitat types within the state are at relatively increased risk due to projected changes in climate. Among the highest at risk were Cold Water Streams, Tidal Marsh, Open Water Marine, Beaches and Dunes, Freshwater Wetlands, Offshore Islands, Major Rivers, and Forested Swamps.

- ◆ Several other habitats at lower risk are worthy of further consideration due to their limited distribution and unique contributions to overall biodiversity in the state; Rocky Outcrops and Summits, Bogs and Fens, Sand Barrens and Warm Season Grasslands.
- ◆ Seventy-five species that are currently of Greatest Conservation Need or State listed as Endangered/Threatened or Special Concern, were identified as likely to experience a large population decrease due to projected climate change in Connecticut.
- ◆ Nineteen invasive or potentially invasive species were identified as likely to experience a large or moderate increase in abundance in Connecticut due to climate change. The invasion and establishment of invasive species will likely increase with climate change
- ◆ Temperature was identified as a dominate driver for terrestrial and aquatic habitat types ranging from Upland Forest Complexes and Talus Slopes to Cold Water Streams and Lakes, Ponds and Impoundments, and Open Water Marine.
- ◆ Precipitation will drive changes in aquatic habitats such as Freshwater Wetlands, Major Rivers, Warm Water Streams and Bogs and Fens and terrestrial habitats like Rocky Outcrops and Summits and Early Successional Shrublands and Forests.
- ◆ Sea level rise is of most concern for coastal habitat types such as Tidal Marsh, Beaches and Dunes, Offshore Islands, and Intertidal Flats and Shores.
- ◆ Habitats at highest risk were assigned to the most urgent action category – 2020. This suggests that efforts to increase the resilience of high risk habitats such as Cold Water Streams, Tidal Marsh, Beaches and Dunes and Freshwater Wetlands are required during this and the next decade.
- ◆ Distribution and quantity of Cold Water Streams is limited, making this habitat particularly fragile and susceptible to projected changes in climate.
- ◆ Tidal marshes along the coast will be increasingly impacted by sea level rise and storm events.
- ◆ Relatively small changes in the timing and amount of annual precipitation will influence the suitability and distribution of wetlands systems, particularly vernal pools, shorelines and wet meadows, for many wetland dependent amphibians, birds and plant species.
- ◆ Lack of or further reduction in biological corridors (aquatic and terrestrial) that link habitat blocks will reduce the ability of plants and animals to migrate and adapt.
- ◆ As Connecticut’s climate gets warmer, the competitive advantage in our forest habitats will shift to more southerly oak-hickory forest mix over the currently predominant oak and occasional northern hardwoods (sugar maple, yellow birch, beech) cover.
- ◆ With increased water temperatures we can expect the abundance and distribution of coldwater species to decline and warmwater species to increase. Coldwater indicator species already in decline include brook trout, brown trout and slimy sculpin in freshwater; winter flounder, American lobster, and longhorn sculpin in saltwater; and rainbow smelt and tomcod among anadromous species.
- ◆ Increased frequency of droughts and extreme storm events may inflict additive mortality on certain bird species and amphibians during the breeding season.
- ◆ Migratory birds are vulnerable to the timing of food availability during their migration. Climate changes may result in a decoupling and cause increased mortality.
- ◆ In general, larger more adaptable species will benefit from climate change whereas smaller less mobile, habitat-specific species may become isolated with populations being no longer viable.

**Conclusions & Recommendations:**

- ◆ Climate change will have significant landscape-level impacts to Connecticut's habitats and the flora and fauna they support.
- ◆ The degree of impact will vary among habitats and species. Likely changes will include conversion of rare habitat types (e.g., cold water to warm water streams, tidal marsh and offshore islands to submerged lands), loss and/or replacement of critical species dependent on select habitats and the increased susceptibility of habitats to other on-going threats (e.g., fragmentation, degradation and loss due to irresponsible land use management, establishment of invasive species) in addition to climate change.
- ◆ Adapting to a changing climate will require ongoing monitoring of Connecticut's natural resources and development of a constantly evolving "tool-box" of adaptation strategies. In the short-term, reducing impacts from non-climate related stressors such as pollution, invasive species, fragmentation due to development, and water withdrawals will help to minimize the effects of a warming climate.
- ◆ Land acquisition that improves the connectivity of protected lands, critical habitat, migration corridors and increased conservation of important watersheds, shorelines and riparian lands, will be among the most important actions that can be taken to maintain long term ecosystem resiliency.
- ◆ The NRWG will endeavor to apply this information to develop an adaptation strategy, or roadmap, for the continued conservation of natural resources in Connecticut, our adjoining states and the larger region.



Confluence of the Eight Mile and the Connecticut River in Lyme Connecticut. © Jerry Monkman

## Introduction

Climate change and the dramatic impacts it will have on natural resources (forests, coastlines, rivers, estuaries, wildlife, inland and marine fisheries) will be an increasingly critical concern for countless citizens and organizations within Connecticut and across the Northeast. One of the many challenges lies in our need to identify and address the future impacts on natural resources given our current understanding of projected climate changes. Impacts from our changing climate will not be equally distributed across the State or amongst the diversity of habitats and species. Furthermore, the ability of a natural resource to accommodate projected climate changes will differ due to inherent characteristics, current status and distribution across the landscape. In addition, consideration of climate impacts on natural resources can not be addressed independently of human alterations (e.g., forest fragmentation, filling of wetlands, damming of rivers) that have resulted in dramatic changes in the Connecticut landscape over the last two centuries. Success in addressing the future health and survival of our natural resources will depend on our ability to accurately assess their vulnerability and better manage the capacity of our habitats to accommodate change.

In April 2008, legislation (Public Act 08-98) was passed that established a subcommittee under the Governor's Steering Committee on Climate Change. This "Subcommittee on Climate Change Impacts" is specifically tasked with assessing projected climate change impacts on, among other topics, natural resources and habitats within the State, and developing recommendations to enable those resources to adapt. The two legislatively mandated products that must be completed by July 2010 are: (1) an assessment of climate change impacts, and (2) a set of actionable recommendations. The Natural Resource Working Group (NRWG) will accomplish these tasks for the natural resources of the state of Connecticut.

The NRWG is comprised of an assemblage of experts who can provide information on the impacts to the state's natural resources and represent the perspectives of the private sector, academic community, and resource managers. Through a focused workshop and online survey, the NRWG identified the likelihood and severity of climate change impacts on habitats as well as key indicator species. The findings and results presented here reflect a credible consideration of habitats and species across the state, but are not intended to convey a comprehensive assessment of specific impacts.

The principal goal of the NRWG is to clearly articulate our current understanding of future impacts on habitats and species in order to eventually develop climate adaptation recommendations for Connecticut's natural resources. The specific objective for this first phase is to prepare an assessment of likely climate impacts to natural resources for the Governor's Steering Committee on Climate Change. This report is the first of two mandated products referenced above, and is a testament to the importance and urgency with which we must prepare our State for the very serious changes looming ahead.

## Approach and Scope

### Climate Drivers:

Climate change impacts on the natural resources within the state of Connecticut will be driven by changes in temperature, precipitation, and sea level along with increased frequency of extreme weather events. For the purpose of the NRWG's task, we assumed that climate change predictions developed by the New York City Panel on Climate Change (NPCC)<sup>12</sup> for the greater New York region would apply equally well to the state of Connecticut.

The general predictions for the primary climate drivers and extreme weather events are as follows (NYC Panel on Climate Change (2009)):

- Temperature: 1.5 – 3° F increase by the 2020s, 3 – 5° F by the 2050s and 4 – 7.5° F by the 2080s.
- Precipitation: 0-5% increase by the 2020s, 0-10% by the 2050s, and 5-10% by the 2080s.
- Sea level rise: 2-5 inches by the 2020s, 7-12 inches by the 2050s and 12-23 inches by the 2080s.
- Increased frequency of extreme weather events such as heat waves, droughts, intense precipitation events, and storm-related flooding.

**Risk Assessment:** We developed our assessment of risk to the natural resources of the state by determining anticipated impacts on 18 different terrestrial and aquatic habitat types (Table 1) and their associated species. Habitat types were identified from Connecticut's Comprehensive Wildlife Conservation Strategy (CWCS) (2005) with modification. The habitat types are representative of the current diversity in Connecticut. Taxa specifically considered in the species-based evaluation included all Greatest Conservation Need (GCN) species as listed in the CWCS. This list was expanded by adding all plant species officially listed as Endangered, Threatened, or Special Concern by the state. In addition, selected invasive species and pathogens were included to consider climate change related threats from increased competition, predation and disease.

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<sup>12</sup> New York Panel on Climate Change (NPCC). 2009. Climate Risk Information. The City of New York.

**Table 1.** Description of eighteen habitat types within Connecticut specifically evaluated during the Natural Resources Working Group workshop.

Habitat	Characteristics
<b>Upland Forest Complex</b>	Upland Forest habitats are characterized by deciduous trees, evergreen trees, or mixed evergreen-deciduous trees with overlapping crowns forming between 60-100% canopy cover. Upland Forest is the predominant (60%) vegetation type in Connecticut. Hardwood forests make up 80% of Connecticut's forests, with oak/hickory accounting for 51% and northern hardwoods for 29%.
<b>Coastal Uplands</b> (Headlands, Maritime Forests)	Include dry coastal headlands and dry to moist coastal or maritime forests that are exposed to wind and salt spray effects. Typical trees include pitch pine, post oak, red oak, American beech, white oak, tulip tree, scarlet oak, and sassafras. Understory or groundcover typically includes bayberry, beach plum, flowering dogwood, and switchgrass
<b>Rocky Outcrops/Summits</b>	(a) <u>Red Cedar Glades</u> are found on exposed summits, ledges, and outcrops and include red cedar, low shrubs, and medium-tall grasses/herbs, such as little bluestem. (b) <u>Grassy Glades and Balds</u> are found on dry exposed summits, ledges, and outcrops, including acidic (gneiss, schist, granite), subacidic (basalt, diabase, calcareous schists) and pH neutral (marble, dolerite) soil types. Grassy Glade and Bald vegetation is typically low shrubs, grasses, and herbs, including bearberry, lowbush blueberry, sand cherry, poverty grass, and little bluestem.
<b>Sand Barrens and Warm Season Grasslands</b>	Sandplain and Other Warm Season Grasslands are found on fine deposits from glacial outwash, distributed primarily in the coastal counties and also historically in the Connecticut Valley north to Hartford. These grasslands include shrubby or grassy vegetation maintained by fire, including bear oak, big bluestem, little bluestem, Indian grass, orange grass, and poverty grass.
<b>Early Successional Shrublands/Forests</b>	This habitat is generally comprised of shrubs less than 0.5m tall with individuals or clumps overlapping but not touching. This forms less than 25% canopy coverage. Tree cover also is less than 25%. Early Successional Forest stands are generally dominated by regenerating stands of birch, aspen, oaks, maples, hickories, and beech. Shrub dominated wetlands, are comprised primarily of shrubs, such as alder and dogwood species, as well as seedling to young sapling forest stands. Early Successional Shrublands and Forests generally occur when mature forest canopy is disrupted, allowing sunlight to reach the ground.
<b>Forested Swamps</b>	Forested Inland Wetland habitats are characterized by wetland soils, and dominated by evergreen or deciduous trees with crowns forming 60-100 % cover. Connecticut has about 100,000 acres of Forested Inland Wetlands, with red maple forests being the most common. This habitat classification includes sub-habitat types important to wildlife. (a) <u>Atlantic White Cedar Swamps</u> and seasonally flooded forests are dominated by Atlantic white cedar, and include highbush blueberry, rosebay rhododendron, swamp azalea, red maple, and yellow birch. (b) <u>Red/Black Spruce Swamps</u> are saturated bog forests of northwestern Connecticut, dominated by black spruce or red spruce. (c) <u>Northern White Cedar Swamps</u> are seasonally flooded forests dominated by white cedar and are restricted to calcareous wetlands (Robbins Swamp, Canaan, CT).
<b>Bogs and Fens</b>	Bogs and Fens are dominated by wetland soils and woody vegetation greater than 1.5 feet and less than 20 feet in height, arranged individually or clumped. The shrub layer generally forms more than 25% of the canopy cover, with whatever trees are present forming less than 25% of the canopy. Bogs and fens are natural peatlands that occur in topographic basins influenced by groundwater. Spring fens are characterized by saturated wetland soils that receive groundwater discharge throughout the year.
<b>Herbaceous Freshwater Wetlands</b>	This habitat is dominated by a herbaceous layer of grasses, forbs, and ferns and includes less than 25% of scattered tree, shrub, and dwarf-shrub cover. Freshwater Marshes are typically adjacent to rivers and streams, and are periodically flooded and influenced by run-off from adjacent upland areas. Typical plants include cattail, buttonbush, highbush blueberry, water willow, and swamp loosestrife. Vernal Pools fill with water seasonally, often with the rising water table in fall and winter, or with meltwater and runoff of snow and spring rain. Vernal Pools generally, but not always, are dry by late summer.
<b>Major Rivers and Associated Riparian Zones</b> (including floodplain forests)	Large Rivers and their riparian zones support a diverse assemblage of fishes, including resident and diadromous species and marine visitors. These deep freshwater habitats provide adult holding areas, migration staging areas, and foraging and spawning areas for many fish. Several mussels and the federally listed Puritan tiger beetle also depend on this habitat.
<b>Cold Water Streams and Associated Riparian Zones</b>	Cold Water Streams are rapidly flowing clear waters with gravelly or cobbly substrate. They include the smaller (< 30 ft wide) perennial streams located at the headwaters of drainage systems, surface springs, seeps, and thermal refuges. These habitats support many of Connecticut's most sensitive fish, including the slimy sculpin, brown trout, and brook trout. Cold Water Streams in Connecticut are typically associated with undeveloped forested areas, where shade from the forest canopy and inflow from groundwater and undisturbed wetlands maintain stable and suitable water temperatures, especially during summer.

Habitat	Characteristics
<b>Warm Water Streams and Associated Riparian Zones</b>	Warm Water Streams constitute a transitional habitat continuum connecting Cold Water Streams and Large Rivers. They include both relatively small perennial streams located near headwaters, medium size streams, and relatively large streams with considerable width. In general these habitats include waters where cold water species such as trout are absent or only seasonally abundant and dependent on thermal refuges for over-summer survival.
<b>Lakes, Ponds and Impoundments and Shorelines</b>	Lakes and their Shorelines include an open water zone, a shallow littoral zone where light penetrates to the bottom, and the adjacent terrestrial shoreline. Lakes vary in depth and productivity. Some deep lakes with greater than average transparency are low to moderately productive, maintaining dissolved oxygen levels at or above 3 ppm during summer. Other less deep lakes are very productive, with low transparency and abundant aquatic plants, but may experience a drop in dissolved oxygen during summer because of the heavy accumulation of organic matter. Submerged and emergent vegetation are found in the littoral zone.
<b>Beaches and Dunes</b>	Coastal Dunes are found adjacent to low energy beaches along Long Island Sound. Coastal Dune vegetation typically includes beach grass, switchgrass, beach plum, and bayberry, and are a critical habitat type for many plants, birds and invertebrates of conservation concern.
<b>Intertidal Flats and Shores (salt, brackish, fresh)</b>	Intertidal Beaches and Shores are often adjacent to vegetated wetlands, extending from high tide to those areas only occasionally exposed along the coast. Intertidal Beaches and Shore vegetation and associations vary with the salinity of the flooding waters. These may include three-square bulrush, water hemp, and arrowhead species. Sea rocket and pigweed are mostly found on salt shores and along a few tidal rivers. Intertidal Beaches and Shores are usually located adjacent to the vegetative Tidal Wetlands along Long Island Sound.
<b>Tidal Marsh (salt, brackish, fresh)</b>	Tidal Wetlands include salt, brackish, and fresh marshes, intertidal flats, and regularly flooded intertidal swamps. The intertidal flats are regularly or irregularly exposed mud or sand areas with sparse to dense vegetation. The vegetation changes with the salinity of the water and with the duration and frequency of flooding. Typical salt marsh vegetation includes marsh elder, saltmarsh cordgrass, saltmeadow cordgrass, glasswort, switch grass, and spikegrass. Typical brackish marsh vegetation includes saltmarsh cordgrass, three-square bulrush, narrowleaf cattail, saltmeadow cordgrass, eastern lilaopsis, salt-marsh bulrush, swamp rose-mallow, switch grass spikegrass, and creeping bentgrass. Typical freshwater tidal marsh vegetation includes wild rice, sweet flag, lake sedge, arrowleaf, sensitive fern, pickerelweed, bluejoint reedgrass, Canadian wild rye, straw-colored nutsedge, and river bulrush.
<b>Subtidal Aquatic Beds</b>	<u>Vegetation Beds</u> include submerged aquatic beds on various substrates and in various salinities (e.g., freshwater tidal) with significant cover of macrophytes, such as eel grass, horned pondweed, and widgeongrass. Vegetation Beds are highly productive estuarine communities that provide critical habitat for a diversity of estuarine organisms at some stage of their life cycle. The beds are important nursery and refuge grounds for juvenile fish. <u>Sponge Beds</u> are underwater marine communities exhibiting significant three dimensional relief. They include well-developed communities of sponge, such as <i>Cliona spp.</i> <u>Shellfish Reefs and Beds</u> are underwater concentrations of shellfish. These reefs or beds may include, but are not limited to, the eastern oyster and various mussels. Connecticut contains both natural and man-made or maintained Shellfish Reefs and Beds.
<b>Offshore Islands</b>	Offshore Islands are found in the off-shore and near-shore waters of Long Island Sound. They are unique landscape features that share many of the same characteristics and face the same threats as the other coastal and estuarine aquatic habitats. Islands are critically important for the breeding success of many shorebirds and provide valuable haul-out sites for marine mammals and important stopover sites for migratory species.
<b>Open Water Marine</b>	Open Water includes all the deep water areas of the Long Island Sound estuary. This habitat is directly connected to and influenced by the open Atlantic Ocean water through Block Island Sound and New York Harbor. The Open Water provides critical habitat to marine fish, mollusks, and crustacean species. Hypoxia, or low oxygen content, has been identified as a major impairment of Long Island Sound with improvements on a gradient from west to east. The condition is the result of excessive growth of phytoplankton, stimulated by nitrogen loading.

A risk assessment workshop of the NRWG was held on May 27, 2009, to evaluate climate change impacts to the 18 different terrestrial and aquatic habitats. Forty-one participants from various academic institutions, natural resource agencies, private sector, and environmental NGOs attended (Appendix). At this workshop, the NRWG was further divided into three facilitated groups. Each group was tasked to discuss each individual habitat type and evaluate the (1) likelihood of its being impacted by climate change by the year 2080, (2) the severity of impact by 2080, (3) the primary climate driver, and (4) the likely time horizon for impacts to occur and urgency for action in 30-year blocks – 2020, 2050, or 2080. Individual participants filled out a form for each habitat (Figure 1). In addition, discussion notes from the breakout sessions were recorded by facilitators. Risk for each habitat was quantified by assigning integer values of 1 (low) through 4 (high) to the “likelihood” and 1 (low) through 3 (high) to the “magnitude” components of the matrix in Figure 1. Likelihood and magnitude scores were multiplied to calculate values ranging from 1-12 for each of the blocks in the ranking table. Responses from each participant were thus transformed into numerical values that were averaged for each habitat to produce risk scores. A subsequent pair-wise analysis of likelihood and severity was conducted by Dr. Gary Yohe (Wesleyan University, Middletown, Connecticut).

Habitat: _____	2080 Perspective	Name _____		
Likelihood Severity	LOW	MEDIUM	HIGH	Virtually Certain/ Already occurring
HIGH				
MEDIUM				
LOW				
Climate Driver		Time – Urgency - Action		
Precipitation		2020		
Temperature		2050		
Sea Level Rise		2080		

**Figure 1.** Form used by individual participants during the May 27, 2009, Natural Resources Working Group workshop to evaluate impacts of Climate Change for each of the 18 habitat types identified.

The subsequent species assessment was done via a web survey administered to all members of the NRWG, technical staff in the DEP Bureau of Natural Resources, and all members of DEP Taxonomic Committees. The Taxonomic Committees consist of volunteers from academia, resource agencies and NGOs with expertise in specific taxonomic groups (birds, plants, fish,

etc.). These Committees are responsible for reviewing the status of plant and animal populations every five years and for making recommendations to list species as endangered, threatened or special concern status. The survey effectively reached the majority of individuals within the state with expertise on likely climate change impacts to species.

The animal species listed in this survey were identified by DEP staff, the U.S. Fish and Wildlife Service, the members of the DEP's Taxonomic Advisory Committees, and other species experts for inclusion in the CWCS as GCN species. Plants included in the survey were taken from the state of Connecticut list of endangered, threatened or special concern species. This survey included additional categories for invasive species (aquatic and terrestrial) and diseases in order to better understand the potential impact of climate change on these threats to natural resources. Invasive animals and diseases that threaten Connecticut's natural resources were determined by DEP and The Nature Conservancy staff. In the survey, species were divided into the taxonomic groups of birds, fish, herps (reptiles & amphibians), mammals, and plants. Participants were instructed to provide information only for species for which they had personal knowledge.

One question was asked for each species with seven possible responses. Question: To what extent will populations of the following species be impacted by climate change in CT? (a) Large decrease due to Climate Change, (b) Moderate decrease due to Climate Change, (c) Minimal decrease due to Climate Change, (d) No change, (e) Minimal increase due to Climate Change, (f) Moderate increase due to Climate Change, and (g) Large increase due to Climate Change.



Pine Brook Falls © Alden Warner

## Findings and Results

### Impacts of Climate Change on Connecticut Natural Resources

The natural resources of Connecticut will undoubtedly be impacted by on-going and future changes to our climate. Information on the anticipated affects of climate change on natural resources was summarized in a series of Climate Adaptation Briefs prepared by the Department of Environmental Protection in 2008. Separate briefs were prepared for the State's biodiversity and habitats, forestry, fisheries, and wildlife resources (CT DEP 2008). These briefs provide an excellent introduction and overview of anticipated impacts to large-scale resources and taxonomic groups. The following are some key findings from the DEP Climate Adaptation Briefs.

#### *Biodiversity and Habitat:*

- The future of Connecticut's natural resources and biodiversity is tied to effective environmental planning and responsible growth.
- The reduction in or elimination of biological corridors (aquatic and terrestrial) that link large habitat blocks will reduce the ability of plants and animals to migrate as the climate changes.
- The invasion and establishment of invasive species and non-native plants and animals will likely increase with climate change resulting in additional impacts to Connecticut's habitat and native species.
- Climate change is expected to increase the rate of extirpation and addition of rare and endangered species by altering conditions within critical habitats.
- Habitat loss or conversion will occur that will require adaptive management and the creation of space for relocation, expansion and/or inland migration of habitats at risk such as tidal marshes due to sea level rise and alteration of spring freshets.
- The timing of biological events including flowering, breeding, and migration will continue to be altered by climatic change, resulting in a decoupling and degradation of ecological relationships and food webs.

#### *Forest Resources:*

- Forests in Connecticut are dominated by mature trees. Despite the high species diversity, there is not a diversity of age classes. The future health and resiliency of Connecticut's forest depends on both species and age diversity.
- As Connecticut's climate warms, the competitive advantage will shift to the more southerly oak-hickory mix over northern hardwoods (sugar maple, yellow birch, beech).
- Connecticut's forests have a history of disturbance including the introduction and establishment of exotic pests such as the chestnut blight, gypsy moth and hemlock woolly

adelgid. This adds stress to the forest ecosystem and reduces its ability to accommodate climate change. Winter warming may favor further establishment of pests.

- Connecticut's forests play an important mitigating role against the expected effects of climate change. Trees shade homes, businesses and rivers; filter, clean and absorb water; cleanse the air by intercepting airborne particles through respiration; and act as carbon sinks by storing carbon dioxide in wood (living and dead), roots and leaves. Forests also will play a key role in reducing erosion, runoff and flooding, given that precipitation levels (and severity of storms) are predicted to increase.
- The forests of Connecticut support a diverse array of critical habitats and species that will depend on large intact blocks and migratory corridors to accommodate climatic changes.

#### *Freshwater and Marine Fisheries Resources:*

- With increased water temperatures we can expect the abundance and distribution of coldwater species to decline and warmwater species to increase. Long-term datasets show that water temperatures in both the Connecticut River and Long Island Sound have been increasing steadily over the last 30 years.
- Due to development and its impacts on water temperatures and stream flow, Connecticut has already experienced a dramatic decrease in coldwater fish habitat.
- Fragmentation of migratory corridors by dams and flow reduction by consumptive diversion has reduced the ability of fish populations to accommodate the continued temperature changes.
- In Connecticut's freshwater environment, diadromous species (those that migrate between saltwater and freshwater) and coldwater species (such as trout) will be the first and most severely impacted by a warming climate.
- Earlier snowmelt and the altered timing of the spring freshet may inhibit or reduce spawning of American shad, alewife, short-nosed sturgeon, and blueback herring.
- Coldwater indicator species already in decline include brook trout, brown trout and slimy sculpin in freshwater; winter flounder, American lobster, and longhorn sculpin in marine waters; and rainbow smelt and tomcod among anadromous species.
- The aquatic food web (plankton and fish) that supports finfish populations is likely to be altered by climate change. However, individual fish species will be differentially affected.
- Hypoxia events in Long Island Sound may expand with increased temperature and changes in wind fields.
- Aquatic invasive species have been a long-standing problem in both freshwater and marine environments. A warming climate will likely result in many new invasions and establishment.
- Both freshwater and saltwater marshes are vital to fisheries production. They are buffers against storms and pollution events and important nursery areas for many dependent species. As marshes and marsh grasses are inundated by sea level rise or severe storms, all associated aquatic species will be affected.

*Wildlife Resources:*

- As temperatures warm, some bird species will benefit from milder winters and extended breeding seasons, whereas others, such as northern species dependent on health forest systems will decline.
- Increased frequency of droughts and extreme storm events will inflict additive mortality on birds and amphibians during the breeding season. Conversely, greater annual rainfall may benefit some amphibians and other aquatic species.
- Migratory birds are vulnerable to the timing of food availability during their migration. Climate changes may result in a decoupling and cause increased mortality.
- Insectivorous birds synchronize nesting to coincide with insect emergence. Climate changes may result in decoupling and decreased reproductive success.
- Extended droughts at nesting sites and inundation of coastal wintering marshes could reduce waterfowl reproduction and abundance.
- In general, larger more adaptable mammal species (e.g., white-tail deer) will benefit from climate change whereas smaller less mobile species (e.g., New England cottontail) may become isolated and decrease beyond viable population levels.
- Species of amphibians or invertebrates associated with ephemeral aquatic habitats such as vernal pools and bogs are particularly vulnerable.
- Synchrony between plants and native pollinators may be changing resulting in far-reaching ecosystem impacts.
- Under accelerated sea level rise, rare plants and insect species associated with fresh and brackish tidal marsh and/or beach and dune habitat will not be able to persist and become locally extirpated.

**Overall Habitat Types at Risk:**

The collective response from the NRWG suggests that certain habitat types within the state are at relatively increased risk to projected changes in climate (Table 2). Those habitats suggested to be at highest risk are Cold Water Streams, Tidal Marsh, Open Water Marine, Beaches and Dunes, Freshwater Wetlands, Offshore Islands, Major Rivers, and Forested Swamps. These habitat types are broadly distributed from Long Island Sound and the coast to the upper watersheds and forests across our State. The degree of impact will vary but, likely changes include conversion of rare habitat types (e.g., cold water to warm water streams, tidal marsh and offshore islands to submerged lands), loss and/or replacement of critical species dependent on select habitats, and the increased susceptibility of habitats to other on-going threats (e.g., fragmentation, degradation and loss due to irresponsible land use management, establishment of invasive species) in addition to climate change. The additive stress of climate change will certainly have implications on the overall ecosystems supported and maintained by not only the high risk

**Habitats at the Highest Risk  
from Climate Change**

1. Cold Water Streams
2. Tidal Marsh
3. Open Water Marine
4. Beaches and Dunes
5. Freshwater Wetlands
6. Offshore Islands
7. Major Rivers
8. Forested Swamps

habitats mentioned above, but also all the other habitats and species within the State. (Note that one additional habitat type, talus slopes, not on the original list was added during the workshop.)

**Table 2.** Connecticut habitat types listed by sensitivity risk, primary climate driver and time to impact and urgency for action (2020, 2050, 2080) due to impacts from projected climate change.

Habitat	Sensitivity Risk (likelihood x severity)	Average Risk Score	Climate Driver	Time Urgency Action
<b>Cold Water Streams &amp; Associated Riparian Zones</b>	High	10.2	Temperature	2020
<b>Tidal Marsh</b>	High	9.7	Sea Level Rise	2020
<b>Talus Slopes</b>	High	9.0	Temperature	2050
<b>Open Water Marine</b>	High	8.9	Temperature	2020
<b>Beaches and Dunes</b>	High	8.2	Sea Level Rise	2020
<b>Herbaceous Freshwater Wetlands</b>	High	7.6	Precipitation	2020
<b>Offshore Islands</b>	High	7.3	Sea Level Rise	2020/2050
<b>Intertidal Flats and Shores</b>	High	6.4	Sea Level Rise	2050
<b>Major Rivers &amp; Associated Riparian Zones</b>	High	5.9	Precipitation	2050
<b>Forested Swamps</b>	High	5.2	Precipitation & Temperature	2050
<b>Subtidal Aquatic Beds</b>	High	5.0	Sea Level Rise	2050
<b>Lakes, Ponds, Impoundments &amp; Shorelines</b>	Medium	4.4	Temperature	2080
<b>Upland Forest Complex</b>	Medium	4.3	Temperature	2080
<b>Coastal Uplands</b>	Low	3.7	Temperature	2080
<b>Rocky Outcrops &amp; Summits</b>	Low	3.4	Precipitation	2080
<b>Warm Water Streams &amp; Associated Riparian Zones</b>	Low	3.3	Precipitation	2050
<b>Bogs and Fens</b>	Low	3.1	Precipitation	All Dates equal
<b>Early Successional Shrublands/Forests</b>	Low	2.0	Precipitation	2080
<b>Sand Barrens &amp; Warm Season Grasses</b>	Low	1.8	Precipitation & Temperature	2080

Several other habitats with low risk scores (Table 2) are worthy of further consideration because of their limited distribution and unique contributions to overall biodiversity in the State. These include: Rocky Outcrops and Summits, Bogs and Fens, and Sand Barrens and Warm Season Grasslands. These habitats in particular are restricted in distribution by the limited availability of suitable geologic formations at elevation, specific hydrologic conditions and select glacial deposits, respectively. As with many of our unique or spatially limited habitats, the principal option is to assume these habitats will accommodate the projected changes in temperature, precipitation and sea level rise or be converted to other habitats. This is currently occurring along our coast where Fens at sea level are converting to brackish wetlands.

### **Dominant Climate Drivers:**

The primary climate drivers, or variables that are most likely to impact natural resources across the State, are temperature, precipitation and sea level rise (Table 2). Extreme events such as more intense and frequent storms and extensive droughts will play a critical role in defining impacts to natural resources. The emphasis below is on three dominant climate drivers.

Temperature was identified as a dominate driver amongst a variety of terrestrial and aquatic habitat types ranging from Upland Forest Complexes and Talus Slopes to Cold Water Streams and Lakes, Ponds and Impoundments and Shorelines. The dominate driver for the Open Water Marine systems in Long Island Sound was increased water temperature. Alterations in precipitation will drive changes in not only aquatic habitats such as Freshwater Wetlands, Major Rivers, Warm Water Streams and Bogs and Fens, but also in terrestrial habitats like Rocky Outcrops and Summits and Early Successional Shrublands and Forests. For coastal habitat types such as Tidal Marsh, Beaches and Dunes, Offshore Islands, and Intertidal Flats and Shores, the dominant driver is sea level rise. While our understanding of the pace of sea level increase will improve as data and modeling become more refined, sea levels will continue to rise. Several habitats were identified as likely to be influenced by both expected precipitation and temperature changes: Forested Swamps and Sand Barrens and Warm Season Grasslands.

### **Timing of Risk and Urgency for Action:**

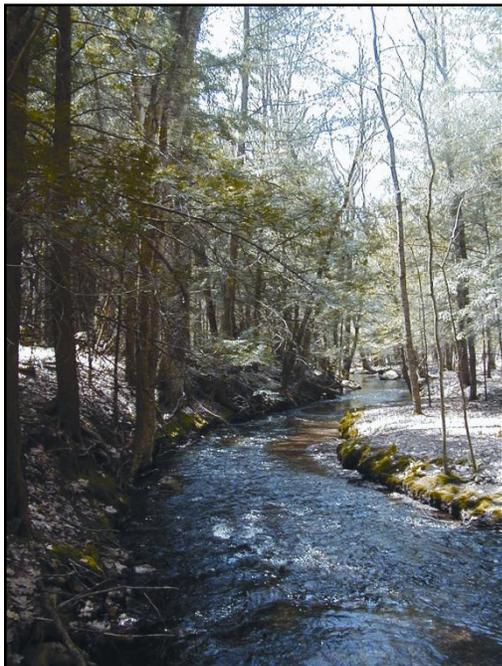
The pace at which change will occur within habitat types is identified by assignment of urgency for action categories (by decade 2020, 2050, or 2080). The habitats with the highest risk are, in most cases, assigned to the most urgent action category – 2020 (Table 2). This result implies that the necessary action to increase the capacity to accommodate change for risk habitats such as Cold Water Streams, Tidal Marsh, Beaches and Dunes and Freshwater Wetlands, is required during this and the next decade. Habitats with high risk scores in the 2050 category include Major Rivers, Forested Swamps, Subtidal Aquatic Beds, and Warm Water Streams. The majority of the remaining habitats were in the 2080 category. Note that these assignments are intended to provide an initial assessment and are not prescriptive or authoritative. Tangible manifestations of changes in climate may in fact be realized much sooner or later than suggested by these responses.

**Select Habitats at Risk:**

During the breakout sessions at the NRWG workshop, participants provided additional critical information concerning the likely impacts on habitats. A summary of the responses for several high risk habitats follows.

*Cold Water Streams and Associated Riparian Zones:*

The limited distribution and quantity of this habitat in the State makes it particularly fragile and susceptible to projected changes in climate. As air temperatures increase, the suitability of cold water streams for critical species such as brook trout and burbot will decline. In many locations the critical water temperature threshold is already being exceeded, particularly during the late summer months in shallow reaches. This has important ramifications on the abundance of not only top predators like brook trout and brown trout, but also on many important aquatic organisms that support a dynamic food web within the streams and the adjoining terrestrial ecosystems. The continued viability of this habitat is certainly an important consideration given the revenue generated through active and passive recreation in the State. Ninety-five percent of the 35 NRWG respondents indicated that the likelihood was high to virtually certain and the severity was high for impacts from climate change on this habitat by 2020 (Figure 2).

*Tidal Marsh:*

Tidal marshes along the coast have been and will continue to be impacted by both sea level rise and storm events. The pace of sea rise will likely outpace accretion and inundate existing coastal marshes resulting in rapid loss and conversion (from high to low marsh to mudflat) with concurrent impacts on dependent plant and wildlife species. In addition, the supportive nursery function of these coastal marshes for ecologically and recreationally important finfish will be impaired by changes in condition and availability of this habitat. Further upstream on major rivers like the Connecticut River, freshwater tidal marshes will be lost or converted. This will be the result of increases in salinity as the estuaries move upstream, lack of suitable adjoining areas to accommodate



upland migration, and alteration in the amplitude and timing of the annual spring freshets and lower summer flows. The reduction in extent and complexity of these highly productive interfaces between land and water will have impacts on ecological function (storm buffering, flood storage, fish nurseries, water filtering) and biodiversity within the state. The collective response of the 25 NRWG respondents suggests that the likelihood and severity of impact, although variable, are ranked high or above (76%) for this habitat by 2020 (Figure 2).

#### *Open Water Marine:*

Changes have already been observed in the Open Water Marine habitat in Long Island Sound. The projected changes in water temperature will result in an increase in the occurrence of warm-water species from the south and a retreat of coldwater species to northern marine systems. Rebuilding commercially harvested species like American lobster and winter flounder through fishery management actions will be more difficult and alteration of migratory patterns and timing in anadromous fish species are likely. The potential alteration of plankton dynamics from temperature and salinity gradient shifts, coupled with continued nutrient loading may result in sustained changes to the entire food web of Long Island Sound. Seventy-nine percent of the 19 NRWG respondents indicated that the likelihood of impacts from climate change was virtually certain and already happening (Figure 2). Forty-seven and 32% indicated that the severity of impact will be moderate to high for this habitat by 2020, respectively.

#### *Beaches and Dunes:*

The Beaches and Dunes habitat is highly susceptible to impacts from sea level rise and storm events given the limited distribution and position of this habitat along our coastal fringe. The



ongoing erosion and transport of sediment along the coast will likely increase with projected future climatic conditions resulting in further loss of this habitat and conversion of supportive dunes to beaches. Important beach-and-dune dependent species such as horseshoe crabs, piping plovers, other migratory shorebirds, and terns will be impacted with the loss of this critical habitat. In addition, a decline in recreational opportunities and property values for the citizens of Connecticut will

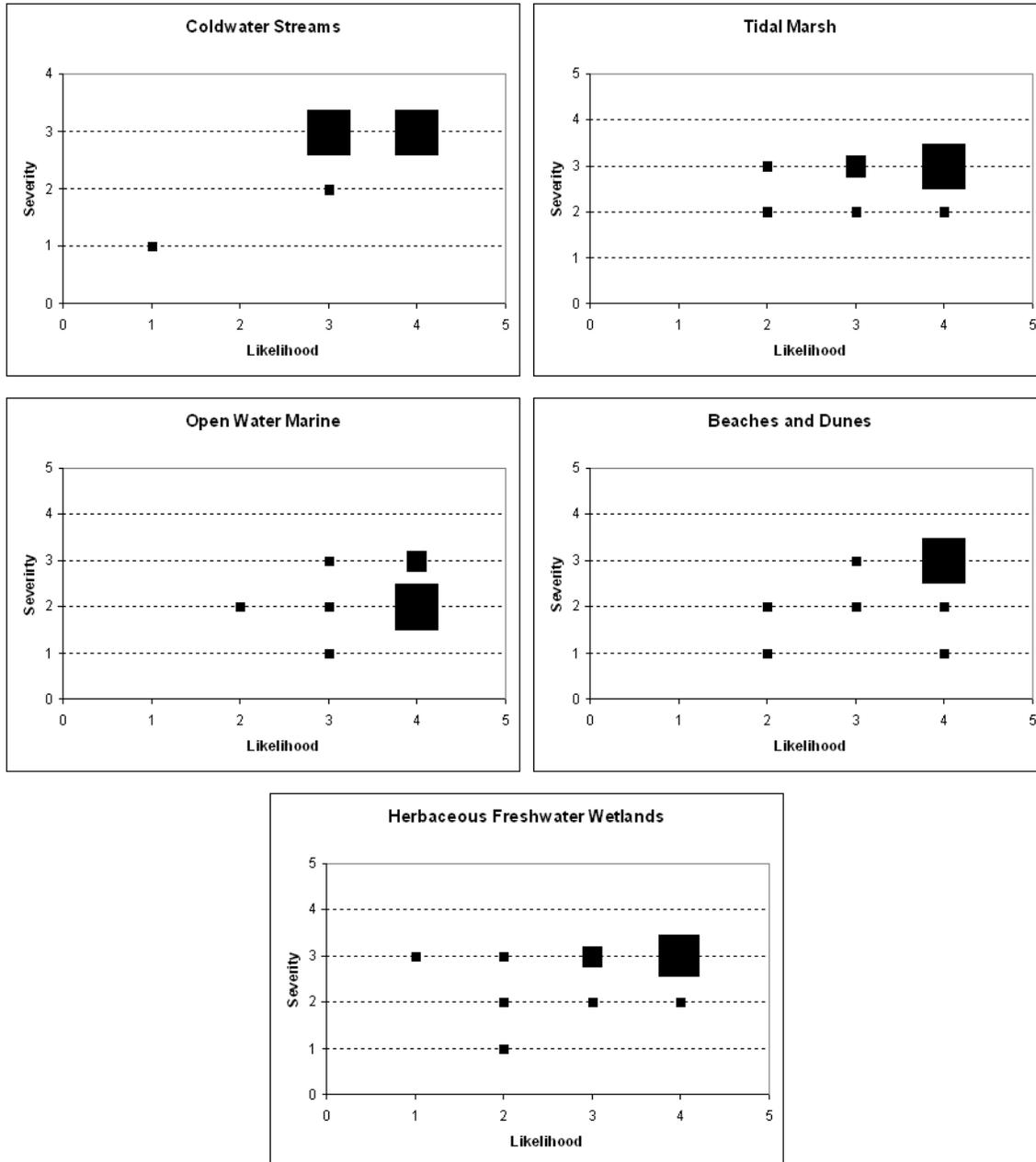
occur without substantial investment to mitigate these projected losses. Forty-one percent of the 17 respondents indicated that the impact likelihood is virtually certain and already happening while the severity is high for this habitat by 2020 (Figure 2).

*Herbaceous Freshwater Wetlands:*

Herbaceous Freshwater Wetlands represent a diversity of ecosystems that are highly dependent on, and susceptible to, alterations in hydrology, both in surface water runoff and groundwater discharge. Relatively small changes in the timing and amount of annual precipitation will influence the suitability and distribution of wetlands systems, particularly vernal pools and wet meadows, for many wetland-dependent amphibians, birds and plant species. These changes will require that wetland dependent species relocate via available corridors to other wetland systems if able or perish if not. Extended droughts that occur earlier in the breeding season along with elevated temperatures and lower groundwater table may reduce the distribution and condition of wetlands throughout the state. The



The collective response of the 22 NRWG respondents suggests that the likelihood and severity of impact, although variable, are ranked high or above (55%) for this habitat by 2020 (Figure 2).



**Figure 2.** Pair-wise analysis of responses by the NRWG during the May 27, 2009 workshop on Likelihood and Severity of impacts on select habitat types: Cold Water Streams (35 respondents), Tidal Marsh (25), Open Water Marine (19), Beaches and Dunes (17), Herbaceous Freshwater Wetlands (22) as a result of projected climate changes. Larger box size reflects a larger number of respondents. Likelihood: 1(Low), 2 (Medium), 3 (High), 4 (Virtually Certain/Already Occurring); Severity: 1 (Low), 2 (Medium), 3 (High). Analysis was conducted by Dr. Gary Yohe, Wesleyan University, Middletown, Connecticut.

### **Climate Change Impacts on Connecticut Species**

Seventy-five species that are currently among those of Greatest Conservation Need or State-listed as Endangered/Threatened or Special Concern, were identified as likely to experience a large population decrease as a result of projected climate change in Connecticut. This list includes two turtle species, one amphibian species, five bird species, six fish species, 16 invertebrates, and 44 plant species (Table 3). Impacts to populations of many currently common/secure species are also likely to be significant (e.g., sugar maple) but are beyond the scope of this analysis.

Nineteen invasive or potentially invasive species were identified as among those likely to experience a large or moderate increase in abundance in Connecticut as a result of climate change (Table 4). However, the 46 species included in this assessment was only a subset of the total number of invasive or potentially invasive species that are likely to affect the state. Of the 46 species evaluated, 41% were assessed as likely to experience a large or moderate increase from climate change and 96% (44 species) were likely to experience some increase. Based on these percentages it is clear that the threat from invasive species is considerable, particularly when the total number of species identified in the Connecticut Aquatic Nuisance Species Plan (2007) and on the state list of invasive plants (State Invasive Plant Council) is considered, and recognizing that the State currently lacks lists of invasive terrestrial vertebrates and invertebrates. It is also reasonable to conclude that Connecticut's native flora and fauna will be subject to increased stress from the cumulative effects of climate change and increased competition with newly-established and existing invasive species.

**Table 3.** Greatest Conservation Need or State-listed species identified as likely to experience a population decrease due to projected climate change.

Taxa	Species	Taxa	Species
<b>Birds</b>	Seaside Sparrow ( <i>Ammodramus maritimus</i> )	<b>Plants cont.</b>	Dwarf Mistletoe ( <i>Arceuthobium pusillum</i> )
	Piping Plover ( <i>Charadrius melodus</i> )		Dwarf Scouring Rush
	Roseate Tern ( <i>Sterna dougallii</i> )		( <i>Equisetum scirpoides</i> )
	Saltmarsh Sharp-tailed Sparrow		Eastern Few-Fruit Sedge ( <i>Carex oligocarpa</i> )
	( <i>Ammodramus caudacutus</i> )		False Hop Sedge ( <i>Carex lupuliformis</i> )
	Black Rail ( <i>Laterallus jamaicensis</i> )		Largeleaf Sandwort
			( <i>Moehringia macrophylla</i> )
			Foxtail Sedge ( <i>Carex alopecodioides</i> )
			Fries' Pondweed ( <i>Potamogeton friesii</i> )
			Sickleleaf Silkgrass ( <i>Pityopsis falcata</i> )
			Seaside Threeawn ( <i>Aristida tuberculosa</i> )
			Handsome Sedge ( <i>Carex formosa</i> )
			Long-bracted Green Orchid
			( <i>Coeloglossum viride</i> )
			Torrey's Bulrush ( <i>Scirpus torreyi</i> )
			New England Sedge ( <i>Carex novae-angliae</i> )
			Northern Bog Violet ( <i>Viola nephrophylla</i> )
			Hookedspur Violet ( <i>Viola adunca</i> )
			Canadian White Violet ( <i>Viola Canadensis</i> )
			Sweet Coltsfoot
			( <i>Petasites frigidus</i> var. <i>palmatum</i> )
			Labrador Tea
			( <i>Rhododendron groenlandicum</i> )
			Bitter Panicgrass ( <i>Panicum amarum</i> )
			Sea Sandwort ( <i>Honckenya peploides</i> )
			False Heather ( <i>Hudsonia tomentosa</i> )
			Cosmopolitan Bulrush
			( <i>Bolboschoenus maritimus</i> ssp. <i>paludosus</i> )
			New England Bulrush
			( <i>Bolboschoenus novae-angliae</i> )
			Water Pygmyweed ( <i>Crassula aquatic</i> )
			Parker's pipewort ( <i>Eriocaulon parkeri</i> )
			Eastern Grasswort ( <i>Lilaeopsis chinensis</i> )
			Bearded Sprangletop
			( <i>Leptochloa fusca</i> ssp. <i>fascicularis</i> )
			Seacoast Angelica ( <i>Angelica lucida</i> )
			Scotch Lovage ( <i>Ligusticum scoticum</i> )
			Mudwort ( <i>Limosella australis</i> )
			Alkali Buttercup ( <i>Ranunculus cymbalaria</i> )
			Sea Pink ( <i>Sabatia stellaris</i> )
			Mountain Woodfern
			( <i>Dryopteris campyloptera</i> )
			Balsam Fir ( <i>Abies balsamea</i> )
			Milletgrass ( <i>Milium effusum</i> )
			Red Pine ( <i>Pinus resinosa</i> )
			Red Currant ( <i>Ribes triste</i> )
			Small Bur-reed ( <i>Sparganium natans</i> )
			Huckleberry ( <i>Vaccinium myrtilloides</i> )
			Twinflower
			( <i>Linnaea borealis</i> spp. <i>americana</i> )
<b>Reptiles &amp; Amphibians</b>	Bog Turtle ( <i>Glyptemys muhlenbergii</i> )		
	Diamond-backed Terrapin ( <i>Malaclemys terrapin</i> )		
	Blue-spotted Salamander ( <i>Ambystoma laterale</i> )		
<b>Invertebrates</b>	American Lobster ( <i>Homarus americanus</i> )		
	Atlantis Fritillary ( <i>Speyeria atlantis</i> )		
	Cicindela Marginata ( <i>Cicindela marginata</i> )		
	Conglomerate Dart ( <i>Euxoa pleuritica</i> )		
	Hairy-necked Tiger Beetle ( <i>Cicindela hirticollis</i> )		
	Harpoon Clubtail ( <i>Gomphus desertus</i> )		
	Labrador Tea Tentiform Leafminer		
	( <i>Phyllonorycter ledella</i> )		
	Yellow Bog Anarta ( <i>Anarta luteola</i> )		
	Maritime Sunflower Borer ( <i>Papaipema maritima</i> )		
	Puritan Tiger Beetle ( <i>Cicindela puritana</i> )		
	Ski-tailed Emerald ( <i>Somatochlora elongata</i> )		
	Morrison's Mosaic ( <i>Eucosma morrisoni</i> )		
	Coastal Heathland Cutworm ( <i>Abagrotis nefascia</i> )		
	Lanced Phaneta ( <i>Phaneta clavata</i> )		
	False Heather Underwing ( <i>Drasteria graphica atlantica</i> )		
	Sand Prairie Wainscot ( <i>Leucania extincta</i> )		
<b>Fish</b>	Atlantic Salmon ( <i>Salmo salar</i> )		
	Rainbow Smelt ( <i>Osmerus mordax</i> )		
	Atlantic Tomcod ( <i>Microgadus tomcod</i> )		
	Brook Trout (wild) ( <i>Salvelinus fontinalis</i> )		
	Slimy Sculpin ( <i>Cottus cognatus</i> )		
	Winter Flounder		
	( <i>Psuedopleuronectes americanus</i> )		
<b>Mammals</b>	Least Shrew ( <i>Cryptotis parva</i> )		
<b>Plants</b>	Skunk Currant ( <i>Ribes glandulosum</i> )		
	Shrubby Fivefingers ( <i>Sibbaldiopsis tridentate</i> )		
	Floating Bur-reed ( <i>Sparganium fluctuans</i> )		
	Canadian Sandspurry ( <i>Spergularia canadensis</i> )		

Nineteen invasive or potentially invasive species were identified as among those likely to experience a large or moderate increase in abundance in Connecticut as a result of climate change (Table 4). However, the 46 species included in this assessment was only a subset of the total number of invasive or potentially invasive species that are likely to affect the state. Of the 46 species evaluated, 41% were assessed as likely to experience a large or moderate increase from climate change and 96% (44 species) were likely to experience some increase. Based on these percentages it is clear that the threat from invasive species is considerable, particularly when the total number of species identified in the Connecticut Aquatic Nuisance Species Plan (2007) and on the state list of invasive plants (State Invasive Plant Council) is considered, and recognizing that the State currently lacks lists of invasive terrestrial vertebrates and invertebrates. It is also reasonable to conclude that Connecticut's native flora and fauna will be subject to increased stress from the cumulative effects of climate change and increased competition with newly-established and existing invasive species.

**Table 4.** Invasive species likely to experience an increase in abundance or successfully establish as a result of projected climate change in Connecticut.

Taxa	Species	Taxa	Species
<b>Aquatic Plants</b>		<b>Invertebrates</b>	
	Water hyacinth ( <i>Eichhornia crassipes</i> )		Asiatic clam ( <i>Corbicula fluminea</i> )
	Mudmat ( <i>Glossostigma cleistanthum</i> )		Chinese mitten crab ( <i>Eriocheir sinensis</i> )
	Parrot feather ( <i>Myriophyllum aquaticum</i> )		Asian shore crab ( <i>Hemigrapsus sanguineus</i> )
	Water lettuce ( <i>Pistia stratiotes</i> )		Man O' War ( <i>Physalia physalis</i> )
			Woolly adelgid ( <i>Adelges tsugae</i> )
<b>Marine Algae</b>		<b>Birds</b>	
	Killer green algae ( <i>Caulerpa taxifolia</i> )		Monk parakeet ( <i>Myiopsitta monachus</i> )
<b>Terrestrial Invertebrates</b>		<b>Fish</b>	
	Asian tiger mosquito ( <i>Aedes albopictus</i> )		Blue catfish ( <i>Ictalurus furcatus</i> )
<b>Terrestrial Plants</b>			Flathead catfish ( <i>Pylodictis olivaris</i> )
	Black swallow-wort ( <i>Vincetoxicum nigrum</i> )		Lionfish ( <i>Pterois volitans</i> , <i>Pterois miles</i> )
	Kudzu ( <i>Pueraria montana var. lobata</i> )		
	Mile-a-minute vine ( <i>Persicaria perfoliata</i> )		
	Porcelainberry ( <i>Ampelopsis brevipedunculata</i> )		

Of the nine different pathogens and parasites that were included in our survey, three were identified as having a likely to moderately increase as result of climate change in Connecticut. These were dermo (*Perkinsus marinus*), which affects shellfish, particularly oysters; chytrid fungus (*Batrachochytrium dendrobatidis*), which affects amphibians; and spring viremia which affects fish in the minnow family. The six other pathogens were unlikely to increase as a direct result of climate change; however, an increased frequency of disease outbreaks among wild populations is still likely to occur as an indirect effect of climate-induced stress on populations of fish, wildlife and plant species.

Many of the species identified as likely to experience a significant decrease in abundance are also inhabitants of Connecticut habitats identified as being at high risk from climate change

(Table 5). The continued existence of viable populations of these species and many others will depend on our ability to increase the resilience of and buffer habitats to the impacts of climate change. The combination of habitat descriptions and species presented in Table 4 will better enable the reader to visualize what is at risk. Again, note that our evaluation of climate change does not focus on impacts to currently common and ubiquitous Connecticut species. Detail of this sort is simply beyond the scope of this report. However, the general concept is one of a gradual northward shift of mid-Atlantic species and a subsequent replacement of many Southern New England flora and fauna.

**Table 5.** Connecticut habitats identified as being at high risk from climate change and representative flora and fauna that are also vulnerable to the affects of climate change.

Habitat	Species	Habitat	Species
<b>Cold Water Streams &amp; Associated Riparian Zones</b>		<b>Offshore Islands</b>	
	Brook trout ( <i>Salvelinus fontinalis</i> )		American oystercatcher ( <i>Haematopus palliatus</i> )
	Slimy sculpin ( <i>Cottus cognatus</i> )		Roseate tern ( <i>Sterna dougallii</i> )
	Atlantic salmon ( <i>Salmo salar</i> )		
	Brown trout ( <i>Salmo trutta</i> )		
	N. spring salamander ( <i>Gyrinophilus porphyriticus</i> )		
	Harpoon clubtail dragonfly ( <i>Gomphus desertus</i> )		
<b>Tidal Marsh</b>		<b>Intertidal Flats &amp; Shores</b>	
	Seaside sparrow ( <i>Ammodramus maritimus</i> )		Semipalmated sandpiper ( <i>Calidris pusilla</i> )
	Saltmarsh sharp-tailed sparrow ( <i>A. caudacutus</i> )		Clapper rail ( <i>Rallus longirostris</i> )
	Diamond-backed terrapin ( <i>Malaclemys terrapin</i> )		Least tern ( <i>Sterna antillarum</i> )
	Clapper rail ( <i>Rallus longirostris</i> )		Yellow-crowned night-heron ( <i>Nyctanassa violacea</i> )
	Black duck ( <i>Anas rubripes</i> )		Hairy-necked tiger beetle ( <i>Cicindela hirticollis</i> )
	Yellow-crowned night-heron ( <i>Nyctanassa violacea</i> )		
<b>Open Water Marine</b>		<b>Major Rivers &amp; Associated Riparian Zones</b>	
	American lobster ( <i>Homarus americanus</i> )		Northern leopard frog ( <i>Rana pipiens</i> )
	Winter flounder ( <i>Pseudopleuronectes americanus</i> )		Puritan tiger beetle ( <i>Cicindela puritana</i> )
	Atlantic tomcod ( <i>Microgadus tomcod</i> )		Yellow lampmussel ( <i>Lampsilis cariosa</i> )
	Rainbow smelt ( <i>Osmerus mordax</i> )		
<b>Beaches and Dunes</b>		<b>Forested Swamps</b>	
	Piping plover ( <i>Charadrius melodus</i> )		Northern waterthrush ( <i>Seiurus noveboracensis</i> )
	Sanderling ( <i>Calidris alba</i> )		American black duck ( <i>Anas rubripes</i> )
	Least tern ( <i>Sterna antillarum</i> )		Blue-spotted salamander ( <i>Ambystoma laterale</i> )
	Sickleleaf silkgrass ( <i>Pityopsis falcata</i> )		
	Seaside threeawn ( <i>Aristida tuberculosa</i> )		
<b>Herbaceous Freshwater Wetlands</b>		<b>Subtidal Aquatic Beds (Marine)</b>	
	Bog turtle ( <i>Glyptemys muhlenbergii</i> )		Bay scallop ( <i>Argopecten irradians</i> )
	Northern leopard frog ( <i>Rana pipiens</i> )		Jonah crab ( <i>Cancer borealis</i> )
	Black duck ( <i>Anas rubripes</i> )		Rock crab ( <i>Cancer irroratus</i> )
	King rail ( <i>Rallus elegans</i> )		
	Least bittern ( <i>Ixobrychus exilis</i> )		
	American bittern ( <i>Botaurus lentiginosus</i> )		
	Alkali buttercup ( <i>Ranunculus cymbalaria</i> )		
		<b>Talus Slopes</b> (currently limited high risk species)	

## Interactions with other Adaptation Working Groups

A number of topics overlap between the NRWG and the Subcommittee's other three workgroups. To the extent possible, the following is a summary of each of these topics from a Natural Resource perspective.

## 1) Impacts of Climate Change on Connecticut's Forest Products:

Considering the impact of climate change on Connecticut's forest products, the forest resource, the forest products industry itself, and the forest product markets come into play. Industry and markets have historically varied as a result of changes in consumer needs. The industry is affected not only by the demand for forest products but also by economic factors influencing production and competition. It is arguable that market shifts from changes in consumer demand and economic factors that influence the industry's ability to competitively produce forest products may have equal or greater impact than climate change on future production in Connecticut. Discussion of the impact of climate change on the forest does not necessarily predict how it will affect the industry – we can only predict what trees might be available in the forest for the industry to use or not use.

For maple syrup producers, the future is cloudy. In the near term (the next several decades), maple syrup production should hold its own, particularly as the demand for locally-produced foods becomes more fully established. Climatic conditions may even favor enhanced maple syrup production. Over the longer term, however, as regeneration of sugar maples begins to fail due to climatic changes, the resource upon which this industry is based will begin to decline.

Regarding lumber and other wood products, opportunity may accompany change. As Connecticut warms, the competitive advantage is likely to shift to the more southerly oak-hickory mix over northern hardwoods (sugar maple, yellow birch and beech). Longer growing seasons and warmer climates will favor an increase in the volume growth of currently preferred species like oaks. At the same time, storms and other weather extremes will cause increased tree mortality. A consequence of these disturbances will be an accelerated transition of the forest to new species and conditions. Increased wood volume and storm-damaged trees (as salvage after past storms has shown) will provide market opportunities for those who harvest wood.

Christmas tree growers will continue to match what they grow with market preference and what environmental conditions allow. With the exception of Eastern white pine and white spruce, the Christmas tree species grown in Connecticut are not native. Warming weather may cause a shift in the suite of species available to growers, including creating greater opportunity for species such as Frazier fir and Virginia pine, and diminished opportunity for species such as balsam fir and Colorado blue spruce.

The best approach for Connecticut's forest product industry is to keep the forest resource as resilient and adaptable as possible. Some of the practices that will help achieve this goal are improving forest health by controlling invasive species, maintaining and expanding forest lands, and minimizing fragmentation of the existing resource.

## **2) Impacts of Climate Change on Stream Flows and Water Supplies:**

Fish, wildlife and other aquatic biota are expected to be affected in a variety of ways if changes in stream flow from climate change become manifest. The summer low flow season (i.e., July through September) can already be a stressful period for riverine resources, especially during short term and extended droughts. As the frequency and duration of summer droughts and other low precipitation periods increases, additional stresses are expected on stream-dwelling biota, particularly on thermally-sensitive species that require colder water such as brook trout, brown trout, and Atlantic salmon. The requisite cool-water habitats are often found only in small headwater streams – those most prone to short-term stream flow cessation and in severe instances, outright channel desiccation. Therefore, an increased frequency and duration of low or even no flow periods is likely to result in the compression of some species into smaller and smaller areas, leading ultimately to localized extinction of some fauna from certain areas of the state. Areas currently providing only marginal habitat would likely be the first places where population reductions or localized extinctions would materialize. The continued reduction in suitable riverine habitat for these species will likely impact the use of public and private lands by the citizens of Connecticut and the revenue derived from this recreation.

It is more difficult to predict the potential effects on fish and wildlife from predicted changes in the timing of seasonal high flows (expected to occur earlier in the late winter or early spring), and increased intensity and frequency of high flow events. The extent to which population-level effects may materialize remains unknown; changes in the timing of high flows could conceivably effect spawning-related migration and the survival of early life history phases (i.e., eggs and larvae) of some fishes. Gradual shifting of the timing of high flow events over longer time scales may dampen any population level effects as species adapt to the slowly changing conditions.

Effects of climate change on water supplies in Connecticut would likely exacerbate the threats to riverine resources already stressed by summer low flow conditions. This would result from increased societal demand for water during periods of extended warming and drought. Effects would be magnified in water supply systems reliant upon groundwater sources and on surface water sources without sufficient storage capacity. Stream flow may be protected to some extent during extended drought periods downstream of reservoirs having large storage capacities. Balancing stream flows required for the environment with consumptive societal uses, including during droughts, is a focal point of the new instream flow standards and regulations that have been drafted pursuant to Public Act 05-142.

## **3) Impacts of Climate Change on Connecticut's Critical Aquatic Nurseries and Aquaculture Beds:**

### *Critical Aquatic Nurseries*

The marine finfish and macroinvertebrate communities in Long Island Sound are becoming increasingly dominated by demersal warm-adapted species (such as black seabass and dogfish shark) whereas epibenthic cold-adapted species (such as American lobster, windowpane and winter flounder) are becoming less abundant. This northward shift in species abundance is one of the ecosystem changes occurring throughout the northeast US continental shelf and is the result of the combined effects of the harvest of regulated food species and environmental changes to habitat that affect growth, survival and reproduction of all species. While fishing

affects primarily adults, climate change can have profound effects on all age classes, especially larval and juvenile life stages. Eel grass beds provide sheltered nursery areas for many common finfish species. Warming trends will subject these grass beds to thermal stress that could potentially increase algae blooms that may limit light penetration and reduce oxygen levels, and promote epiphytic and bacterial growth. Deep water in the Sound will also provide increasingly important refuge nurseries if storm activity becomes more frequent and more violent as climate warming models predict.

#### *Aquaculture Beds*

Shellfish beds filter millions of gallons of water daily, and help maintain the state's water quality. Oyster reefs reduce eutrophication by removing nutrients from the water and converting them to pseudofeces which are then taken up by benthic feeders. This process of shifting nutrients from the water column to the benthos may also reduce the abundance of secondary gelatinous consumers (e.g., ctenophores). Oyster reefs typically support a host of other associated organisms that are not found in surrounding sand or mud habitats. These complex habitats are utilized by fish, crustaceans, other bivalves (e.g., mussels), and numerous other invertebrates, birds, and mammals and often rival salt marshes in terms of biodiversity. One of the most ecologically important and common estuarine invertebrates associated with oyster reef habitats are members of the genus *Palaemonetes* (grass shrimp) which are a major food item for many managed fish species. Throughout their range, these small, abundant decapod crustaceans are often found in densities exceeding 150 individuals/m<sup>2</sup>. Pollutants, particularly cadmium reduce the thermal tolerance of oysters while lower salinity levels increase susceptibility to common shellfish diseases.

#### **4) Impacts of Climate Change on Vectors of Human and Animal Diseases and Occurrence of Animal Diseases in Connecticut:**

The greatest public health threats associated with vector-borne diseases are those transmitted by *Aedes aegypti* mosquitoes (yellow fever, dengue and eastern equine encephalitis) and *Aedes albopictus* (dengue, dengue hemorrhagic fever, eastern equine encephalitis). This conclusion is drawn in part from the projections of the northward range expansion of *A. aegypti*, from the species current limit of about 35° N latitude (Memphis, TN). *Aedea albopictus* has been detected in Connecticut, but has not successfully overwintered. However, this species has become a major pest/vector as far north as New Jersey.

Conversely, a gradual decline in the prevalence of La Crosse encephalitis is anticipated. The vector for the La Crosse encephalitis virus (*Aedea triseriatus*) depends in part on tree-holes of hardwoods forests for breeding, and for maintenance of its vertebrate hosts – chipmunks and squirrels<sup>13</sup>.

Analyses of wind trajectory models indicate that mosquitoes potentially infected with eastern equine encephalitis virus could be carried by storm fronts from North Carolina northeastward as

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<sup>13</sup> Although tree holes are its native habitat, *A. triseriatus* does not do very well in artificial cavities like used tires. Also the La Crosse encephalitis virus has been detected in the north, but is more of a public health threat in North Carolina, Tennessee, and the Midwest

far as southern New England. The introduction of new vector mosquitoes, in combination with increased frequency of summer drought conditions that favor *Culex* populations (warm, wet summers favoring *Culiseta melanura*; and late season rains favoring bridge vectors) could exacerbate the occurrence of eastern equine encephalitis.

West Nile viral encephalitis was first reported in the United States, in the New York area, in 1999. Since then, the disease has dispersed more rapidly than expected, with *Culex* mosquitoes and migratory birds as the suspected agents of spread. This trend is likely to be amplified by the increased frequency of extreme weather conditions accompanying long-term climate change.

In the 1990's, outbreaks of locally transmitted malaria occurred in New Jersey (1991), Queens, New York (1993), and Rhode Island (mid-1990's), during hot, wet summers. These small localized outbreaks are consistent with model projections that warmer, wetter conditions are likely to result in increased incidence of malaria at higher latitudes, including Connecticut.

Some have suggested that the public health threat associated with Lyme disease, *babesiosis* and *ehrlichiosis* will increase with a changing climate. Using various climate change models and an *Ixodes scapularis* population model (i.e. for the tick species that transmits Lyme disease), researchers investigated the northward extension of the species range for 2020, 2050 and 2080. When driven by projected annual temperature cycles, tick abundance almost doubled by the 2020's, and populations moved northward approximately 200 km by 2020 and 800 km by 2080, extending the public health threat into new areas. However, it is important to note that the prevalence of Lyme disease in any given area is dependent, in part, on the co-occurrence of the tick adult stage and deer on which the ticks depend for their blood meals.

Information on the potential effects of climate change on pathology in animals was limited to bats. Adult female survival in little brown bats (*Myotis lucifugus*) is highest during years with high cumulative summer precipitation and seasonable temperatures. Climate projections for periods of extensive droughts indicate that summer survival of little browns, and perhaps other bats, may decline with increasing temperatures which negatively impact insect availability. In addition, as temperatures increase and possibly include more frequent and longer periods of unusually warm and climatically erratic winters, hibernating bats may exhaust their fat reserves to such an extent that they may become more susceptible to pathogens.

## **5) Impacts of Climate Change on Ecosystem Services provided by Natural Resources**

Ecosystem services refer to the many ways in which ecosystems support and fulfill peoples' lives. These services include production of goods (food, timber), life-support processes (maintaining soil fertility, purifying water, mitigating floods, stabilizing climate), and life-fulfilling conditions (providing aesthetic beauty, biodiversity and cultural stimulation). Unfortunately, the ability of Connecticut's natural resources to deliver ecosystem services has been altered by habitat degradation, land and water conversion, pollution and now the likely impacts from climate change.

Valuable infrastructure adjoins Connecticut's water bodies and Long Island Sound's coast, ranging from roads and bridges to private property and municipal and state facilities. Billions of

dollars have been invested to create this infrastructure, and millions more are invested annually in its protection and maintenance. Losses from increases in storm surge on the metropolitan east coast region of New Jersey, New York, and Connecticut could increase to \$1.5 billion in the year 2100. The potential for extremely large infrastructure damage and replacement cost will require innovative inclusion of ecosystem service solutions.

Ecosystem services provide protection for man-made structures at low cost. Maintaining these services has the potential to save substantial amounts of money in terms of major repairs to existing man-made infrastructure and/or the forced creation of new synthetic protection systems. As an example, tidal marshes often buffer the effects of coastal inundation and flooding as a result of increasing sea levels and intense storms. Research has shown that coastal marsh in United States provides approximately \$23 billion annually in hurricane protection services. In Connecticut, reduction in storm damage costs by coastal wetlands is estimated at \$13,000 per acre annually. As sea level rises, these coastal wetlands may migrate inland if able and allowed access to undeveloped and deconstructed shoreline. However, if hard protection measures are implemented to protect private property, wetland migration may be prevented. In these cases, coastal wetlands are likely to be inundated by rising sea level and ultimately converted to open water thus forfeiting the flood control and storage services and associated cost reductions. Similar types of buffering and storage services are provided by freshwater wetlands and floodplain forests. If these tidal marshes and/or floodplain forests are allowed to be further degraded or converted, large increases in federal, state and municipal funding will be spent controlling coastal and inland flooding, installing additional infrastructure to protect property and human life, and repairing repetitive flood damage. In addition, the increased absorption and retention of precipitation from storm events by large intact forest and wetland systems in the State will help reduce downstream flooding impacts and minimize cost of infrastructure repair.

Long Island Sound supports a great diversity of fish and shellfish species. These species have provided food resources for thousands of years. While many species are fished recreationally, historically lobsters, clams and oysters have been the most valuable commercial species. Beyond providing sustenance to local residents, fishing and shell fishing are an integral part of the Sound's culture and heritage. These industries support livelihoods for commercial fishermen and support a wealth of associated businesses, such as seafood restaurants. In 2007, Connecticut landings of all finfish and shellfish combined totaled over \$42 million. The clam harvest in 2007 from Long Island Sound was worth \$31 million, with oysters bringing in an additional \$7.4 million. Lobster catches have dropped precipitously since the late-1990s, but Connecticut catches still brought in \$3.2 million in 2007. The commercial fishery resources of Long Island Sound also provide economic benefits for associated shore-side businesses. In 2006 commercial landings revenue for the entire United States was \$4.1 billion. In that same year the fishing industry (commercial harvest sector, seafood wholesalers and distributors, seafood processors and dealers, and seafood retailers) generated \$44.3 billion. A similar multiplier effect can be observed in the Long Island Sound region as well.

Climate change is thought to affect marine fisheries most directly through increases in water temperature. Elevated temperatures could mean decreased abundance of cold-water species (American lobster, winter flounder), and greater numbers of more warm-water species. Warmer water temperatures may also make fish and shellfish species more susceptible to illness and disease. Additional declines due to climate change may have an impact on not only direct

economic gains, but also on the water quality improvement or filtering service provided by shellfish along the coast of Connecticut.

Connecticut's habitats support a wide range of plants and wildlife species from upland forests to the nursery grounds for commercial and recreational fish species in the Sound. This abundance in turn supports a diversity of wildlife-based recreation opportunities. Recreational hunting, fishing, shellfishing, waterfowl hunting, and bird-wildlife viewing are popular pastimes for Connecticut residents and visitors. In the United States as a whole, recreational anglers spent a total of \$5.8 billion on fishing trips in 2006, and annually contribute an estimated \$30.5 billion to the US economy through related expenditures. Connecticut anglers alone took 5.4 million freshwater and saltwater fishing trips in the state and spent over \$190 million in 2006. This total includes nearly 2 million trout fishing trips, making them the State's most sought after type of fish. This is particularly significant relative to climate change as trout are dependent on cold water streams, a habitat identified in this report as being at high risk in Connecticut. Furthermore, the later establishment and earlier break-up of lakes and pond ice may negatively impact recreational winter fishing.

Nationwide nearly 15 million people spend nearly 900 million days bird watching along coastal areas, and an additional 13 million people spend 341 million days viewing other marine and coastal wildlife. Over 1 million Connecticut state residents reported that they participated in wildlife-watching in 2006. The health of the state's natural resources and these services influence both the quality of the experience and revenue generated. Projected changes in sea level and temperature may lead to degradation and loss of supporting habitats and shifts in the assemblages of species valuable to recreational fishing, hunting, and bird-wildlife viewing.

Many other ecosystem services are provided by habitats and species in the state. These include water filtration, carbon sequestration (wetlands and forests), intrinsic values, genetic and species diversity and waste decomposition and detoxification. Shellfish beds and tidal/freshwater marshes filter millions of gallons of water daily, and help maintain the state's water quality. Since the State's watershed includes high densities of point and nonpoint sources of nutrients and other pollutants this service is especially important. Water filtration is essential to supporting commercial and recreational fishing, since many valuable fish and shellfish species depend on clean water to survive. Water quality also affects swimming and beach going opportunities, since poor water quality can lead to beach closures and decrease desire to visit beaches and lakes due to increased public health concerns. As noted above, poor water quality in turn leads to decreased tourism revenues for state businesses.

Given the importance of the ecosystem services provided by natural resources, careful consideration of both the benefits and true costs of degradation and loss should be standard practice as we assess the impacts and responses to a changing climate across multiple sectors and locations within the State.

## Concluding Statement and Next Steps

This report addresses the projected impacts of climate change on the natural resources of the state of Connecticut. Public Act 08-98 further requires by July 1, 2010, a report on “recommendations for changes to existing state and municipal programs, laws or regulations to enable municipalities and natural habitats to adapt to harmful climate change impacts and to mitigate such impacts.” The next step in this process will be for the NRWG to develop and provide these recommendations.

We envision four steps in this process: 1) looking at habitats within the larger context of Connecticut’s overall landscape, 2) identifying specific threats to habitats at risk that may be amplified by climate change, 3) determining areas where additional information (i.e., data gaps) is needed through research, surveys or monitoring, and 4) identifying priority actions that will increase the resilience of habitats to different climate drivers and extreme events.

The habitat types evaluated in this report should be revisited to assess their size (acreage), distribution, and/or connectivity within the state of Connecticut and generally within the southern New England region. Information on local and regional distribution, along with the habitat-at-risk assessment done in this report, provides a valuable context for making subsequent climate adaptation decisions on implementation.

Looking forward, the goal of climate adaptation is to reduce the risk of environmental degradation with actions that increase the resilience of Connecticut’s natural resources. Ecosystem resiliency is the ability of an intact, interacting ecological unit to withstand challenges (both climatic and non-climatic) to its continuing function. Approaches that have been identified in other studies to enhance resiliency include conservation of key habitat features, reducing non-climate related stressors, maintaining or reestablishing connectivity between habitats, restoring degraded habitats, relocating populations of species at risk, and ensuring that representative area(s) of each habitat persist (this may include establishment of additional refugia).

Adapting to a changing climate will require ongoing monitoring of Connecticut’s natural resources and development of a constantly evolving “tool-box” of adaptation strategies. In the short-term, reducing impacts from non-climate related stressors such as pollution, invasive species, fragmentation due to development, and water withdrawals will help to minimize the effects of a warming climate. Land acquisition that improves connectivity of protected lands, critical habitat, migration corridors and increased conservation of important watersheds, shorelines and riparian lands, will be needed to maintain long-term ecosystem resiliency. Over the next six months the NRWG will endeavor to apply this information to develop an adaptation strategy, or roadmap, for the continued conservation of natural resources in Connecticut, our adjoining states and the larger region.

## Appendix: Natural Resource Working Group

### Natural Resources Working Group Co-chairs

William Hyatt	Connecticut Department of Environmental Protection
Adam Whelchel	The Nature Conservancy

### Natural Resources Working Group Core Team

John Volin	University of Connecticut
Jason Vokoun	University of Connecticut
Mike Willig	University of Connecticut
Roslyn Reeps	Connecticut Department of Environmental Protection

### Natural Resources Working Group Members

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Nels Barrett	USDA, Natural Resource Conservation Service
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Penelope Howell	Connecticut Department of Environmental Protection
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# Appendix E: Public Health

## **The Public Health Risk to Connecticut from Projected Climate Changes**

### **The Challenge of Adaptation**

Public Act 08-98 tasked the Governor's Steering Committee on Climate Change (GSC) to assess the impacts to Connecticut public health due to expected climate changes. The Adaptation Subcommittee of the GSC established a Public Health Workgroup to specifically address this threat. The Public Health Workgroup is co-chaired by Pamela Kilbey-Fox, MPH, Chief of the Local Health Administration Branch at the Connecticut Department of Public Health, and A. Dennis McBride, MD, MPH, Health Director for the City of Milford Health Department, and comprised of leaders in the areas of Connecticut air quality, epidemiology, public health and health infrastructure.

The Public Health Workgroup took a multi-faceted approach to the assessment of climate change impacts on public health. This scoping process for this assessment led to consideration of the impacts of variability in temperature, precipitation, sea level rise, air quality and extreme weather events, on areas where public health would be primarily impacted. These areas of primary impact included vector-borne diseases, food, air, water, human health, health infrastructure and environmental justice communities. During the climate change impacts assessment planning and reporting period, the members of the Public Health Workgroup and the rest of the public health community in Connecticut were required to reprioritize limited resources due to the pandemic H1N1 influenza virus. Due to this more pressing priority the Public Health Workgroup's efforts were more limited in scope and thus, this report entails a more limited review of the potential impacts of climate change on public health. The Public Health Workgroup believes a more thorough assessment is warranted and that it will be a worthwhile endeavor to revisit this element of Connecticut's Climate Change Adaptation Plan at a later date.

### **Public Health Infrastructure**

The public health community has an important role to play in preventing the more severe impacts of climate change (Are We ready, 2008). Nearly 70 percent of local health directors believed that their jurisdiction had already experienced climate change in the past 20 years. Given the challenges that public health faces, the agencies and organizations responsible for protecting the public's health need to increase their capacity to cope with climate change-related health risks.

According to the Public Health Workgroup, public health infrastructure has a medium degree of sensitivity due to climate change. It is likely that health infrastructures, such as the Department of Public Health (DPH), will be highly adaptive to climate change. DPH will likely be able to meet demands as the department modifies its emergency response plans under the CDC Public Health Preparedness Grant. These plans assist with statewide preparedness. Local Health Departments and Districts are also required to have preparedness plans in place. It will be

important for these plans to include sections for disasters due to extreme weather events which may become more frequent due to climate change.

### *Impacts on Health Infrastructure*

Extreme weather events can impact Connecticut's infrastructure. The Northeast suffered an estimated \$130 million in property damage from several intense storms in the fall of 2005 and spring 2006 (State of Connecticut Department of Environmental Protection [CTDEP], 2009). Increases in storms can take an economic toll on Connecticut due to infrastructure damage. Connecticut's coast has almost \$405 billion of insured coastal assets including coastal homes, roads, and infrastructure that are at increased risk as sea level rises and as storms become more intense. Scientists, insurers, investors, planners, designers, and policy makers must respond to the significant consequences of climate impacts on human health, coastal infrastructure, ecosystems, agriculture, and the economy.

Climate change will impact the public health infrastructure including hospitals, health departments, emergency medical services, and private practices. According to the US Energy Information Agency, homes and commercial buildings use 71% of the electricity in the United States, and this number will rise to 75% by 2025 (National Renewable Energy Laboratory, 2009). Energy consumption in commercial buildings will continue to increase until buildings can be designed to produce enough energy to offset the growing energy demand of these buildings. Leadership in Energy and Environmental Design (LEED) criteria was developed by the US Green Building Council in order to assess and rank the sustainability of all buildings, including those that house health care services. The rating system is recognized nationally and internationally as the green building design standard (US Green Building Council [USGBC]). The Mark Twain Museum built in 2003 in Hartford, CT, was the first LEED-certified museum in the country (Union of Concerned Scientists, 2007). The overall energy efficiency of its heating and cooling system is nearly 30 percent greater than a system designed to satisfy the building code.

According to the American Hospital Directory (AHD), there are about 8,373 staffed beds in Connecticut and approximately 2,423,215 patients daily (AHD, 2008). Hartford and New Haven are the two areas with the highest numbers, with up to 847 staffed beds at Yale-New Haven Hospital, and about 763 at Hartford Hospital. Hospitals are high-energy enterprises as they have bright lights, refined air-filtration, stable temps with adequate heating and cooling, and use a variety of devices, equipment, and chemicals on a daily basis. American hospitals generate more than two million tons of waste each year (Health Care Without Harm, [HCWH], 2009). Reducing waste can benefit the budget as well as the environment. It is estimated that a 1,000 bed hospital that uses reusable sharps containers rather than disposable ones could save \$175,000 per year and reduce waste by 34,000 pounds. Reducing carbon footprints within health care facilities will be difficult, but it is something that is worth the efforts. In the 1980s, the thought of

health care “greening” arose, drawing attention to such practices as cleaner manufacturing methods and reduction in waste volume, toxicity of medical materials, and packaging. This movement towards more eco-friendly hospitals is led by the Health Care Without Harm (HCWH) group, which holds annual CleanMed conferences featuring green products. This group has tackled issues related to incinerator emissions, mercury in the waste stream, plastic materials that leach out environmental estrogens, disposal of electronics, and toxic hospital cleansers.

### *Population Migration*

Population, or Eco-migration, is a shift in population of a certain area into another due to climate change impacts. For example, extreme temperatures may lead to droughts, causing conditions that decrease quality of life. Environmental disasters, such as hurricane Katrina forced the movement of persons out of New Orleans. Larger migrations in a limited period of time can lead to an increased likelihood of conflicts, including clashes over jobs, resources, and ways of life. New Orleans resident’s overall quality of life decreased due to hurricane Katrina. It was estimated that 90% of the tap water in New Orleans was not drinkable (Levine, 2005). Water was contaminated due to sewage, oil, gasoline, bodies of humans/animals, and toxic household chemicals. Initial tests from the Environmental Protection Agency (EPA) revealed high levels of *E. Coli* and fecal Coliform bacteria. Thousands of containers were found in the water containing contaminants, and facilities containing hazardous wastes were submerged in water. Even when conditions are made livable for residents to move back, contaminants can still be found in the dirt and mud. Asbestos, lead, and mold found in old buildings can remain in soils and water sources. Mold can lead to lung infections, skin irritations, and other dangerous health conditions. It was noted in the first Intergovernmental Panel on Climate Change (IPCC) report compiled in 1990 that the greatest single impact of climate change might be on human migration. The report estimated by 2050, 150 million people could be displaced by climate change related phenomenon’s (Climate Change Induced forced Migrants, 2009).

Climate change can significantly affect migration in a variety of ways. First, the effects of warming and drying in some regions will reduce agriculture potentials and undermine ‘ecosystem services’ such as clean water and fertile soil. Second, increases in extreme weather events can lead to heavy precipitation and resulting floods. Lastly, sea level rise will permanently destroy extensive and highly productive low-laying coastal areas that are home to millions of people who will have to relocate permanently (Climate Change Induced forced Migrants, 2009). Connecticut’s coastal area is home to more than 2 million people, more than 60 percent of the state’s population (Union of Concerned Scientists, 2007). According to the CT Department of Environmental Protection (DEP) flooding along rivers and streams is the number one natural hazard in Connecticut, and its frequency is expected to increase as climate change alters precipitation patterns. The 2007 IPCC Report projects more frequent and intense storms for the Northeast Region, leading to an increased change of flooding. Connecticut has about 8,400 miles

of rivers and streams, 6,000 lakes and ponds, 4,300 dams, and 25.3 miles of shoreline (CTDEP, 2007).

### *Sheltering*

Sheltering issues may arise due to extreme weather events. Hurricanes and floods may lead to evacuations, which will stress Connecticut's sheltering assets. The American Red Cross has been working with the Department of Emergency Management and Homeland Security (DEMHS) and with Emergency Management Directors (EMDs) from towns and cities within the state, to compare sheltering data. The goal is to compile one complete database that is kept in the National Shelter System (NSS). The NSS is a comprehensive web-based, data system created to support agencies (government and non-governmental) responsible for elements of shelter management. The NSS allows users to identify, track, analyze, and report on shelter data in a consistent and reliable manner (Federal Emergency Management Association [FEMA], 2009). The NSS data will assist in developing strategies to support state and local governmental agencies to ensure prompt and effective mass care service delivery, especially during mass evacuations by:

- Providing a coordinated system for government and non-governmental agencies to manage shelter facility data.
- Providing a standardized tool to establish baseline shelter data, vital for comprehensive shelter planning.
- Providing local agencies with a tool to manage the shelter process through all shelter management phases: planning, alert, stand-by, opening and closure.
- Determining the potential number of evacuees that can be sheltered in a specific locale.
- Providing from the onset of any disaster incident the capability for informed shelter decision-making, contribute to the declaration process and recovery efforts.

Currently, the American Red Cross and DEMHS are approximately 95% completed with reconciling all of New Haven County sheltering data. Data collections throughout the remaining counties within the state are in progress. In September 2008, DEMHS signed an agreement with the State University System including Eastern, Western, Southern, and Northeastern Connecticut State Universities, regarding sheltering. These Universities have agreed to stand as regional shelters throughout the state in the event of an emergency, such as an extreme weather event. Events such as flooding and hurricanes can lead to major evacuations. It will be important to develop adequate procedures for opening and closing shelters throughout the State.

### *Forward Movement of Patients*

In an incident involving a large number of victims, it is likely that the local healthcare facilities will be overwhelmed, requiring the rapid forward movement of patients to healthcare facilities in other areas of the state. Connecticut has compiled a State Forward Movement of Patients Plan

(2008) which addresses the medical management and the transportation of patients at the local/regional level prior to implementing the National Disaster Medical System (NDMS). NDMS is a federally coordinated system that augments the nation's medical response capability (Department of Health and Human Services [DHHS], 2009). The overall purpose of the NDMS is to supplement an integrated national medical response capability for assisting State and local authorities in dealing with the medical impacts of major disasters and to provide support to the military and the Department of Veterans Affairs medical systems.

*Environmental Justice Communities*

In the state of Connecticut, the most impacted by climate change will be communities of color and low-income communities that are socially disadvantaged, disproportionately burdened by poor environmental quality, and the least able to adapt. These are defined as environmental justice (EJ) communities. These communities will experience extreme heat events, and see increases in cardio-respiratory illness, vector associated infectious diseases, food insecurity, and natural disasters.

The State of CT defines EJ communities as a group, determined in accordance with the most recent United State Census, for which 30% or more of the population consists of low income persons who are not institutionalized and have an income below 200 percent of the federal poverty level or a distressed municipality.



The overall consequences of climate change will likely disproportionately impact vulnerable and socially marginalized populations, many of whom already have poor health status. Community vulnerability to climate change is determined by its

ability to anticipate, cope with, resist, and recover from the impact of major climate-related events, such as heat waves. Climate change will likely reinforce and amplify current as well as

List of 25 Cities and Towns in CT Designated as Distressed in 2009				
Ansonia	Meriden	Plymouth	Vernon	Norwich
Bridgeport	Naugatuck	Putnam	Winchester	Hartford
Bristol	New Britain	Sprague	Plainfield	Windham
Brooklyn	New Haven	Torrington	Killingly	East Hartford
Derby	New London	Waterbury	North Canaan	West Haven

future socioeconomic disparities leaving low-income minority, and politically marginalized

groups with fewer economic opportunities and more environmental and health burdens (CA EPA Air Resources Board). Severe health impacts will be concentrated in the most vulnerable groups and regions, particularly children, older adults, pregnant women, and those with pre-existing medical conditions or mobility and cognitive constraints (Are We Ready, 2008). Poverty also increases susceptibility to climate-related health effects. During extreme weather events, poor people and communities may lack adequate shelter or access to protective resources such as air conditioning, transportation.

Below is a list of low income communities located in the following towns determined by CTDEP GIS staff from current US Census data:

- Bloomfield
- Danbury
- East Haven
- Windsor
- Fairfield
- Griswold
- Groton
- Hamden
- Manchester
- Middletown
- North Haven
- Norwalk
- Plainville
- Shelton
- Southington
- Stamford
- Stonington
- Stratford
- Thompson
- Wallingford
- West Hartford
- Westbrook
- Wethersfield
- Windsor
- Windsor Locks

The Connecticut Coalition for Environmental Justice was formed to protect urban environments, primarily in Connecticut, through educating communities, promoting changes in local, state, and national policy, and promoting individual, corporate and governmental responsibility towards our environment (CT Coalition for Environmental Justice, 2009). In May 2008, Connecticut passed its first ever environmental justice law. The law recognizes 25 low income towns and low income neighborhoods in 34 other CT towns as environmental justice communities.

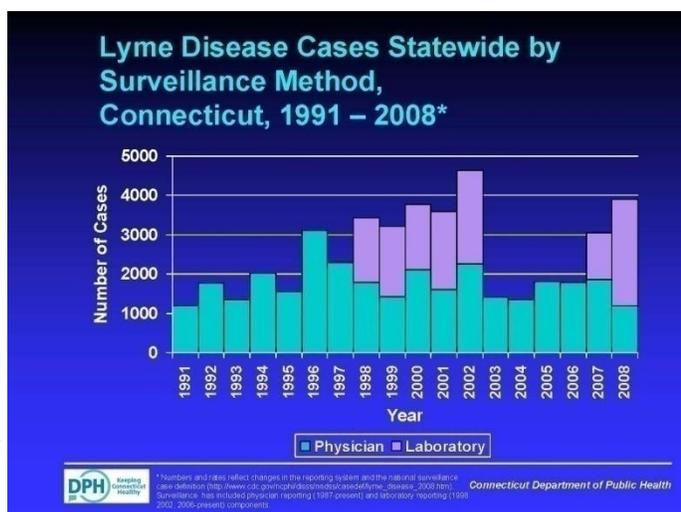
Environmental Justice is defined as the “fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies.” The State’s largest polluters of green house gases are located in EJ communities. Transportation corridors such as I-95, I-84, and I-91 also contribute to the poor air quality in EJ urban communities.

Asthma is 50% higher in urban schools in CT when compared to rural schools. Hospitalization rates for asthma in the largest cities of Bridgeport, Hartford, Waterbury, and Stamford was more than twice the average for the state and higher than the national average. These five town combined make up 18% of the state population but account for 37.7% of all asthma hospitalizations, 37.9% of all asthma emergency room visits and 30.1% of all asthma deaths in Connecticut.

A number of EJ communities are vulnerable to storm surges and flooding as they are located in coastal areas. Flooding can cause health impacts including direct injuries, death, infectious disease, and mental health problems. Floods can also lead to financial loss if adequate insurance isn’t affordable.

### Human Infectious Disease Impact

Disease transmission to humans may occur through a vector, an insect or other invertebrate carrier that transmits an infectious agent. Vector-associated diseases will be impacted by climate change. These diseases can be transmitted from ticks, mosquitoes, and rodents. In regards to Connecticut, ticks are associated with Lyme disease, Rocky Mountain Spotted Fever (RMSF), and Babesiosis. The CDC reported Lyme disease cases per 100,000 in the state. In 2002 4,631 cases were recorded, which was a steady increase from 1993 reports. Although there were decreases in reported cases between 2003 and 2006; there was another increase in 2007 (CDC, 2008). *Derma-centor variabilis* is the vector of *Rickettsia rickettsii*, the etiologic agent of RMSF. RMSF has been a reportable disease in the United States since the 1920s. In the last 50 years, approximately 250 to 1200 cases of RMSF have been reported annually, although it is likely that many more cases go



unreported. RMSF can be a severe illness, and the majority of infected patients are hospitalized (CDC, April 2008). Rodents have the potential to transmit Hanta virus. Mosquitoes are known to carry Eastern Equine Encephalitis (EEE) and West Nile Virus (WNV). According to the public health workgroup, ticks and mosquitoes are very likely to be affected by climate change, and pose great risk in Connecticut. Temperature, precipitation, soil moisture, and water runoff are all drivers of vector-associated diseases. Climate change affects ecosystems that will influence vector survival, replication, biting frequency, and geographic range.

### *Ticks*

*Ixodes scapularis* is the vector of *Borrelia burgdorferi* and *Baesia microti*; the etiologic agents of Lyme disease and human babesiosis, respectively. It is unknown if global warming will increase or decrease the severity of Lyme disease by changing the feeding habits of the deer ticks that transmit the disease. These ticks are relatively long-lived and spend most of that time off of their hosts. Deer ticks have a two-year life span with three feeding stages; larval, nymphal, and adult. To survive, ticks must obtain a blood meal during each stage. The seasonal cycle of feeding for each stage of a tick's life determines the severity of infection in a given region. Ticks need a relatively high moisture environment in order to survive when they are not on a host animal. Current climate conditions in Connecticut are conducive for survival of tick species. Tick habitats will be affected by climate change, therefore a change in climate will affect tick populations, though the change will occur slowly (over years). According to data collection from the public health workgroup, ticks are already being affected by climate change. By 2080, the temperature in Connecticut could increase by 4 to 7.5F (NPCC, 2009). Ticks, their life cycles, natural histories, and ability to transmit pathogens will be influenced, increasing the states vulnerable to vector-associated diseases.

### *Mosquitoes*

Increased temperatures can lead to changes related to the development, transmission, and lifespan of mosquitoes. Adult mosquitoes actively feed during the spring, summer, and fall months. Higher temperatures speed development of larvae and pupae, thereby producing more generations. Higher temperatures shorten the extrinsic incubation temperature of both viruses; thereby enhancing transmission. Higher temperatures would likely lengthen the mosquito-season, thereby extending the transmission season.

Risks of infection from mosquitoes can include diseases such as EEE and WNV. As warm weather increases, mosquitoes have more places to breed, increasing changes of vector-associated diseases. *Culiseta melanura* and *Culex pipiens* are the primary vectors of EEE and WNV, respectively. Both species feed primarily on birds. There are several other species, referred to as bridge vectors, which feed more abundantly on humans and could transmit the virus from birds to humans. *Culiseta melanura* is associated with red maple-white cedar swamps. *Culex pipien* is associated with man-made structures, such as catch basins, but will also be found breeding in earthen pools that are either natural or created by humans. Both species occur in states to the South, North, and West of Connecticut.

Increased rainfall will likely increase the population of *Culiseta melanura* by providing more suitable habitats for the juvenile stages. Increased rainfall may decrease numbers of *Culex pipiens* by flushing juvenile stages out of the catch basins and into bodies of water with fish. Increased rainfall will increase populations of many of the potential bridge vectors of these viruses. However, increased mosquito populations may not necessarily increase virus transmission. Populations of mosquitoes can be affected positively or negatively by the amount of rainfall. Increased rainfall could increase the life of the adult mosquitoes by increasing the humidity. Increased temperatures could produce more generations of mosquitoes, extend the transmission season, and enhance transmission of viruses; though the life of the mosquito may be shorter. The Northeast Climate Impacts assessment (2007), predicted a limited increase of rainfall in the summer months. Increased storms and hurricanes throughout other seasons may create a higher level of rainfall during other months.

Human activity also impacts mosquito habitats. New catch basins are continually being constructed by humans, thereby increasing the numbers of breeding *Culex pipiens*. Swimming pools abandoned for economic or other reasons may produce relatively large numbers of *Culex pipiens*. Populations of host animals, upon which mosquitoes feed, are changing for many reasons. A warmer climate could change the character of Connecticut forests, suburban areas, and urban areas, thereby altering botanical species as well as abundance and diversity of vertebrate animals.

### *Rodents*

As determined by the public health workgroup, Connecticut residents have lower risks of vector-associated diseases from rodents compared to ticks and mosquitoes. Deer mouse, *Peromyscus maniculatus*, is the vector of Sin Nombre Virus (SNV) in the southwest United States. The New York virus, a closely related strain, has caused Hantavirus Pulmonary Syndrome (HPS) in persons living in New York and Rhode Island. In the wild, rodents transmit the virus in their burrows. Inhalation of infected aerosolized rodent urine or dried excreta can lead to infections. The white-footed mouse, *Peromyscus leucopus*, is considered to be the reservoir in Northeastern United States. In 1993, an outbreak in Southwestern United States was traced to an increase in the population of deer mice that carried the virus. Mouse habitats will be affected by climate change, and therefore a change in climate may affect rodent populations. According to the workgroup, the magnitude and impact of the problem is low. Much of the changes in habitats are brought about by humans. Populations of host animals are continually changing. Although temperatures in Connecticut may rise, white-footed mice will likely continue to be present.

### **Food Safety**

The safety and supply of food is essential for human life. Connecticut is faced with temperature changes throughout the year creating obstacles in growing and maintaining safe and ample food supplies. Changes in the food supply in terms of crop-yields, aquaculture, and livestock will be affected by climate change. Food safety and security is focused on four main areas including availability, stability, utilization, and access. Extreme weather events can lead to a variety of

changes including adjustments in planting dates, changes in crop varieties, crop relocations, and land management. These changes can pose a financial burden and can be limited by current technology. In extreme heat events, crops will be damaged and heat stress will be placed on livestock. Fewer cold days and frost over land areas will lead to a loss of crops and fruits, and can extend the range of pests leading to an increase in diseases.

Changes in precipitation, temperature, humidity, and water have been shown to affect the quality of water used for drinking and commercial purposes. Storm water runoff from heavy precipitation events can increase fecal bacteria counts in coastal waters. This, coupled with increased sea-surface temperature, can lead to increases in the frequency and range of harmful algal blooms (red tides) and potent marine biotoxins such as ciguatera fish poisoning. *Vibrio* bacteria infections following the consumption of seafood and shellfish have been associated with temperature increase. Heavy rainfall has also been implicated as a contributing factor in the overloading and contamination of drinking water treatment systems in the U.S., leading to illnesses from organisms such as *Cryptosporidium* and *Giardia*.

Extreme weather events can lead to power outages and electrical problems that will disrupt the maintenance of our food supply. A disruption in energy sources will lead to issues related to food storage. Electricity is necessary to maintain adequate cold storage units such as refrigerators and freezers. If proper storage is not maintained, food will spoil, leading to increased risks of food borne illnesses. Connecticut can be economically burdened by the high turnaround of food due to spoilage. Alternative methods of cooling may lead to increased electrical costs leading to financial burdens.

### *Food borne Illnesses*

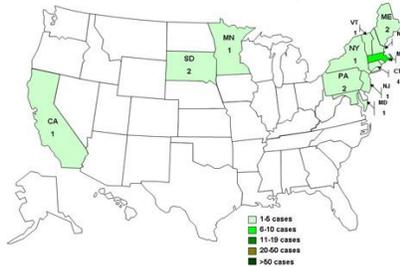
The Centers for Disease Control and Prevention (CDC) estimates that 76 million foodborne illness cases occur in the United States every year. This amounts to one in four Americans becoming ill after eating foods contaminated with pathogens. The annual dollar costs of foodborne illnesses, in terms of medical expenses and lost wages and productivity, range from \$6.5 to \$34.9 billion. Commonly recognized food-borne infections include *Campylobacter*, *Salmonella*, and *E. coli*. Below is a brief overview of the health effects these infections may have on humans.

*Campylobacter* is the genus of the infectious disease *Campylobacteriosis*. Most people who become infected with this disease get diarrhea, cramping, abdominal pain, and fever within two to five days after exposure. The illness typically lasts for one week. Those with compromised immune systems are at higher risks for the organism to spread to the bloodstream, causing serious life-threatening infections. *Campylobacter* is one of the most common causes of diarrheal illness in the United States. About 13 cases are diagnosed each year for every 100,000 persons in a population. Many cases go undiagnosed or unreported, increasing the estimated persons infected each year. (Center for Disease Control and Prevention [CDC], 2009)

*Salmonellosis* is the infection caused by the bacteria *Salmonella*. Most people infected with the disease develop diarrhea, fever, and abdominal cramps. *Salmonella* is a microscopic living creature that passes from the feces of people or animals to other people or animals. There are

many different kinds of *Salmonella* bacteria. Those most common in the United States include Typhimurium and Enteritidis (CDC, 2009). Recent *Salmonella* outbreaks in the U.S., including CT, have been linked to peanut butter.

*E. coli* infections can result from consumption of contaminated foods and water that has not been disinfected. People have become infected by swallowing lake water while swimming, touching the environment in petting zoos and other animal exhibits, and by eating food prepared by people who did not wash their hands (CDC, 2009). Current cases of *E. coli* have been found in contaminated meats, sparking recalls in many production companies. To the left is a map from the CT DPH displaying outbreak clusters of *E. coli* between August 21<sup>st</sup> and November 2<sup>nd</sup>. Twelve states including Connecticut reported confirmed cases.



States where persons infected with the outbreak strain of *E. coli* O157:H7 live, United States, by state, from August 21, 2009 to November 2, 2009.

### Food Supply and Safety

Changes in climate can lead to production limitations, placing economic burden on sellers, and shifts in supply and demand. Inadequate water supply due to droughts can limit food production. Crops will not grow properly with limited supplies or contaminated waters. As with extreme heat, cold weather events will affect the food supply. Colder temperatures may not allow adequate crop growth, limiting the supply of food produced. There may be an increase in the use of electricity in order to provide adequate environments for crop growth. Increases in electricity, fuel oil, and coal will add to energy consumption, driving up costs.

Other potential impacts of climate change on food safety include impacts on microbial evolution and stress response, and pathogen emergence. Over the course of time, many bacterial agents have developed mechanisms that allow them to survive and even grow under unfavorable or “stressful” conditions. An example is seen in *E. coli*, where the organism is able to survive an acid shock as low as pH 2 after previous exposure to pH5. Microorganisms acquire increased tolerance after pre-exposure to a stressor. From there, the microorganism frequently develops enhanced resistance to other types of stress, which is referred to as cross-protection.

The emergence or re-emergence of infectious disease agents are affected by changes in climate. Emerging food borne pathogens have newly appeared in populations. Many were thought to be controlled but are now resurging, or have existed but are rapidly increasing in incidence, geographic range, or by some other factor. Pathogen emergence is associated with changes in the following sectors: ecology and agriculture, technology and industry, globalization, human behavior and demographics, epidemiological surveillance, and microbial adaptation.

### Water Quality and Quantity

Land-use is altered due to changes in climate and human activity. Land-use changes, due to human activity, increases levels of CO<sub>2</sub>, methane, and nitrous oxide. Increases in populations

lead to more buildings and industries, leading to higher levels of pollutants and release of fossil fuels. A variety of natural resources are affected by these changes. Altered land-use due to climate change will affect the quality and quantity of the water supply. This can place an economic burden on agricultural groups, and affect human health.

### *Contaminated Water Sources*

Contaminated sources of drinking water can impact public health and cause a variety of aesthetic problems such as bad tasting water or the staining of laundry items and plumbing fixtures. There are a variety of contaminants that can potentially infect water supplies. These include:

- Microbial contaminants, such as viruses and bacteria, may come from sewage treatment plants, septic systems, agricultural livestock operations, and wildlife, and can lead to health issues.
- Organic chemical contaminants include synthetic and volatile organic chemicals, which may come from the production or storage of industrial products or petroleum, urban storm water runoff, and septic systems.
- Radioactive contaminants can occur naturally or result from industrial processes.
- Pesticides and herbicides may come from a variety of sources such as agriculture, storm water runoff, and residential uses.
- Inorganic contaminants, such as salts and metals, can result from urban storm water runoff, industrial or domestic wastewater discharges, or farming.

(Source Water Assessment Program [SWAP] Report, 2007)

Surface and groundwater sources are also vulnerable to potential contamination from non-point source pollution. Unlike pollution from industrial and sewage treatment plants, non-point pollution comes from widely distributed sources such as highways, large parking areas, or land that is prone to erosion. Non-point pollution is caused by rainfall or snowmelt moving over and through the ground. As the runoff travels through a drinking water source area, it picks up and carries away natural and human-made pollutants, which are deposited into lakes, rivers, wetlands, coastal waters, and underground sources of drinking water. Non-point source pollutant categories include:

- Fertilizers, herbicides, and insecticides
- Bacteria and nutrients
- Airborne Pollutants
- Oil, grease, and toxic chemicals
- Sediments

The table below lists potential contaminants and their respective categories.

<b>Category</b>	<b>Subcategory</b>	<b>Potential Contaminants</b>
<b>Agriculture</b>	Animal Feeding, Waste Storage Or Disposal Operations	Microbials  Inorganic Chemicals, Pesticides & Herbicides
	Orchards, Row Crops, Tree Farms, Ornamental Growers	
	Pesticide Storage, Handling Or Application	
<b>Bulk Chemical or Petroleum Storage</b>	Underground Storage Tank (UST)	Petroleum & Chemical Products
	Tank Farms	
	Warehouse	
<b>Industrial Manufacturing or Processing</b>	Chemical Producers And Allied Production	Chemical Products
	Chemical Use Processing	
<b>Commercial Trades and Services</b>	Automotive And Related Businesses Or Services Using Chemicals	Petroleum & Chemical Products
		Chemical Products
<b>Waste Storage, Handling, Disposal</b>	Hazardous Waste	Organic And Inorganic Chemicals, Microbials
	Solid Waste	
<b>Miscellaneous</b>	Major State And Interstate Highways, Rail Lines	Petroleum & Chemical Products
	Petroleum Or Chemical Pipelines	
	Failing On-Site Septic Systems	Microbials & Chemical Products

*Types of Significant Potential Contaminant Sources Impacting Surface or Groundwater Evaluated By Connecticut's Source Water Assessment Program: State of Connecticut Department of Public Health Drinking Water Division*

Most bodies can fight off microbial contaminants the way they fight off germs and do not have permanent effects. If high enough levels occur, the contaminants can make people ill, and can be dangerous or even deadly for a person whose immune system is already weak. Chronic effects occur after people consume a contaminant at levels over EPA safety standards over many years. Drinking water contaminants that produce chronic effects are chemicals (such as disinfection by-products, solvents, and pesticides), radionuclide's (such as radium), and minerals (such as arsenic). Chronic effects of drinking water contaminants can be cancer, liver or kidney problems, or reproductive difficulties.

### *Contaminants*

*Cryptosporidium parvum* is a bacteria found in human and animal fecal waste (CDC, EPA, 2001). This contaminant can enter rivers, lakes, and streams, and though less likely, can also

contaminate groundwater. Due to its small size and composition, it is resistant to typical filtration and disinfectant methods, therefore over recent years; the EPA has tightened its standards required for public water systems specifically to address these contaminants. Exposure to *Cryptosporidium parvum* can come from drinking or swimming in infected water; and can cause gastrointestinal problems such as diarrhea, vomiting, and cramps. Those with weakened immune systems from AIDs, chemotherapy, a recent transplant, or other reasons are most vulnerable. Diarrhea and vomiting may lead to dehydration, which can pose a variety of complications ranging from acute to chronic. Electrolyte abnormalities such as sodium and potassium levels may result. A loss of electrolytes can lead to muscle weakness, cramping, and abnormal heart rhythms. Hypotension (low blood pressure) may occur, potentially leading to shock; and seizures may result due to low sodium levels. Extreme effects may limit blood flow to vital organs leading to kidney failure. Failing kidneys can lead to treatments in intensive care units including blood transfusions and dialysis treatments.

*Escherichia coli* (*E. coli*) is from fecal coliform bacteria, commonly found in intestines of animals and humans. *E. coli* found in water supplies is a strong indicator of recent sewage or animal waste contamination. *E. coli* mainly causes illness when humans consume contaminated foods, though can also be transmitted through drinking water. Effects of consuming these bacteria are abdominal cramps and bloody stools. Severe complications are more likely to be seen in children less than five years of age and the elderly. Severe complications may lead to Hemolytic Uremic Syndrome in which red blood cells are destroyed and the kidneys can fail.

Nitrates and Nitrites can run-off into water sources from excessive fertilizer use and animal waste, leaching from improperly constructed or maintained septic tanks, cesspools, and sewage erosion of natural deposits. Nitrate contamination can cause *Methemoglobinemic* or “blue-baby” syndrome in infants less than 6 months. “Blue-baby” syndrome is a blood disorder in which there is a reduction in the oxygen-carrying capacity of blood. Symptoms can be subtle, as mild to moderate complications may include diarrhea, vomiting, and/or feeling lethargic. In more serious cases, infants will start to show obvious symptoms of cyanosis, in which the skin, lips, or nail beds develop a slate-gray or bluish color. The infant may also have trouble breathing. Nitrate contamination may occur if an infant formula is mixed in water with high levels of nitrates. This can be life-threatening without immediate medical attention, and if the infant is already sick. Disinfectants and disinfectant by products can link to bladder, renal, and colon cancers. The contaminants can infect drinking water and can lead to reproductive and developmental problems such as spontaneous abortion, neural tube defects, pre-term delivery, and low body weights.

### *Connecticut Wells*

Water quality and supply coincides with well-reliance in Connecticut. There are approximately 400,000 private wells in Connecticut serving approximately 15% of the state’s population of 3,510,300 persons (CTDPH, 2009). About 526,545 people are served by their own domestic drinking water sources. Private Wells are not regulated by the EPA, meaning owners are responsible for the quality of their own drinking water. Local Health Departments have the authority over private wells. Decreases in water quality due to climate change may place a burden on local health departments who must regulate private wells. The EPA will be burdened

if the quality of domestic water sources decrease, and there will be an increased risk towards the public's health.

### *Water Quantity*

Changes in temperature, precipitation patterns, and snowmelt will impact the quantity, and availability of water in the state. Temperature increases can lead to a loss of water through increased evaporation. Heavier precipitation can affect the quality and management of water more difficult. The impact on water supplies will ultimately depend on changes in precipitation including the amount, form, and time of year. According to the IPCC (2007) climate change will strain many of North America's water resources. The Northeast United States faces increases in the extent and frequency of storm surge, coastal flooding, erosion, property damage, and loss of wetlands (Reg. Climate Impacts NE Report). The availability of water will affect Connecticut residents. A limited supply will stress domestic and commercial use, and an excess of water run-off and flooding will impact water quality and public health infrastructure.

### **Air Quality and Extreme Heat**

Human health in Connecticut will be impacted by climate change primarily by increasing extreme weather events, extreme heat, and its potential exacerbation of existing air quality problems. Connecticut residents will also experience a reduction in extreme cold events due to climate change, a potentially positive benefit to public health from climate change during the winter months.

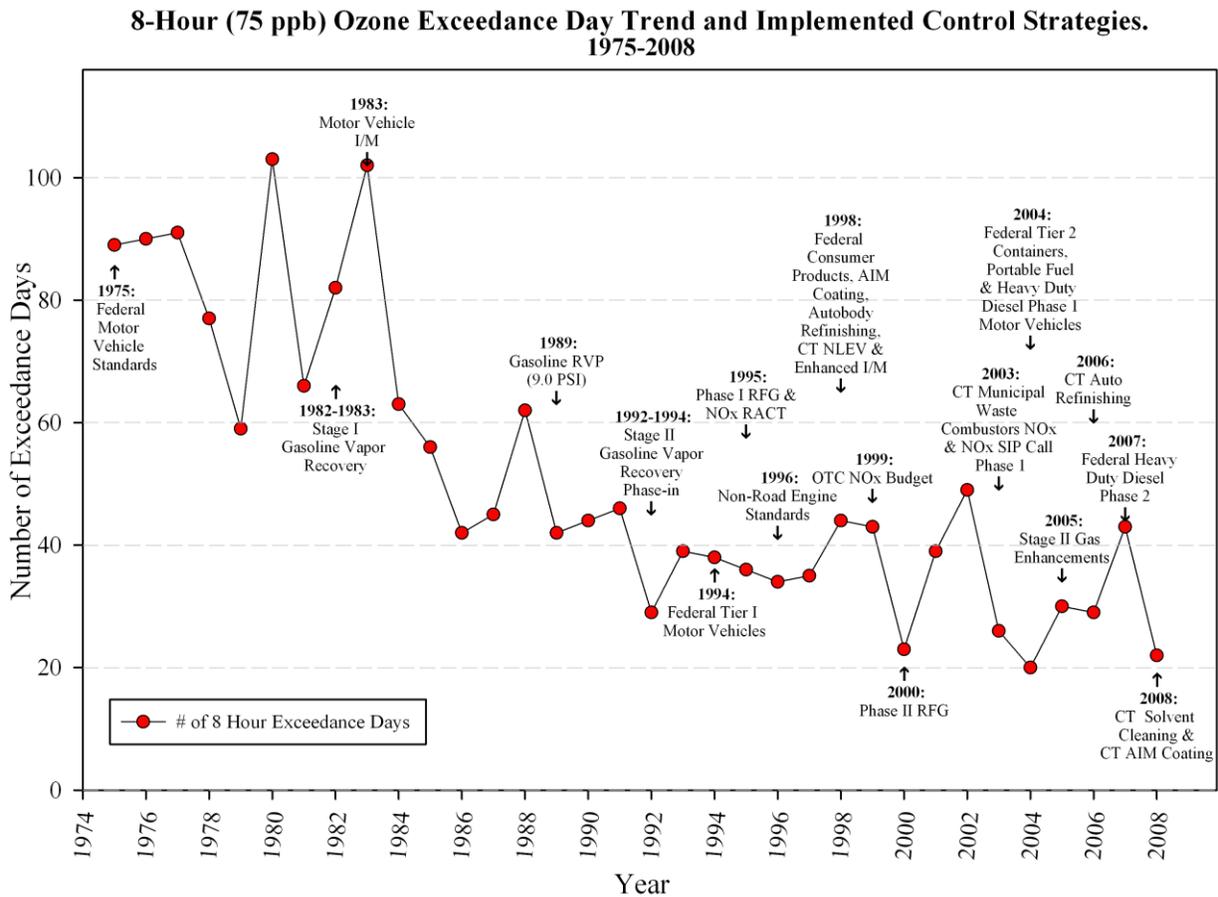
### *Ozone levels*

Ground level or tropospheric ozone is a major component of urban smog. Ozone is not directly emitted from any source; it is a secondary pollutant formed by the reaction of nitrogen oxides with sunlight and hydrocarbons. The formation of ozone is temperature sensitive, reaching peak production when ambient air temperatures are above 90° F. Thus, ozone would be generated at a greater rate under the elevated temperatures projected with climate change. Ground level ozone and its precursor pollutants can be transported by wind currents for hundreds of miles, complicating mitigation efforts. On days when high levels of ozone are monitored in Connecticut, prevailing, surface-level winds from a southwesterly direction transport emissions from the New York City area, as well as other urban areas along the Interstate-95 corridor into our state. Simultaneously, prevailing, upper level westerly winds transport emissions from large power plants in the Midwest into Connecticut. Other weather related variables can also affect ozone formation, for example, cloud cover in the northeast is expected to decrease with a warming climate which will provide more sunlight for ozone creation (Kunkel et al. 2007). Since ground level ozone is not directly emitted from industrial sources, only the control of nitrogen oxides, produced in the high-temperature combustion of fuel (e.g., cars and power plants) and volatile organic compounds (e.g., paints, solvents, gasoline), can effectively limit the production of ground level ozone.

Exposure to ozone has been linked to a number of respiratory health effects, including significant decreases in lung function and inflammation of airways. Ozone exposure also has been shown to cause new-onset asthma and increased sensitivities to allergens (Shea et al. 2008). Children are among the most at risk from ozone exposure because their respiratory systems are still developing and they breathe more air per pound of body weight than adults. Children often spend significant time outdoors during the summer, when ozone levels are at their highest. Furthermore, children, in general, have a higher incidence of asthma than adults, which may be aggravated by ozone exposure. The elderly and individuals with existing respiratory diseases, such as chronic obstructive pulmonary disorder (COPD) and asthma, also are at risk from ozone exposure because their lung function is already impaired. Aggravation of existing respiratory disease impacts the public health infrastructure because it can result in increased medication use, as well as increased hospital admissions and emergency room visits. Even healthy adults who are active outdoors (e.g., outdoor workers, joggers) respond more severely to ozone exposure than people at rest.

As discussed in more detail in the agriculture chapter, high concentrations of ozone can reduce agricultural crop production. Ozone is toxic to most plant growth (Hatfield et al. 2008), and can increase the susceptibility of plants to disease, pests and other environmental stresses such as extreme weather. Potential impacts on the local supply of fruits and vegetables could increase the cost of these items, further challenging Connecticut's economically disadvantaged resident's ability to afford healthy food.

The Connecticut Department of Environmental Protection (CTDEP) has been measuring ambient ozone levels since the 1970's. CTDEP's current monitoring network includes eleven ozone monitoring sites located around the state. Typically, measured ozone levels in Connecticut exceed the National Ambient Air Quality Standards (NAAQS) on several days each summer, depending on weather conditions. Although the state is classified as "nonattainment," peak ozone levels and the number of days on which air quality in Connecticut exceeds the standard have steadily decreased since 1974 as a result of numerous local, regional and national emission control strategies (Figure PH1; CEQ 2008; CTDEP 2009).



**Figure PH 1**

In 2008, the United States Environmental Protection Agency (EPA) adopted a more stringent ambient air quality health standard for ozone, lowering the standard from 84 ppb to 75 ppb, averaged over an 8-hour period. The above figure shows that the number of days Connecticut exceeded the revised standard has declined considerably over the past thirty years. During the early 1980's, Connecticut experienced as many as 100 days with ozone levels exceeding the revised standard. In more recent years, Connecticut has recorded twenty to forty exceedance days per year. This overall improvement in air quality is due to the implementation of a number of emission reduction programs aimed at automobiles, fuels and stationary sources. The timing of some of these programs is shown above in Figure PH1. In 2009, preliminary data indicate that air quality exceeded the 8-hour (75 ppb) standard on six days in Connecticut. This significant reduction is likely due to the efficacy of state and regional air pollution control programs, favorable meteorological conditions (i.e., the cool wet summer) and reduced economic activity resulting from the current recession.

Bell et al. (2007) and Hogrefe et. al. (2004) project an increase in ambient ozone, due to temperature increases and irrespective of reductions in emissions of anthropogenic precursors, of 4.2-4.4 ppb by the year 2050. Assuming no additional control measures are adopted in

Connecticut, increases of ozone production due solely to temperature increases could undo much of what has been accomplished in Connecticut since 1983 in terms of ozone abatement.

The risk to Connecticut's air quality due to the climate driver of higher temperatures was rated as medium by air quality experts during the risk assessment process, conducted by the workgroup. Connecticut air quality experts believe that ongoing efforts to reduce ozone precursor emissions (oxides of nitrogen and volatile organic compounds) through 2020 coupled with the issuance of more stringent National Ambient Air Quality Standards (NAAQS) for ozone, will largely reduce ozone concentrations before the effect from higher temperatures outpaces mitigation efforts by mid- to late-century. This means that any potential increases in ozone formation due solely to the climate change driver of higher temperatures will likely be of concern only in the mid to later years of this century (2050/2080). Potential for increased ozone formation in this time period will also be influenced by developing national policies that may significantly drive potential changes to the national electricity generation infrastructure and transportation systems by mid- to late-century leading to less reliance on fossil fuel. Reduced fossil fuel use from these systems could lead to fewer precursor emissions available to oxidize into surface level ozone, thus reducing ozone formation due solely to the climate driver of higher temperatures.

The CTDEP continuously monitors ozone from May through September, and alerts Connecticut residents when ozone concentrations are expected to exceed the health standard. Such days are termed "Ozone Action Days," and the forecast is made available to the public through a 24-hour toll free Clean Air Hotline<sup>14</sup> and online at the CTDEP's Air Quality Index webpage<sup>15</sup> and US EPA's AIRNOW website<sup>16</sup>.

As shown in the Figure PH1, numerous local, regional and national emission control programs have been implemented over the last twenty-five years in Connecticut to produce the improvements in ozone levels described above. Some of the ongoing ozone reduction programs include:

- National motor vehicle emission standards and, more recently, the adoption of the California Low Emission Vehicle II program for new cars and trucks;
- Reformulated gasoline;
- Gasoline vapor controls for bulk storage tanks, tanker trucks, underground storage tanks and dispensing pumps at gas stations;

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<sup>14</sup> 1-800-249-1234

<sup>15</sup> [www.ct.gov/dep](http://www.ct.gov/dep)

<sup>16</sup> [Airnow.gov](http://Airnow.gov)

- Vehicle emission inspection and maintenance;
- National standards for paints, consumer products and automobile refinishing;
- “Reasonably Available Control Technology” at industrial and commercial facilities;
- Requirements for sale of gasoline cans that minimize spillage and vapor emissions;
- Increasingly stringent emission standards for large sources such as power plants and municipal waste combustors; and
- A phase-in of tighter emission standards for engines used in construction equipment, watercraft, locomotives, farm equipment and lawn & garden equipment.
- Additional control measures are being analyzed for possible adoption into the State Implementation Plan for Air Quality over the next several years to continue progress towards achieving current and anticipated ozone NAAQS. The CTDEP continues to work with industry and government stakeholders to identify and implement those cost-effective control programs that are necessary to meet federal air quality standards in a timely manner.

### *Airborne Allergens*

Climate change also will impact air quality and effect public health by increasing airborne allergens. Most plants will respond favorably to increased temperatures and carbon dioxide (up to a certain threshold; Hatfield et al. 2008), resulting in increased pollen production and other allergens aggravating seasonal allergies and asthma. For example, ragweed, a common fall allergen, will increase pollen production significantly as a result of predicted climate change (Ziska and Caulfield 2000). Allergy season also will be lengthened due to the increase in the growing season in Connecticut, prolonging suffering to those who have seasonal allergies (Ziska, Epstein and Rogers 2008). Increased incidences of allergic rhinitis (i.e., hay fever) and asthma will increase medication, hospital and employee sick days, stressing Connecticut’s public health infrastructure and economy (Ziska, Epstein and Rogers 2008).

### *Extreme Heat Events*

Increasing ambient air temperatures caused by climate change will increase the occurrence of extreme heat events. Extreme heat events can cause a heat wave, which is classified as more than three consecutive days over 90 degrees Fahrenheit (F), and often combined with excessive humidity. Extreme heat can be measured by a heat index, which is the temperature that the human body perceives when relative humidity is added to the air temperature. .

Climate change projections for Connecticut indicate that extreme heat event will increase in the next century (Frumhoff et al. 2007; NPCC 2009). Currently, Hartford experiences an average of seventeen summer days over 90° F (recorded at Bradley Airport), and two days a summer over 100° F. Climate change projections for low and high emissions scenarios indicate that 90° F days will increase in around early-century to twenty-three to twenty-six, mid-century to thirty-six to fifty-one and late-century to forty-one to seventy-eight (first number represents the low emissions scenario and the second number represents the high emissions scenario). Days over

100° F will increase to eight (low emissions scenario) to twenty-eight (high emissions scenario) by the end of the century in Hartford. Adding the heat index, extreme heat days could feel 12 to 16 degrees F hotter in Connecticut by late-century (Frumhoff et al. 2007).

### *Heat Related Illness*

Extreme heat can cause heat cramps, heat exhaustion, heat stroke and death. Heat cramps are muscular pains and spasms due to heavy exertion. Although heat cramps are the least severe, they are often the first signal that the body is having difficulty cooling itself. Heat exhaustion occurs when blood flow to the skin increases, causing blood flow to decrease to the vital organs, which results in a form of mild shock. If heat exhaustion is not treated, the victim's condition will worsen; body temperature will keep rising and the victim may suffer heat stroke. Heat stroke is a life-threatening condition that occurs when the victim's temperature control system, which produces sweating to cool the body, stops working. Body temperature can rise so high that brain damage and death may result if the victim is not cooled quickly. Most heat disorders occur because the victim has been overexposed to heat or has over-exercised for his or her age and physical condition. Extreme heat vulnerability can be compounded if a person is overweight or sick.

Conditions that can induce heat-related illnesses include stagnant atmospheric conditions, poor air quality and the "urban heat island effect"<sup>17</sup>, which can produce higher nighttime temperatures. Consequently, people living in urban areas may be at greater risk from the effects of a prolonged heat wave than those living in rural areas. Specific populations that are disproportionately affected by extreme heat, and are typically more sensitive, include people who are elderly, economically disadvantaged, and homeless and those that work or spend significant amounts of their day outdoors.

Although Connecticut Light and Power has determined that eighty percent of homes in their service territory had some form of air conditioning (e.g., central, window, room) in 2005, certain populations, such as the elderly and economically disadvantaged, are less likely to have air conditioning in their residences. The table below displays the projected population of Connecticut's elderly population (65+) compared to the U.S. between 2000 and 2030.

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<sup>17</sup> The "urban heat island effect" is when heat is absorbed by man-made structures, making the area significantly warmer than the surrounding, non-urban areas.

<b>Year</b>	<b>CT 65+ Population.</b>	<b>Projected % Increase</b>	<b>65+ as a % of Total CT Population</b>	<b>US 65+ Population</b>	<b>US 65+ Pop. as a % of Total Population</b>
<b>2000</b>	470,183		13. 8%	34,991,753	12. 4%
<b>2005</b>	479,443	2%	13. 7%	36,695,904	12. 4%
<b>2010</b>	515,621	8%	14. 4%	40,243,713	13%
<b>2015</b>	577,083	12%	15. 9%	46,790,727	14. 5%
<b>2020</b>	642,541	11%	17. 5%	54,631,891	16. 3%
<b>2025</b>	723,326	13%	19. 6%	63,523,732	18. 2%
<b>2030</b>	794,405	10%	21. 5%	71,453,471	19. 7%
<b>Total % Increase 2000-2030</b>		<b>69%</b>			

Source: created from U. S. Census Bureau data on "U. S. Population Projections for Selected Age Groups by State: 2005-2030.

In addition, those that work outdoors also will be at increased risk during extreme heat events. Employees who work outside could account for slightly over five percent<sup>18</sup> or more of the workforces, however, statistics are only kept by industry category and not by job specification, so the number of employees who work outside for all or part of their job could be much higher (Connecticut Department of Labor 2009).

### *Workgroup Intersections*

Among the four workgroups, there is an overlap of issues related to climate change. The Public Health Workgroup examines impacts of climate change that interconnect with the three additional workgroups. The Agriculture Workgroup directly relates to Public Health in discussing food and water sources, which directly affect the health of Connecticut residents. The Infrastructure Workgroup examines the impact climate change has on the States Infrastructure; which links with public health infrastructure as well. The Forward Movement of Patients from hospitals can be limited due to road erosion or flooding. The Natural Resources Workgroup explored a variety of issues including coastlines, rivers, and marine fisheries. Fisheries intersect with the food supply previously discussed by the public health workgroup. Coastline and river flooding can lead to a variety of issues including evacuation and sheltering. Globally, climate change is a major concern. We must work together in order to mitigate the effects climate change will have on Connecticut and the nation.

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# **Appendix F: Public Comments on the Draft Workgroup Reports**

Report 1 Comments			
Date	Workgroup Report or General Comment	Subject	Comment
1/12/2010	Agriculture	Impacts- CC variability	Commenter wanted to emphasize the danger of climate change variability and the planning challenge that it presents. Commenter expressed the benefits of organic farming when it came to mitigation.
1/12/2010	Agriculture	Process- Questions	Did the Agriculture workgroup look at other states when looking at climate change impacts on agriculture? For example, if California can't grow as much food as it used to, maybe Connecticut would have to increase production to satisfy the food needs of the U.S. and the rest of the world.
1/17/2010	Agriculture, Infrastructure and Natural Resources	Process and Impacts- Comments and Changes	Suggested changes and commented on the Agriculture, Infrastructure and Natural Resources reports (see e-mail for specifics).
12/17/2009	General	CC Validity	Commenter hopes that the Subcommittee is going to provide a clear, objective analysis of climate change that doesn't just dwell on the negative aspects. He believes that discussing uncertainty in climate change projections would add validity to the report.
12/17/2009	General	CC Validity	Commenter expressed concern with the validity of the climate change projections and with climate change itself. He believes that people are currently living and thriving in warmer climates, so a Connecticut adaptation process is unnecessary. He also believes that jobs will be lost if climate change legislation is passed. He therefore believes that the Subcommittee should examine all sides of the issue.
1/12/2010	General	CC Validity	Commenter disputed the opinions of some of the other commenters.
12/14/2009	General	CC Validity	Commenter's e-mail references a Hartford Courant article about the possible decline of the Salt Marsh Sparrow due to sea level rise in Connecticut. Commenter questions the possibility of climate change and the projected effects.
12/17/2009	General	CC Validity	As a former meteorologist, commenter doesn't think that climate change will happen. He specifically questioned the validity of the sea level rise data.
1/12/2010	General	CC Validity	As a former meteorologist, commenter doesn't think that climate change will happen. He specifically questioned the validity of the sea level rise data.

12/17/2009	General	CC Validity	Commenter questions the validity of climate change. He believes that climate change may not be the cause of melting glaciers, and that there is no connection between carbon dioxide and global warming.
1/12/2010	General	CC Validity	Commenter questions the validity of climate change. He believes that climate change may not be the cause of melting glaciers, and that there is no connection between carbon dioxide and global warming (verbal comments). "Criticizing the claim of dangerous AGW and commentary on the need for an objective evaluation to inform citizens of Connecticut" (written comment given to the panel on 1/12/10).
1/22/2010	General	CC Validity	Commenter questioned the validity of climate change and offered sources. Offered the e-mail as a follow-up to his testimony at both public information meetings.
1/12/2010	General	CC Validity	Commenter disputed the opinions of some of the other commenters. Commenter hoped that the next phase on adaptation strategies would focus on resiliency and redundancy (e.g., with the electrical grid). He also believes that it would be beneficial to engage the insurance industry.
1/12/2010	General	Impacts- Questions	Is the Subcommittee accounting for population dynamics in equations for climate change projections? What will be the climate change impact on population dynamics?
1/12/2010	General	Impacts- Questions	What will be the impact of climate change on raw water quality?
1/12/2010	General	Misc.- Fuel additive	Commenter expressed an interest in using a fuel additive (additive name not mentioned) to mitigate the climate change effects of diesel fuel in Connecticut. He wanted to let the public know that there will be a bill in the CT legislature this session that seeks to reduce carbon dioxide and fuel consumption in Connecticut.
12/17/2009	General	Misc.- Solar Panels	Praised the state adaptation process and advocated the use of solar panels as a mitigation strategy.

<p>1/14/2010</p>	<p>General</p>	<p>Misc.- Support the work of the GSC</p>	<p>Clean Water Action is an environmental non-profit representing 25,000 Connecticut members. We support the Governor's Steering Committee on Climate Changes work to mitigate global warming pollution as well as to protect state residents from unavoidable impacts of global warming. We strongly support the path taken by the GSC to work with stakeholders to outline climate risks and create strategies to mitigate potential impacts. This draft report is an excellent and comprehensive initial assessment and we applaud the GSC for building from the work of New York City and the Union of Concerned Scientists rather than starting from scratch. We urge the GSC to prioritize action on climate impacts which endanger human health and to prioritize protection for our most vulnerable residents, such as environmental justice communities.</p>
<p>1/14/2010</p>	<p>General</p>	<p>Misc.- Support the work of the GSC</p>	<p>I am impressed by the depth of information and analysis in the Draft Climate Change Impacts Workgroup Reports, and read each of the sections. Although I do not have comments on any of the sections I will be able to use the information in my volunteer work. I am grateful that Connecticut's Department of Environmental Protection had the foresight to analyze the impact of climate change on CT's natural resources and habitats, its infrastructure, agriculture and public health. In addition, I'm a member of the CT Climate Change Education Committee and am grateful that the DEP has designated a staff person to work with educators from various CT organizations who want to bring information about climate change issues into communities.</p>

<p>1/15/2010</p>	<p>General</p>	<p>Misc.- Support the work of the GSC</p>	<p>These are just general comments on why this report is a good idea. Change is coming, that's life. It's wise to hope for the best but prepare for the worst. Connecticut is connected to the rest of the world through the environment and economics. It increasingly looks like we'll have to adapt to climate change while we tip toe towards a more sustainable way of living with this planet. The changes needed in our economy and, more importantly, our way of thinking are not happening fast enough to ward off the environmental changes stemming from climate destabilization. Currently, there are approximately 6.7 billion people on earth. How are we going to have a green and peaceful planet with 8 or 9 billion people when we don't even take care of the people and planet we have now. There are 4 basic scenarios with climate change and I only see a downside to 2 of these: Climate change is real and we do nothing (worst case) Climate change is real and we do everything to change our ways. (better economy, more sustainability, cleaner environment) Climate change is not real and we do nothing (more of what we're getting, which isn't too great) Climate change is not real and we go to a green economy (where's the downside there?)</p>
<p>1/15/2010</p>	<p>General</p>	<p>Misc.- Support the work of the GSC</p>	<p>I applaud the efforts by DEP to address potential climate change impacts in Connecticut. By preparing ahead of time, hopefully our state will be better situated to handle events such as storm surges, flooding, etc. that are predicted to occur in this region due to climate change. If infrastructure and management tactics are left unaddressed, we run the risk of crisis in the future. With sound thought and preparation, as exemplified by this draft, we can avoid potential destruction and loss and the costs associated with them.</p>
<p>1/17/2010</p>	<p>General</p>	<p>Process and Strategies- Draft Reports on Adaptation and Next Steps</p>	<p>Offered suggestions on communication, education and regional planning, budget, strategic planning and next steps in the process (see letter for specifics).</p>
<p>12/17/2009</p>	<p>General</p>	<p>Process- CC Planning Experience</p>	<p>Commenter was a past member of the Land use Planning Committee in Guilford, which undertook climate change planning for the town. He shared his experience and urged the Subcommittee to involve the towns in adaptation planning. He felt that there was a critical need to educate the public and municipal officials.</p>

12/17/2009	General	Process- GA Help	Commenter thought that the presentation was good and that the presenters laid out a positive long-term plan. He offered his help if the Subcommittee need legislation or funding for future efforts and to implement any adaptation strategies.
12/17/2009	General	Process- NYC Projection data	Commenter questions the usage of the NYC climate change projection data, and would like to see Connecticut- specific data used in the adaptation process.
1/12/2010	General	Strategies- Questions	Is there funding for climate change adaptation planning on the local level?
12/15/2010	Infrastructure	Process- Cover Page Graphic	I think the Fairfield graphic is not a good choice as folk, at least from Fairfield, will note that the flood control dikes and gates will prevent the area behind Fairfield Beach from flooding. I would use another low-lying area of CT to illustrate potential future flooding scenarios - Milford, Madison (including Hammo), Old Saybrook (Plum Bank area).
1/12/2010	Infrastructure	Process- Questions	Was temperature taken into account, especially as it relates to the climate change impacts on infrastructure? The reports seem to be heavily weighted towards the climate change effects from changes with precipitation.
1/12/2010	Infrastructure	Strategies- Green Building Standards	Commenter wanted the panel to consider Green Building standards when recommending adaptation strategies. He also wanted to hear more information on how climate change is going to impact buildings (e.g., higher humidity leading to more mold). Commenter wanted to know if the panel examined the indoor air quality of buildings, and the rate of groundwater infiltration of stormwater.
12/17/2009	Natural Resources	Misc.- Natural Resource Availability	Commenter is concerned with the availability of natural resources.
1/22/2010	Public Health	Impacts- Environmental Justice	Commenter suggested some changes to the environmental justice language in the Public Health report. She also provided the latest list of environmental justice communities (see e-mail for specifics).

<p>1/12/2010</p>	<p>Public Health</p>	<p>Strategies- Public Health Recommendations</p>	<p>I didn't see any recommendations in the Public Health Report. How will information be shared with the public at large to deal with the various effects of climate change.(heat, vectors, ticks etc.). How can the public help to prevent some of the problems that may be created by climate change? How will climate change effect people with disabilities? Are there educational programs for schools on climate change? What are the remedies for each of the identified effects of climate change. Will there be massive pesticide spraying if there are mosquitoes. What about the health affects of pesticides on the population? While the report notes the problems it doesn't give suggestions for preventing, coping or dealing with the problems other than including them in the emergency preparedness plan.</p>
<p>1/13/2010</p>	<p>Public Health and Natural Resources</p>	<p>Strategies- Recommendations</p>	<p>Many people are converting to natural gas heating. The cheapest and most efficient installation is a direct exhaust pipe three feet above ground level. They are really a problem for people with asthma. No HVAC contractor wants to bother sending the exhaust up the chimney, but it greatly improves air quality at ground level. Would the public health panel consider discussing this problem? Also, in Hamden and New Haven where we are losing our grand oak trees, some from old age, but many from rampant fungus invasions, we must plant now for 2090 and perhaps longer. Will one of these panels make some projections about the appropriate large trees for a warmer climate and a different moisture pattern?</p>