

# CLIMATE CONSIDERATIONS

*for* **MANAGEMENT of NATURAL  
AREAS and GREEN SPACES** *in the  
CITY of CHICAGO*



# ADVANCING ADAPTATION IN THE CITY OF CHICAGO: CLIMATE CONSIDERATIONS FOR MANAGEMENT OF NATURAL AREAS

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Suggested citation: Derby Lewis, A., Hall, K.R. and Hellmann, J.J. 2012. Advancing Adaptation in the City of Chicago: Climate Considerations for Management of Natural Areas.

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**We would like to thank The City of Chicago for financial support, and Aaron Durnbaugh for his leadership and continued support throughout the project.**

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## I. INTRODUCTION

Managing natural resources in an effective and cost-efficient way requires responding to changes that are occurring in the climate system. Because rapid changes in climate threaten many of our ecological resources, incorporating ways to both reduce the rate of changes (mitigation), and respond to them in ways that allow us to protect what we value (adaptation) are important components of pro-active planning. This guide focuses on adaptation, with the aim of helping resource managers in the Chicago Wilderness region jump-start the process of updating approaches to management to better incorporate, and reduce the rate of, climate change. Specifically, the goal is to help resource managers identify options that can reduce the exposure of key species or systems to change, reduce their sensitivity to change, or increase their ability to adapt to change. To move forward on adaptation, the first step is to understand what aspects of climate are changing. Many impacts of climate change are already being felt in Chicago, and are expected to increase both in magnitude and frequency in the coming decades (See Box 1).

Box 1: Past Climate Changes and Projected Future Trends in the Chicago Wilderness Climate System (since the mid-20th century).

Recent Changes in Climate	Changes Expected by Middle to End of this Century*
<ul style="list-style-type: none"> <li>• Annual average temperature increase of more than 2°F since 1945;</li> <li>• Increase in temperature was greater during the winter than other seasons, increasing 4°F since 1980;</li> <li>• Much of the warming is concentrated during the cool season and at night;</li> <li>• Fewer cold waves, and a number of major heat waves in the last few decades;</li> <li>• Lengthening growing seasons (indicated by a progressive advance in the last date of spring freeze), current dates are approximately 1 week earlier compared to the beginning of the century;</li> <li>• Lake Michigan ice forming later, lasting for shorter periods, with some years having almost no lake ice;</li> <li>• A doubling in the frequencies of heavy rain events (defined as occurring on average once per year during the past century) since the early 1900's;</li> <li>• Increases in fall precipitation resulting in increased annual mean and low flow of streams, without any changes in high annual flow;</li> <li>• Increasing lake-effect snow during the twentieth century which may be a result of warmer Great Lakes surface waters and decreased ice cover; and</li> <li>• Warmer and wetter growing season.</li> </ul>	<ul style="list-style-type: none"> <li>• Temperature increases—Chicago could expect an annual average temperature increase ranging from 3–4°F under lower emissions to 7–8°F under higher emissions; greatest increases likely to occur during summer and winter seasons;</li> <li>• Hotter summers—number of extremely hot days (over 100°F) could increase from the current 2 days per year to 8 days per year under lower emissions, or as many as 31 days per year under higher emissions;</li> <li>• More heat waves—using the catastrophic 1995 heat wave as a baseline; under higher emissions there could be several heat waves like 1995 each year and one every other year with lower emissions;</li> <li>• More humidity—warmer air holds more water; increased evaporation of surface water would result in increased humidity;</li> <li>• Longer growing season—last spring frost would occur from 20 days earlier under lower emissions to about 30 days earlier under higher emissions;</li> <li>• Less frost—fewer frost days each year and frost depth in the soil will decrease;</li> <li>• Fewer extremely cold days and cold spells—the average coldest day of the year could warm by 4–6°F through this century;</li> <li>• Large seasonal shifts in precipitation—most precipitation occurring in winter and spring, and increased chances of drought in the summer;</li> <li>• More heavy precipitation events—defined as greater than 2.5 inches, the threshold for combined sewer overflow into Lake Michigan. Slightly greater increases are expected for regions closer to the Great Lakes; and</li> <li>• More lake effect snow—increasing winter precipitation (20–30% by the end of the century) combined with less ice cover could, on days when it is cold enough, lead to more lake effect snow.</li> </ul> <p>* The range of values/changes represents different scenarios for greenhouse gas emissions during the 21st century.</p>

Data sources: City of Chicago (2008); Union of Concerned Scientists (2009); Technical Input to the 2013 National Climate Assessment (2012).

Today's decisions on land use and energy production will affect the magnitude and rate of future climate impacts. Regardless of these decisions, however, some continued change will inevitably occur. This "climate commitment" is due to the 100+ years residency time that carbon dioxide (CO<sub>2</sub>) has in the atmosphere, and the thermal inertia of the world's oceans (read more about [climate commitment here](#)). In other words, there are enough greenhouse gases already in the pipeline to keep the planet warming beyond current conditions, and actions taken now to reduce atmospheric concentrations have a significant lag time. As such, adaptation actions are vital if we want to sustain natural areas and green spaces over the long term. Climate impacts are likely to have direct effects on species and systems (e.g., increases in drought stress, changes in survival that influence species composition) and indirect effects that compound current threats and stresses species and systems already face (e.g., invasive species, habitat loss, fragmentation, pollution). This increase in stress suggests we need to be more strategic in how we spend our financial and personnel resources, and work more efficiently and collaboratively across ownership and jurisdictional boundaries. The success of all our past and new investments depends on our ability to recognize and adapt to changing circumstances.

Adaptation strategies, or actions that help green spaces cope with and respond to a changing environment, can be integrated into management practices in a variety of ways. This includes choices about what on the ground actions (i.e., invasives removal, work to restore hydrology) need to be prioritized, or how a site can be prepared so that it maximizes a desirable outcome in the future. Many projects in the City of Chicago and elsewhere are already "mainstreaming" adaptation into their design decisions (see Appendix 1), and we can build from these examples. With the ultimate goal of helping City landscape projects become more cost-effective and sustainable in the long-term, this guide offers a framework for how to think through asking the "climate question" of projects in order to create low-resource intensity landscapes that can be resilient to a broad spectrum of environmental conditions, and can continue to provide key services to people, while also making the best use of limited resources.

This guide serves as a first step toward protecting species and ecological services over the long-term by identifying "climate sensitive" decisions. Policy makers and landscape managers need to incorporate the best available scientific information regarding what anticipated environmental shifts are likely to play into the decision-making process. This framework enables managers to develop adaptation strategies that help to ensure natural systems can remain viable as changes continue at an ever-increasing rate, while maintaining systems that will work under current conditions. This climate considerations guide provides a list of probing questions, and resources to help managers find answers to those questions.

In some cases, we may need to start making changes right away in our actions, and in other cases, we are likely to be thinking ahead and laying the groundwork for future changes. The goal is to help facilitate climate-ready decision making by individuals working on natural area and green space projects in an urban setting by connecting managers with information, and hopefully also with each other.

To this end, two important issues should be acknowledged. First, projections for how the climate will change can only be described and understood in general trends, but we know that variability will occur and it will be hard to predict maintenance costs, or the specific costs and benefits of planning ahead for climate change. Where it is possible to do so, it is therefore ideal to design management strategies that can be flexible and responsive to climate-related "surprises"

in systems, or key threats. This touches on the second issue, which is that flexibility- or other adaptation principles- may not always be possible because of the constraints and limitations (e.g., long-term fixed budgets, contracts that are very detailed in scope with little room for alternatives) that resource managers are faced with when planning and implementing projects. Nevertheless, it is important to have a clear understanding of what types of actions are ideally needed to maximize the chances that projects are successful and cost effective in order to begin to move toward policies that enable and even encourage them as part of best management practices. In many cases, the odds of making good decisions is likely to improve if we strengthen our ability to assess risks, and communicate trade-offs (i.e., in ecological services, species viability, recreational values) associated with different decisions. However, these kinds of changes often require broad, organizational change. For this transition to occur, it is necessary to engage policy makers in the discussions about how and why climate considerations need to be integrated into project planning, implementation and management of Chicago's natural areas and green spaces.

## II. A CHANGING CLIMATE

It is important to bear in mind that this region will experience changes in both precipitation and temperature, which together can result in a complex suite of projected changes. First, more of the region's precipitation is likely to come down in fewer but more extreme rain events, which will increase the incidence of flooding and stormwater runoff. This could, in turn, cause a greater percentage of water to leave the region, and reduce the amount available to recharge groundwater stores. Secondly, temperatures will continue to increase, leading to higher rates of evapotranspiration. So, while we expect more flooding, we also expect to have drier summer/fall periods, with increased drought stress. [For a detailed summary of climate change impacts in the Great Lakes that is relevant to the Chicago region click here (<http://goo.gl/J6NZI>); see also Table 1 in this document for projected changes for Chicago in means and extremes in temperature and precipitation].

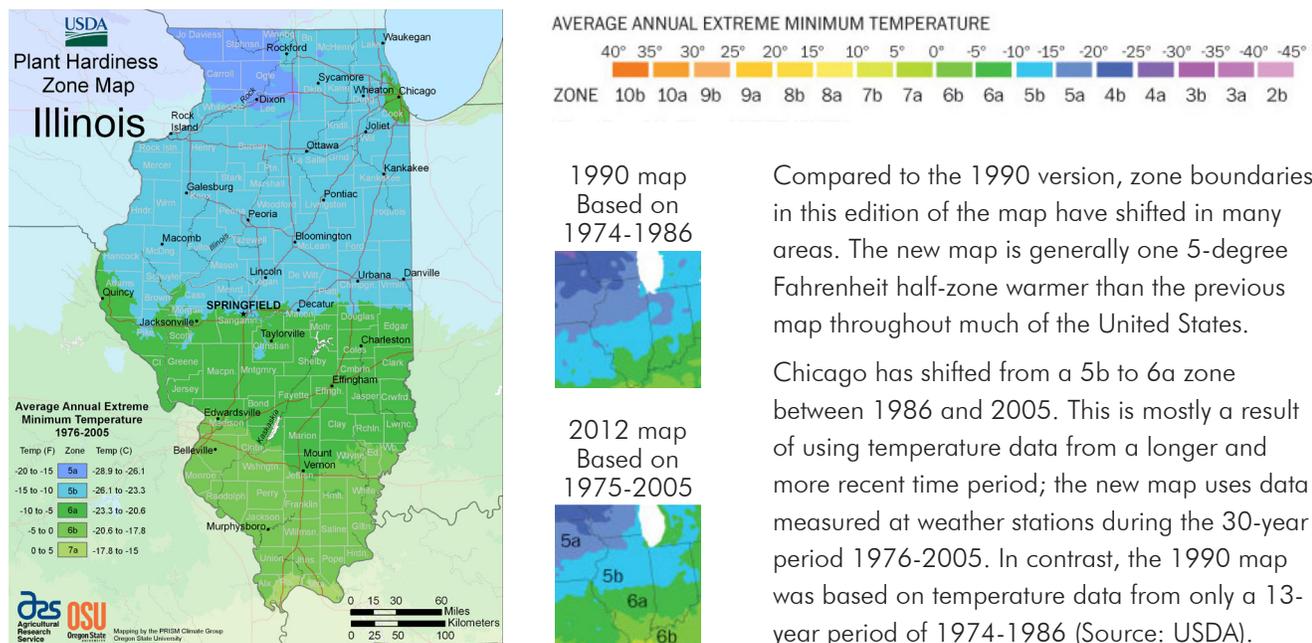
One of the most challenging aspects of climate change is that projected changes are not expected to be linear (i.e., one summer will not necessarily be warmer or wetter than the next). This is because changes induced by human actions (i.e., release of greenhouse gases) feed into a system that has high natural variability at global, regional, and local scales. For example, phenomenon such as the El Niño-Southern Oscillation (ENSO), an interaction between the ocean and the atmosphere over the tropical Pacific Ocean, contribute to variation at a global scale and changes in the jet stream that occur in response to changes in ice cover in the Arctic Ocean can influence winter severity in North America. However, the influence of climate change has been likened to "loading the dice" for more extreme weather events (read more here (<http://goo.gl/02hH8>)). Many lines of evidence – statistical analysis of observed data, climate modeling and physical reasoning – strongly indicate that some types of extreme event, most notably heat waves and precipitation extremes, will greatly increase in a warming world and have already done so (IPCC, 2007; Coumou and Rahmstorf, 2012).

Climate impacts are already evident on the Midwest landscape. Fall migration, for example, is very responsive to weather and snow cover for some species. Sandhill cranes, which typically leave the Chicago region in late Fall, are staying much later into the winter and now regularly remain into late December and early January, as evidenced by hundreds of cranes observed still migrating south through the Chicago area as late as mid-January 2012 (D. Stotz, pers. comm.). Species at different trophic levels responding differently, and at various rates, to changes in temperature have

also been recently reported in the Chicago region. For example, in mid-March 2010 the region experienced a temperature warm-up causing trees such as white oaks to leaf out and many insects to emerge about 2.5 weeks earlier than usual. While these species respond directly to temperature cues, insectivorous migratory birds such as warblers do not. Instead, migratory birds rely on changes in photoperiods, or daylight length, as a cue to begin migration. The result is called a “phenophase mismatch” or the de-coupling of phenological events that have evolved together through time. In this case, the warblers arrived to the region when they usually do, but the lag-time between their arrival and the earlier leaf and insect emergence meant that food availability was reduced during a critical period for the birds (D. Stotz, pers. comm. (<http://goo.gl/NvQo7j>)). It is possible that if this type of timing mismatch continued it could have extreme negative effects on warbler populations. Further, if migratory bird predation on insects is crucial in controlling pest abundance, this timing mismatch could result in increased insect herbivory on trees as they leaf out, potentially reducing the fitness of the trees as well.

Additionally, the Midwest’s plant hardiness zones have shifted and could continue to shift ½ to 1 zone every 30 years, (see Figure 1). Under a high emissions scenario, Chicago is expected to shift to zone 7a by the end of the century (Hellmann 2010). Based on the 1990 map as well as local knowledge (i.e., a moderating effect from the lake compared to Midway or O’Hare temperatures) many managers generally considered the City to be in Zones 5b and 6a (lakefront wards). Using this knowledge along with the updated USDA 2012 map (<http://goo.gl/r4XXW>), Chicago would now be considered a 6a and 6b zone along the lakefront. However, the USDA plant hardiness zone map only looks at the average winter cold temperature, and in terms of addressing adaptation it is important to also consider the American Horticultural Society Heat Zone Map (<http://goo.gl/8rYZP>), which is the number days >86 degrees F, when determining the suitability of a tree or other plants for Chicago. Moreover, site conditions such as soil volume and tree space become critical variables to adapt to anticipated warm, drier summers (drought conditions) and heavier storm events (potential flooding conditions).

Figure 1: Shifting Plant Hardiness Zones



A detailed report on the impacts of climate change to biodiversity in the Chicago region- Climate Change Update to the Chicago Wilderness Biodiversity Recovery Plan- was completed in April 2012 and provides an in-depth review on climate impacts to plants and animals. The Update represents two and a half years of collaborative work and input from more than 100 experts on the expected climate impacts on the region's plants and wildlife. It focuses on habitat-specific adaptation strategies, and highlights research questions that will help inform climate-smart management. The Update is a web-based resource and a living document that will be constantly updated as new knowledge emerges. The resource can be found at [climate.chicagowilderness.org](http://climate.chicagowilderness.org) (<http://goo.gl/8deaM>).

### III. HOW TO ASK THE “CLIMATE QUESTION” OF URBAN NATURAL AREAS AND GREEN SPACE PROJECTS

One of the biggest challenges in designing and updating work in ways that allow us to reach our project goals as climatic conditions change lies in the fact that asking the climate question really means integrating information on climate with site-specific knowledge, conditions, and constraints on management. Once we have a picture of how things we care about are likely to be influenced by changes in climate, we can start to see where we can reduce risks, and evaluate how potential changes fit in with our other management priorities. So, while there is no “one size fits all” answer to this question, or even one set of questions that are appropriate for all situations, it is often helpful to follow a consistent, systematic process. Further, having a shared process, and shared tools, can help us work together by clarifying ideas on impacts and assumptions that underlie any proposed changes in goals or plans for action, especially plans that are most effectively pursued through multi-agency or multi-landowner partnerships. While many different frameworks are available to help organize work toward adaptation, we present a slightly modified version of The Nature Conservancy's (TNC) approach here (this is described in more detail and with examples in TNC 2009, and Poiani et al. 2010, see Appendix 2). This approach was developed to help TNC's project managers update their existing projects and conservation strategies. For efforts where you are engaging in new partnerships and new projects that include addressing climate change, you may find a broader outline of steps to be helpful. Several organizations have developed “start to finish” adaptation processes, and we include one outlined by the GeosInstitute as an example in Appendix 2.

**STEP 1: Understand the potential ecological impacts of climate change.** This step involves evaluating what climate changes are projected, and linking them to potential sensitivities in the ecological systems, species, or even management actions (e.g., effectiveness of some action, such as prescribed burning or pesticide application) that you care about. Key components of this step include identifying a workable time frame (e.g., 20 years), identifying useful sources of climate data and their uncertainties, and working with colleagues and researchers to identify likely impacts.

A

HOW TO ASK THE  
CLIMATE QUESTION

**STEP 2. Formulate specific “hypotheses of change.”** Essentially, in this step you summarize the important ways in which climate change might impact your natural area or green space project. Although there are likely to be many different mechanisms operating in these systems, generating lists of possible changes, and perhaps linking them all in a conceptual model (see Figures 1 and 2 below for examples of diagrams and hypotheses of change), can help a group focus on specific changes, prioritize those changes, and work toward defining specific management responses. Ideally, each of these statements would also be associated with some descriptor of how likely the impact is (very likely, moderately likely, low likelihood), and when combined with the importance of the impact and its reversibility, helps prioritize actions. Developing these hypotheses would be most helpful in a facilitated situation with managers from different projects, cities, etc. in order to gain valuable insight from shared experiences. Examples of hypotheses of change for the Chicago area include the following:

- Increased intensity of peak storm events will increase flooding, which will potentially bring more road salt and other pollutants into natural areas (highly likely).
- Frequent lower level flooding during winter/ early spring events could deposit salt over an extended period, causing damage to natural areas (highly likely).
- Increases in summer temperatures will increase rates of evapotranspiration, leading to increased drought stress for vegetation in both natural and urban settings (street trees) (highly likely).
- Increases in winter minimum temperatures will promote new invasive species that will act as tree pests, and may allow current pests to increase their populations (moderately likely).

Figure 1.

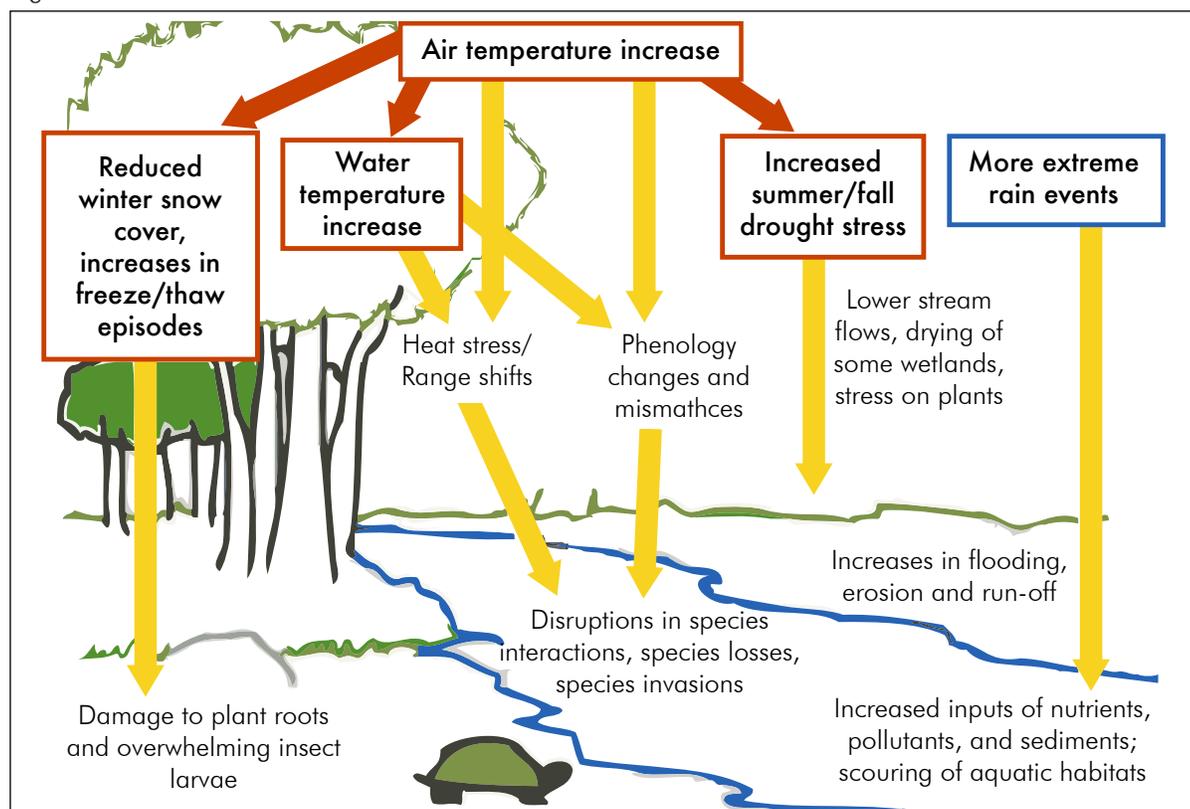
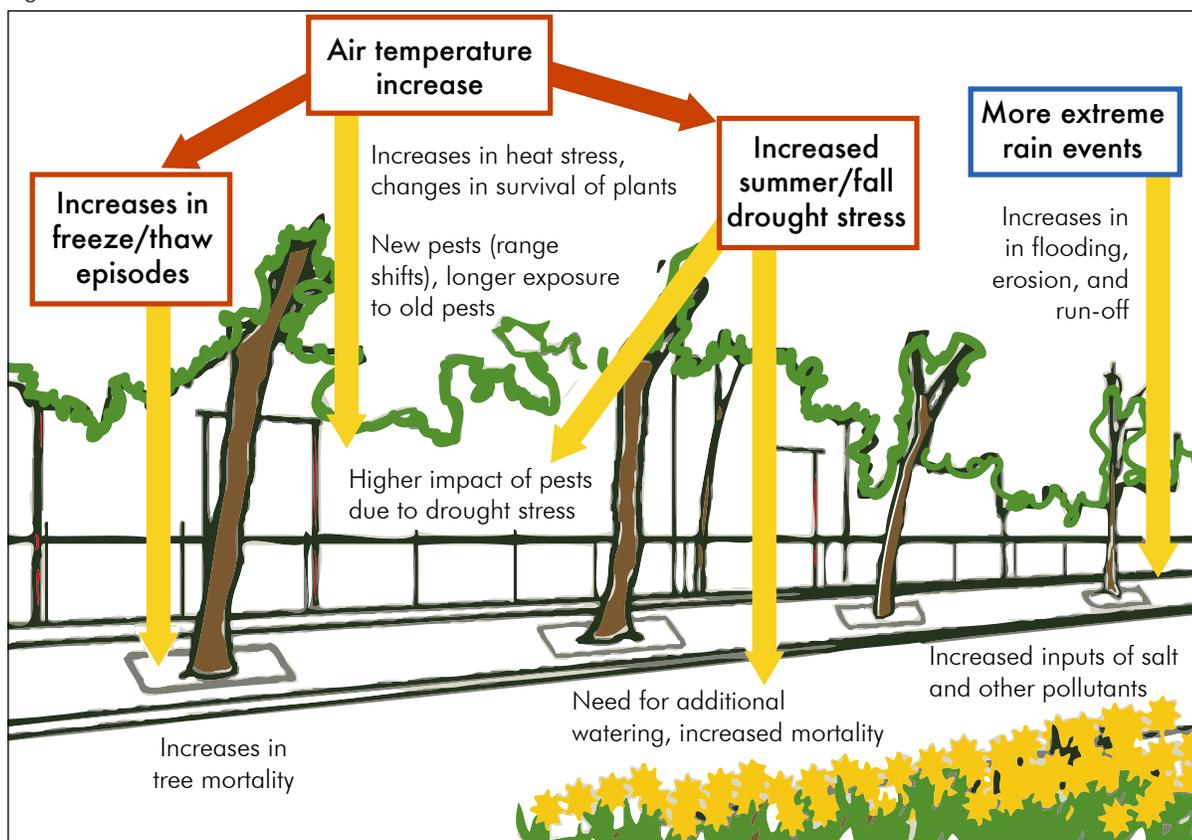


Figure 2.



Conceptual models of how climate drivers may influence the ecology and viability of a natural area (Figure 1) and urban trees and planted areas (Figure 2). Information along or at the end of an arrow represents a “hypothesis of change” for these systems.

**STEP 3. Explore potential bureaucratic and/or societal responses to climate change.** As many of the stressors on the Chicago region’s ecological systems that we already address through management can be traced back to some form of human impact, part of being “climate smart” involves thinking about responses of people to climate change. Some actions to protect people from impacts (e.g., flooding) could cause more problems for natural areas if poorly implemented, which would fall under the category of “maladaptation” in our list of principles (see Appendix I). By thinking about societal responses early and often, we can hopefully identify and communicate ways that natural areas help promote adaptation for people, and anticipate and help avoid actions taken to protect people that could damage natural systems or impede ecological processes. A key component of this step involves communicating with agencies that do not directly manage green spaces and natural areas and discussing climate change responses, especially as many “gray infrastructure” type responses have long planning periods, and are very costly to retrofit. Further, so much of what we do requires input from external partners - lawyers, contract personnel, aldermen, commissioners etc. In order for projects to be successful, it’s important to engage external partners from the onset in why adaptation is important and necessary.



**STEP 4. Determine which climate impacts are critical, and can be addressed.** Using the hypotheses of change described above, have conversations that allow you to integrate the risks posed by climate change with existing management priorities, and focus in on ones that can be addressed through some change in management.

**STEP 5. Evaluate if potential climate change impacts are likely to fundamentally change the project, or preclude project success.** This is often a hard question to ask, but in some cases we may need to rethink our investments in some highly sensitive species or systems, or consider how we could promote transformation to more viable systems.

**STEP 6. Develop adaptation strategies and evaluate their feasibility and cost.**

Adaptation strategies can range from minor “tweaks” in practices (e.g., changing the frequency of some action, like mowing), to more costly changes (varying mowing frequency in response to weather conditions), or new practices (changing species planted to different species that don’t require mowing). Most of the remaining document addresses things to consider as you update practices. Further, this step reminds us to assess the costs and benefits of changes in management, a process that should link back to the hypotheses of change that we defined above. A key checkpoint to consider is, do the actions you have identified as “adaptation” directly address a priority impact? The most successful adaptation actions will clearly show this logical flow, and through our ability to explain the rationale behind our choices, will help build public support for actions that may be more costly than “business as usual.” On the contrary, calling any action that possibly increases connectivity, or reduces the impact of some stressor (like invasives) a climate adaptation strategy has potential to weaken support and understanding. These activities are still vital, and often do promote adaptation, but we should be prepared to describe how, and for what species or system, future viability is likely to be enhanced.

**STEP 7. Develop measures of success, implement, adapt and learn.** To be successful as the climate changes, it is more important than ever to have clear ways of defining and measuring the success of our actions (which very often success is measured primarily in dollars saved). Although full coverage of monitoring and sharing solutions/failures/experiences/data among resource managers is beyond the scope of this document, these activities represent an essential follow-up to “asking the climate question.”

## I. GETTING STARTED.

### a. BASELINE INFORMATION ON SITES

Consider what baseline information underlies project design and management. One of the challenges to addressing climate change is that we tend to overlook the climate-natural system connections, as in our experience these relationships often have remained fairly constant. Once we make these connections more explicit, it is easier to see how a change in climate might influence the success of our decisions. So, we suggest that gathering answers to the questions below provides the foundation for thinking about how actions may need to change. For example, the length of the frost-free season has increased by over a week in this region, mainly due to earlier dates for the last spring frost (but there has been a trend toward later dates for first fall frost recently as well), which has lengthened the growing season (USGCRP, 2009). A trend toward earlier springs suggest we can start shifting planting dates earlier, but that we need to budget for additional days or weeks of mowing or other maintenance, and plan for later dates of dealing with fall leaves. As you think through relationships between management decisions and climate factors, it is important to consider indirect effects – for example, one challenge associated with warming trends is that rises in soil temperatures during the cold season are likely to increase the risk of pest infestation by reducing overwinter mortality of pests (Sinha et al., 2010). These changes could influence various management and budget decisions, such as how much to budget for tree maintenance if there is an increase in the intensity and duration of exposure to pests.

#### Questions to consider:

- How does weather currently affect this site? Is drought stress typically a problem in the summer and fall? In areas with naturalized vegetation that have high levels of dried fuel, will more frequent droughts lead to more intense brush fires and are there strategies and resources to help manage this? Does seasonal flooding influence what species are found at the site, or what the site can be used for?
- What are the critical thresholds associated with this site– such as the maximum rainfall capacity of a storm-sewer system, the flood retention ability of a parkway, the temperature and moisture tolerance of plants used in seed mixes? How might these aspects be affected by more extreme storm events, warmer average winter and maximum summer temperatures etc.? See steps outlined in the adaptation framework, above.
- How healthy is the natural area/green space? If the system is stressed or intensively managed, what are the biggest challenges, and how are they addressed? Consider factors like invasive species, pests/disease, reduced hydrologic function, and effects of fragmentation.
- Where do your seed mixes, seedlings, or trees come from? What factors are considered when selecting the source of plant materials? How well are these choices performing now under heat waves, droughts, or spring floods?



## TOOLS/RESOURCES

1. Chicago Region Restoration Seed Source Policies- A review
2. Biodiversity Recovery Plan climate change update, Plants Section 3, Prescribed Fire (<http://goo.gl/Y6B4U>)
3. Wisconsin Initiative on Climate Change Impacts- plants and natural communities (<http://goo.gl/pmdaf>)

## b. BASELINE INFORMATION ON POSSIBLE RESPONSES TO PROMOTE ADAPTATION

Consider the short- and long-term costs and benefits of various techniques and technologies that could be incorporated into site design or actions that are likely to promote adaptation in some way. These responses are actions that reduce exposure of key resources to current and projected changes, reduce the sensitivity of a system or resource to the change, or enhance that system's ability to handle the change without loss of viability.

### Questions to consider:

- What are the key activities that are performed on a regular basis to manage this site? Will any of these activities be affected by drought, extreme precipitation events, emergence of novel pests or invasive species, or an extended growing season? Which of those activities could be needed in greater amount or frequency under climate change? Which of those activities might be needed in lesser amount or frequency under climate change?
- What are the initial costs associated with the response? If you are considering installing new infrastructure or modifying site conditions (e.g., green roofs and rainwater harvesting and storage systems to help hold storm water and reduce flooding, hydraulic restoration to restore a more natural flow regime, increasing the soil volume in tree planters to help make street trees better able to withstand harsher summer conditions), how much does it cost, and how much benefit is likely to be accrued?
- What are the co-benefits of such changes, and is there a way to quantify any (e.g., in terms of reduced maintenance or replacement costs etc.)? And what is the net outcome for a short- (1 fiscal year) vs. long- (10-20 years) term outlook?
- If you are considering changing the supplier of your plants/trees to include species or seed mixes that seem more likely to thrive in Chicago's warming climate, are there changes in costs to consider?
- How much do various maintenance activities cost now, and is the need for these activities likely to increase or decrease as a result of changes in length of the growing season (more mowing?), length, variability, and severity of the winter season (do we need to update our thinking on road maintenance resources and costs?), and likelihood of interventions needed (pests, replacing plant materials that are lost due to drought or flood).



## TOOLS/RESOURCES

4. Benefit Calculations Table for the Chicago Eco-structure Incentive Program (Center for Neighborhood Technology)
5. Benefits guide (<http://goo.gl/LdvFx>) for the following strategies: sustainable drainage systems; green roofs; structures and products to improve flood resilience; cool roofs, building and pavement material; rainwater harvesting and storage systems; graywater recycling.
6. UFORE/i-Tree Eco Analysis of Chicago's Urban Forest  
<http://www.nrs.fs.fed.us/urban/monitoring/eco-analysis-chicago/>

### c. SOCIETAL VALUES

An issue of increasing relevance to natural area management is the identification of social value and the incorporation of such values into management strategies. These values may include the social attachment of people to landscapes, landscape elements and associated cultural practice. There is a need to expand the practice of documenting, researching and auditing the nature, range and conservation status of cultural heritage to achieve a similar level of knowledge and status of natural heritage. Further, there is a need to acknowledge that sound and equitable conservation outcomes rely not only on educating the public but also in learning from them, particularly in relation to cultural heritage values and the nature of attachment to landscape (McIntyre-Tamwoy, 2004).

Considering what properties and ecological services are seen by communities as the most important to maintain on this site, and whether the current management may have to change in any way in light of climate change is a critical framework to develop in order to evaluate many of the questions and decisions outlined in this Checklist. Ecological services include all of the economic and non-economic benefits of living ecosystems. These may include processes such as flood control and air purification, utilitarian purposes such as shade, shrubbery screening, and increases in property value, and commodities such as fish and berries. The benefits can also include aesthetic values that people make use of in recreation and spiritual purposes, flora and fauna viewing, or simply value for its own existence. In many cost-benefit calculations, ecological services are not considered, but they can be one of the primary reasons why the public endorses or values a particular property or site. They also can change considerably under climate change, as in the case of fish species declining or species composition changes that affect aesthetic value.

Climate change could also pose threats to public safety. For example, climate change could affect the risk of fire, or the risk that people visiting an area are exposed to vector-borne (i.e., mosquitoes, ticks) diseases. Although these risks will be highly dependent on site and regulation, the first step is identifying them and then asking whether they could be affected in any way with a changing climate. In areas with naturalized vegetation (e.g., areas with high levels of dried fuel) it might be advisable to consider implementing a fire weather program to notify users of fire risk during drought.

In the face of climate change, it may be possible to preserve the historic state, and thus societal values, of a site. In other cases, an alternate state might be promoted that retains, or even enhances, these values. The following questions are designed to help managers determine if there are economic or non-economic values on a site of interest and if those particular values--at least the form that they currently take--could be altered by climate change.



**Questions to consider:**

- Is the site used for wildlife viewing or recreational fishing? Is there any evidence suggesting that the wildlife or fish on this site could be directly or indirectly affected by climate change? How would a change in wildlife abundance affect use of the site by the public (e.g., number of visitors per year)?
- Are aesthetic values a primary driver of management decisions for this site? If so, which features of the site (e.g. scenic views or particular floral or faunal species) contribute most to this value, and is there any evidence suggesting that these features could increase or decrease under climate change?
- Are there homes in the surrounding area that could affect, or be affected by, changes in water flow and control?
- Are there public safety issues or other regulations that need to be met at the site of interest that could be influenced by changes in climate?

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**TOOLS/RESOURCES**

7. The Chicago Community Climate Action Toolkit <http://climatechicago.fieldmuseum.org/>
  - A. Understanding people’s attachments to landscapes, and their willingness to change behavior or take new action to maintain the individual and societal values of the landscape or specific species:
    - Climate Change Guide to The Field Museum’s Restoring Earth Exhibition
    - The Amazing Adventures of Chicago’s Climate Change Heroes
    - <http://climatechicago.fieldmuseum.org/learn>
  - B. Engaging Communities in natural area stewardship by linking it to other concerns: <http://climatechicago.fieldmuseum.org/models>
  - C. Specific approaches to engaging communities in climate action; the model here is potentially adaptable to engagement around specific natural areas, including eliciting an understanding of the values connected to the landscape: <http://climatechicago.fieldmuseum.org/doyourown>



## II. SAFEGUARDING SPECIES AND SYSTEMS

### a. CONNECTIVITY AND LANDSCAPE CONTEXT

Responses by species to climate change can be simplified into three types: they will either move to more suitable habitat, adapt to the changes that are occurring, or become increasingly rare and perhaps disappear from the region altogether. Given the rate of climate change, the expectation is adaptation is not likely to occur fast enough for many species. As a result, the ability of species to shift their ranges may be critical to their long-term viability. However, landscapes have dramatically changed over the last century, particularly in urban regions like Chicago. As a result of increasing population growth and land use changes, natural communities such as prairies, woodlands, and wetlands, that were historically mingled together as parts of an interconnected ecosystem, have been severed from one another and currently exist only in small isolated patches (e.g., less than one-hundredth of one percent of Illinois' original Tallgrass prairie still exists [Robertson, 2008]), and the state of Illinois has lost more than 85% of its wetlands relative to early maps from the 1780s (Mitsch and Gosselink, 2007). Small-scale community examples are still intermingled, but often with impaired function. The resulting fragmentation of both natural areas and green spaces, and overall habitat loss, has hindered nature's ability to respond to climatic changes. In particular, these landscape alterations have reduced dispersal ability and, in some cases, the genetic variability needed to adapt and be resilient to current and future changes. Losses of wetlands and riparian areas have also changed the hydrology of our systems by drastically reducing the water absorbing capacity of the landscape. These losses make both people and natural systems more vulnerable to the effects of extreme storms, and highlight the connections we can make between protecting natural features and protecting people.

A critical component to helping species move and/or adapt in response to climate change is to create connectivity between green spaces throughout a geographic region. The location of the City of Chicago- next to Lake Michigan and at the convergence of two major ecoregions (the Eastern Tallgrass Prairie and Big Rivers and the Upper Midwest and Great Lakes (<http://goo.gl/ha03e>)- and the fact that much of the surrounding landscape has been transformed into a built environment makes efforts to enable species movement through the City especially important from a regional ecological context. As such, ways to help improve landscape connectivity between green spaces should be prioritized during project and management planning.

#### Questions to consider:

- How does my project fit into the larger regional ecological scale (GIV 2.0, map 16: urban site scale) and what are the specific goals for biodiversity and functionality?
- Does the location of my site relative to other sites suggest that my decisions can influence the likelihood that larger-scale ecological processes could be supported? For example, can this site serve as a movement corridor, or help protect neighboring sites or people and property from flooding?
- Based on GIV 2.0, has my site location been identified as an important connectivity area to allow for species movement? Is it possible to manage the site(s) to increase connectivity with neighboring habitat, especially along a temperature or precipitation gradient to facilitate species' movements (e.g. south-to north or along water corridors).



- Is there an alternate location where I could pursue my project that is close to existing habitat that could augment those existing habitats and increase the potential for population mixing and gene flow?
- Are there any gaps in the connectivity of habitat for key species of interest that parts of this site could help fill via restoration or habitat creation?
- Is my site likely to be important with respect to how stormwater moves/is managed during major storm events? If my site is at headwaters, how can infiltration be improved to discourage runoff?
- Is it likely that the actions of other managers will influence the success of activities on my site, or that my decisions will influence neighboring sites?
- Are there barriers to movement (i.e., fences, dams or perched culverts) that could be removed without negative consequences?

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## TOOLS/RESOURCES

8. GIV 2.0/2.1 (<http://goo.gl/Bd4Yi>)

### b. NATURAL RESOURCES

Climate change is expected to affect a multitude of variables that will impact plant and natural communities, including phenological, biotic and abiotic, prescribed fire, and weather impacts and extreme events. Aquatic areas will be particularly sensitive to changes in climate change. Potential impacts include:

- Increases in air temperatures leading to an increase in water temperatures, and warmer water holds less dissolved oxygen;
- Longer “warmer” seasons (or shorter, milder winters) leading to a longer growing season for aquatic vegetation, which could have an eutrophic effect on smaller lakes due to increased volume of aquatic vegetation; or, could lead to a need for increased herbiciding of the lakes, which could have negative side effects;
- Increase in drought periods leading to lower water levels which will be very detrimental to lake volume, carrying capacity, shoreline health, etc. particularly in smaller water bodies; and
- A longer growing period for the fish, leading to larger fish sizes.

This set of questions asks you to consider the site resources with respect to how they could be affected by warmer, drier and more extreme weather. For details on climate change impacts to plant and natural communities see the Chicago Wilderness Biodiversity Recovery Plan climate change update, Plants page (<http://goo.gl/d8eDk>), Aquatic communities (<http://goo.gl/Df2QP>), and Terrestrial communities (<http://goo.gl/UN3oD>) sections.



B

SAFEGUARDING SPECIES  
AND SYSTEMS

**Questions to consider:**

- Are there particular ecosystems, habitats, or species that the site is known for, and for which managers have specific objectives to maintain? To what extent are these systems or species likely to decline in abundance, or require more maintenance, as a result of climate change?
- Are key species in the habitat likely to be sensitive to extreme heat or drought events?
- What plants provide cover, habitat, nesting sites, pollen sources etc. for birds, vertebrates and insects in the habitat presently? Could the abundance and/or structure be increased to provide more of these benefits, particularly thermal refuges for animals and more shading for sensitive plants?
- Are there important species interactions supported by the site that might be sensitive to changes in phenology (i.e., changes in timing of annual events such as migration, timing of leaf out or flowering etc.)?
- Are there aquatic resources that may be sensitive to increasing water temperatures (through solar heating, or through exposure to hot stormwater)? Are there ways to increase shading of streams, or protect flows into streams during potential low flow times in the summer, that will help protect aquatic species from increases in water temperature and low-flow volume?
- Is the site adjacent to, or does it include, a wetland, pond, or small lake that may be susceptible to reduced water levels as summer/fall drought stress increases?
- Is the current vegetation on the site likely to persist as temperatures increase and precipitation patterns shift? Is there typically evidence of drought stress during the summer, and/or impacts of flooding in the spring?
- Is the site adjacent to, or does it include, a stream or river that may become flashier (higher flooding risk, lower flow in summer) as a result of changes in the precipitation regime? If some areas near streams are sensitive to flooding, are there actions that can be taken to minimize flooding risk, such as increasing the width of flood-tolerant vegetation?

B

SAFEGUARDING SPECIES  
AND SYSTEMS**TOOLS/RESOURCES**

9. NatureServe's Climate Change Vulnerability Index (<http://goo.gl/BQyMv>)
10. NatureServe Explorer Species Database (<http://goo.gl/EWRTu>)
11. Projected future temperature and precipitation extremes in Chicago (Vavrus and Van Dorn, 2010) (<http://goo.gl/hZeFu>)
12. Introduction: Assessing the effects of climate change on Chicago and the Great Lakes (Wuebbles et al., 2010) (<http://goo.gl/SK6HO>)
13. Climate Change Impacts on Terrestrial Ecosystems in Metropolitan Chicago and Its Surrounding, Multi-State Region (Hellmann et al., 2010) (<http://goo.gl/LFjRF>)
- (2). Biodiversity Recovery Plan climate change update: Plants page (<http://goo.gl/d8eDk>), Aquatic communities (<http://goo.gl/Dt2QP>), Terrestrial communities (<http://goo.gl/UN3oD>)
14. Scanning the Conservation Horizon (<http://goo.gl/eun8M>)
15. US Forest Service's Climate Change Tree & Bird Atlas

### III. CLIMATE-SMART LAND MANAGEMENT DECISIONS

#### a. CHOOSING PLANT MATERIALS

It's important to design and manage projects to have a high adaptation potential with respect to increases in temperature, drought stress, and intense rainfall/flooding. In seeding or stocking, consider species that are tolerant of altered conditions (i.e., will persist in the face of changing conditions) and those that might emerge in the region under climate change and may become native invasives. (In the latter, consult with other managers, sites in the region as well as sites outside the region, particularly south of Chicago, for coordination). Ecologists and evolutionary biologists have shown many times that local adaptation is widespread in many plant species, where local varieties tend to perform best where their ancestors have been exposed and molded to local conditions. Under changing conditions, however, this local adaptation may break down and local forms may no longer be the best performers in a particular region. At a site where performance (e.g., growth rate, biomass) is critical, non-local varieties can be tested, particularly varieties that occur where the historic climate is similar to the projected for the Chicago region. In addition to drawing stock from novel regions, or where testing of alternate stock is impractical, including greater genetic diversity may be advantageous under a changing climate. Some of the newly added diversity will be maladapted to the site and selected out, but greater diversity increases the chance that high-performing genotypes are included in the seed stock and provides maximal opportunities for evolution of the population. Numerous theoretical studies show that increased genetic variance enhances the potential for and rate of evolution (Broadhurst et al., 2008; Bower et al., 2008; McKenney et al., 2009). Working with local scientists and researchers to help answer the questions below is advisable, particularly if you are willing to have research conducted on portions of the site.

An important consideration is that while changing seed stock may be advisable for maintaining ecosystem function, it could negatively affect the preservation of forms that were historically adapted to the local region. From a functional point of view, not all species matter per se for the integrity or the functioning of an ecosystem, but rather it is the loss of individual traits that are essential for the production of organic matter and the functioning of biochemical cycles that is of greatest importance (Inchausti and Loreau, 2002). Coming from this perspective, we may need to adapt some of our longstanding species-specific management strategies and policies to focus more broadly on the functional categories that different species—whether they are native or migrating in from other regions—provide to an ecosystem. It is also crucial to begin managing for biodiversity by managing ecosystems from a landscape perspective to address fragmentation. This does not mean that species no longer matter, or that we completely stop species-specific management (because every natural community is of course composed of the individual species represented within them), but it does imply a broader, more flexible perspective for achieving management goals.



**Questions to consider:**

- Would the current mix, or the selected tree species, hold up well under drier, hotter, and more extreme conditions? If they would not, what changes in practices (e.g., increased use of water, planting larger trees instead of seedlings) would be required in order to establish and maintain them? Connecting back to Section B, I: How much would these changes cost?
- What options would enable a greater number of species to be incorporated into seed mixes, large-scale plantings, or urban forests? Are there ways to also increase the within-species (genetic) diversity of plant materials by obtaining materials from a wider range of sources?
- What species have higher drought tolerances, and could be substituted for species that are not likely to do well with increased drought? If relevant given the site location, what plants could withstand flooding, and even reduce flow rates/absorb more water? Are there plants that handle both drought and flooding well?
- Which species in the current stocking/seedling list are near their southern range boundary at the site? Which species live near their northern range boundary? Which species on the list have relatives or varieties that might be more resistant to drought, extreme rainfall events, or higher temperatures?
- What changes in seed stocking are other sites or land managers making in neighboring areas that could indirectly affect (or appear) in the target site? Would they be accepted or discouraged at the target site if they did arrive?

**TOOLS/RESOURCES**

(11). Overview on precipitation predictions

16. Updated City of Chicago urban tree planting list [looks at climate-readiness based on hardiness zone, heat intolerance and/or poor cultivations in southern United States] [http://www.cityofchicago.org/city/en/depts/streets/provdrs/forestry/svcs/tree\\_planting.html](http://www.cityofchicago.org/city/en/depts/streets/provdrs/forestry/svcs/tree_planting.html)
17. Discussion on how project managers have designed projects differently
18. Discussion on coordinated plant testing and seed sourcing materials
19. Chicago Wilderness Biodiversity Recovery Plan climate change update climate (<http://climate.chicagowilderenss.org>)
20. Focus on restoring hydrologic function to natural areas
21. Discussion on design storm figures
22. Example of updated standards for seed use: Ministry of Forests, Lands and Natural Resource Operations. Province of British Columbia. Chief Forester's Standards for Seed Use. Amendment to the Standards November 2008 and June 2010. <http://www.for.gov.bc.ca/CODE/cfstandards/index.htm> (<http://goo.gl/S0sWa>)
23. Climate Change Adaptation Options for Toronto's Urban Forest [http://www.cleanairpartnership.org/pdf/climate\\_change\\_adaptation.pdf](http://www.cleanairpartnership.org/pdf/climate_change_adaptation.pdf)

**B**CLIMATE-SMART LAND  
MANAGEMENT DECISIONS

## b. MANAGING PESTS AND INVASIVE SPECIES

A number of human influences on the environment, from invasive species to land use change, will interact with climatic change and affect how systems respond to changing conditions. For example, a species already threatened by habitat loss and competition with invasive plants may be fragmented into isolated populations that are more vulnerable to climate change than species in healthy, connected populations might otherwise be. This is the case for the endangered checkerspot butterfly (*Euphydryas editha bayensis*). This species undoubtedly had a wider distribution in northern California before European and Asian grasses and suburban sprawl forced populations into relic patches of native grassland associated with serpentine soils. These isolated populations are then vulnerable to climatic extremes, like those expected under climate change, because population sizes are relatively low and populations cannot be rescued by neighboring sites (McLaughlin et al., 2002). Although from a different location, the case of the Bay checkerspot suggests that we should look out for species with physiology sensitive to climate change (or ecosystems with several species of sensitivity physiology) and ask if the broader ecological context, particularly the presence of competitors or herbivores, intensifies that sensitivity.

Climate change also can exacerbate existing pest problems, or allow the rise of new nuisance species. There is some evidence to suggest that species with rapid growth rates and high dispersal capabilities may be able to shift more readily than some native species (Hellmann et al. 2008), allowing pest species to arise in new locations. Some pest species also have a high degree of plasticity, an ability to tolerate a wide range of conditions, and therefore may have a greater tolerance for changing conditions than native species. To anticipate these effects, one should anticipate if current species could emerge as pests in the future, and if pest species occurring elsewhere in the larger region could emerge in a locality of interest. It also is possible that new pests could arrive from distant locales or that non-native species that arrive with some frequency could begin to successfully establish if conditions were to change, but these are more difficult to anticipate and depend on a number of factors other than climate change, such as pathways of interaction trade and emerging global markets.

### Questions to consider:

- What invasive or pest species require the most attention under current conditions, and are these likely to continue to be a problem in the future under continued climate change? These species could be targets for increased management in the future.
- Is it likely that warmer temperatures will favor new invasive species, such as those species that currently pose a problem in regions to the south (e.g., kudzu)? These species could be targets for early detection and early management to prevent or slow establishment.
- How will climate change affect the effectiveness of current control measures (e.g., will the current frequency of control be sufficient)? For example, species currently controlled with hand pulling could require more intensive measures if their abundance or growth rate increases under climate change. By anticipating such changes, we can work together to develop new control methods before they are needed.
- Are there elements of invasive or pest control that are sensitive to the length of the growing season, or the presence/absence of frozen or wet ground (e.g., prescribed burning, mowing, vegetation planting, timing or effectiveness of pest control)? Can control methods be modified to account for these changes?



B

CLIMATE-SMART LAND  
MANAGEMENT DECISIONS

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**TOOLS/RESOURCES**


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24. USDA Weed Factsheet: Climate change impacts on weeds (<http://goo.gl/p19b4>)
25. Hellmann et al. 2008. Five consequences of climate change for invasive species. *Conservation Biology* 22: 534-543. (<http://goo.gl/QfPGz>)
26. Invasive Species, Climate Change and Ecosystem-Based Adaptation: Addressing Multiple Drivers of Global Change (<http://goo.gl/9rOVI>)
27. Invasive Species and Climate Change (<http://goo.gl/jLIQ6>)

### c. WATER MANAGEMENT

Climate change is already affecting the aquatic systems of the Upper Midwest. For example, all of the Great Lakes have experienced reduced ice cover during the last several decades. Researchers at NOAA's Great Lakes Environmental Research Laboratory have found that ice cover on the Great Lakes declined 71% between 1973 and 2010 (Wang et al., 2011). During this time, Lake Michigan saw a 77% decline. The decline in ice cover is linked to increasing winter air temperatures over the Great Lakes, which have risen by 2.7 °F in the south, and by 4 - 5 °F in the north. Furthermore, the warming of the lakes exacerbates the ice melt by generating an ice-albedo feedback, where the dark water exposed by melted ice absorbs more sunlight and thus heats more quickly and melts more ice. In light of the decline in ice cover, it is anticipated that areas surrounding the Great Lakes will have heavier lake effect snows, and an increased incidence of warm spring weather.

How these changes may impact lake levels has been an active field of research with multiple approaches being used in modeling this function. Recent models for Lake Michigan, derived from using an energy budget-based approach to adjusting the potential evapotranspiration (PET) instead of using air temperature as a proxy to compute PET, suggest either a smaller decrease in net basin supply and smaller drop in lake levels than using the temperature proxy, or a reversal to increased net basin supply and slightly higher lake levels (Lofgren et al., 2011). In other words, lake levels are variable, making it imperative that we manage and restore our systems to handle that fact.

Enhancing water uptake and management is critical in helping to avoid flooding and maintain water quality from stormwater runoff. Examples of this include softscaping and designing vegetation buffers around streams, wetlands, and sensitive restoration sites. In addition to flood reduction, taking action to keep water in the system can have advantages in terms of reducing drought stress in the summer and fall. Changes in precipitation patterns could make the region more likely to experience prolonged periods of drought followed by heavy precipitation events, increasing the incidence of erosion. Due to the Clean Water Act this could be a specific regulatory concern for some agencies during new construction but also throughout the management of retention ponds, swales, etc.


**B**

 CLIMATE-SMART LAND  
MANAGEMENT DECISIONS

**Questions to consider:**

- During extreme rainfall events, where will water flow and how might that affect land management objectives?
- For surface waters, how will increased runoff affect water quality in neighboring areas or downstream?
- Are there ways to increase stormwater capture on site without hindering other functions of the site (e.g. habitat, public enjoyment, etc.)? Connecting back to Section B, II: Are there partners at neighboring sites that might help you implement changes that benefit both your site and theirs in terms of reducing flooding?
- If relevant, what time frame and factors are reflected in the Probable Maximum Precipitation (PMP) estimate used for this project? Does this estimate include the likelihood of more increased frequency of extreme storm events? If not, how might project design change in order to incorporate this likelihood?

**TOOLS/RESOURCES**

28. Chicago's Guide to Stormwater Best Management Practices (<http://goo.gl/hBJGI>)
29. Chicago's Rain Harvesting Blog (<http://goo.gl/tCF1H>)
30. Guideline for soil volume standards (in progress- Bureau of Forestry)
31. The Role of Land Use in Adaptation to Increased Precipitation and Flooding: A Case Study in Wisconsin's Lower Fox River Basin (<http://goo.gl/pnHil>)
32. Hydrology Report Series (12): Climate Change and Probable Maximum Precipitation. Australian Government, Bureau of Meteorology, Water Division. Melbourne, 2009 (<http://goo.gl/YKIJS>)
33. Plants for stormwater design manual (<http://goo.gl/2deHo>)

**d. TIMING AND COST OF LAND MANAGEMENT**

One of the most well documented changes that have occurred in temperate regions in the last several decades is an earlier greening, or earlier bud burst, of trees and other plants. This earlier bud burst signals the early arrival of spring (Bradley et al., 1999; Miller-Rushing and Primack, 2008). Associated with an earlier arrival of spring is a general lengthening of the growing season, and this can affect a variety of management activities, notably the timing and frequency of burning, mowing, pruning, planting, and pesticide and fertilizer treatment. Recent trends in earlier spring green-up and warmer temperatures, for example, have indeed shortened the spring burn window in several recent years and made spring burns more complex. Managers need to be more aware of faunal responses to warmer springs; for example, snakes may be emerging from their hibernacula earlier and insects may be active earlier in the season.

Management activities may be further complicated by an increase in extreme conditions anticipated with climatic change. To the degree that a longer season implies more of these activities, it could also require greater expenditures and costs. It also will require changes in standard protocols and experimentation with alternative management regimes (e.g., frequency and timing of prescribed burns). Unfortunately, there is relatively little guidance on how to pursue such changes in management, other than to anticipate them in the first place and to begin to plan and experiment. One other possible strategy is to look to other regions for guidance, such as

municipalities to the south where one could examine their frequency of tree pruning, total urban forest cover, and total urban forest budget.

### Questions to consider:

- Consider interactions between planting timing and drought stress/flooding. Can timing of planting, or choice of plant materials be shifted to generate a site that is less susceptible to climatic extremes?
- What changes are neighboring land managers making in their timing of management activities, and will any of these changes spill over or affect the focal site?
- Which activities occupy the largest component of site management budget? Is there any expectation that the processes underlying this activity will change under climate change?
- Which activities or resources on the site are not currently managed but could require management attention under climate change?

## TOOLS/RESOURCES

34. USDA Plant Hardiness Zones (<http://goo.gl/lcjS4>)

## IV. OPERATIONS AND MAINTENANCE

### a. RISKS TO SITE OPERATIONS OR INFRASTRUCTURE

Identify future risks to site/project due to climate change. These risks could include the need for more frequent watering, pest control, erosion or tree maintenance from frequent storm events, the potential for culverts, bridges, or other infrastructure to wash out during storms, or the need for a longer maintenance season due to a longer growing season. Specify alternatives for these traditional maintenance activities or adjustments to their frequency, such as refitting infrastructure ex-drainage systems to allow for more infiltration.

### Questions to consider:

- What operations or maintenance requires a large investment of time or money at this site/project? Could that operation or maintenance be affected by climate change, and what would be the consequence of not altering maintenance practices? For example, Spring 2012 tree planting required increases in the amount of watering at a great cost. What if this scenario became more frequent?
- What would be the cost of altering those maintenance practices, if necessary? Would it result in cost savings or increases?

## TOOLS/RESOURCES

This guide is an evolving resource; please send any relevant tools that could be added to this section to [aderby@fieldmuseum.org](mailto:aderby@fieldmuseum.org)



B

OPERATIONS AND  
MAINTENANCE

## b. COST SAVINGS OPPORTUNITIES

Identify cost savings opportunities from climate change such as reductions in salt application on roadways, number of days that snow plows are deployed, or better infiltration that reduces water control structural repair costs. Redirect these savings to operations expenditures that are likely to increase under climate change. Generally speaking, the longer the growing season the greater the costs could be. There's also an inverse relationship between watering and mowing: the more rain the more mowing costs and less watering costs, and the less rain the more watering costs and less mowing costs. Indeed, City managers observed weeding and mowing frequency dropped considerably in 2012 due to the drought, but watering costs increased significantly. Some managers have suggested leaving dropped leaves in shrub and perennial beds in the fall to provide a natural mulch layer that can reduce watering costs during the growing season.

### Questions to consider:

- What operations or maintenance activities in this agency/department could be most affected by climate change?
- Which of these represent cost increases or decreases, and how certain are those estimates?
- Given our level of uncertainty about the specific consequences of climate change, can budget or personnel be adjusted to account for likely changes in maintenance? Can savings in one year, for example, be rolled into another category in the subsequent year? Can flexibility in yearly budgets be built in to buffer the greater unpredictability of needs?
- Over what time horizon do we expect those changes in expenditures to be realized--in the coming years, decades, or later in the century?

## TOOLS/RESOURCES

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B

OPERATIONS AND  
MAINTENANCE

## c. MOSQUITO ABATEMENT

A collection of mosquito abatement districts provides mosquito control services in Chicago and other municipalities in the US. Their primary function is to reduce nuisance and the risk of disease from mosquito-borne diseases, such as West Nile. There is some evidence to suggest that mosquito species could shift northward in the US as the climate changes, particularly as minimum winter temperature increases. In preliminary modeling performed by Jessica Hellmann at the University of Notre Dame (publication forthcoming), northward projections of the invasive mosquitoes *Aedes japonicus* and *Aedes albopictus* is possible. In the former, populations could move out of the Great Lakes region, and populations of the latter could emerge regionally. Both species are competent vectors of West Nile and other viruses, and *A. albopictus* is a vector for dengue in many parts of the world. To anticipate changes in mosquito distributions, existing abatement districts should continue monitoring, and municipalities without abatement programs might consider adding them to protect public health. Different mosquito species respond to different aspects of climate, having to do with different larval habitats, for example. Preliminary

analysis (Hellmann unpublished) of the correlation between long-term mosquito abundance and climate for multiple sites in the Midwest suggest that *Culex tarsalis* and *Culex pipiens* may decline with winter warming because their abundance is negatively correlated with warmer winter conditions. Such a phenomenon has been shown for other insects when warmer winters reduce energy stores in species that are adapted for cold climates (Irwin and Lee, 2000; Williams et al., 2012).

### Questions to consider:

- Which mosquito species are likely to increase in the region under climate change, and are adequate measures in place to detect and control these new species? Climate niche modeling can predict possible changes in species' ranges and community composition, but monitoring programs are needed to detect realized changes in species' ranges.
- Changes in temperature and precipitation can affect the duration of the mosquito season, rates of development, and disease risk. Are monitoring and control measures in place to account for these changes, including periodic testing of infection rates for West Nile virus if mosquito abundances increase?
- Some mosquito species in a region could decrease, as is possible for *A. japonicus* in the Great Lakes region. If species composition were to change, what effect might that have on the amount, duration, and type of mosquito control?

### TOOLS/RESOURCES

35. Projection models for mosquitoes in the Great Lakes region (*Aedes japonicus*, *Aedes albopictus*, and *Culex tarsalis*) from Hellmann, report to the National Commission on Energy Policy and published paper forthcoming.
36. Descriptions of mosquito biology and public health risk at the Centers for Disease Control (<http://goo.gl/t4zBB>)



B

OPERATIONS AND  
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### d. ALTERNATIVE MANAGEMENT/OPERATIONS TECHNIQUES

Identify alternative management or operations strategies that become more cost effective under future climate change. Replace these with current operations protocols where possible.

### Questions to consider:

- Are there novel approaches used by other municipalities to achieve key operations for this type of site/project?
- Could any of these approaches become viable or increasingly cost effective under climate change?
- Are there new partnerships that you could engage in to help address new challenges?

### TOOLS/RESOURCES

This guide is an evolving resource; please send any relevant tools that could be added to this section to [aderby@fieldmuseum.org](mailto:aderby@fieldmuseum.org)

## V. RETHINKING GOALS

### a. WISE INVESTMENT OVER THE LONG TERM & SHIFTING PRIORITIES

Although rethinking goals can be done at any time, many may see more of a need for this step after reading through all of the earlier sections. The key idea is to both address impacts and adaptation to changes that are occurring, and think longer-term about how to use resources wisely. We want to avoid managing for species that will decline or cannot persist through changing climatic conditions locally or regionally, unless other social considerations predominate. The range extensions of species not currently found in this region will likely become increasingly more pervasive due to climate change. We should expect to see spatial shifts both in range boundaries (e.g., moving north in the Northern Hemisphere) and in the density of individual animals or plants within various subsections of a species' range. Further, it's important to recognize that shifts in density and abundance include extirpation (loss of a species from a local area) and extinction (Hall and Root, 2012).

A critical issue to bring up within this context is that arguably, from a functional point of view, not all species matter per se for the integrity or the functioning of an ecosystem, but rather it is the loss of individual traits that are essential for the production of organic matter and the functioning of biochemical cycles that is of greatest importance (Inchausti and Loreau, 2002). Coming from this perspective, we may need to adapt some of our longstanding species-specific management strategies and policies to focus more broadly on the functional categories that different species-whether they are native or migrating in from other regions- provide to an ecosystem. This does not mean that species no longer matter, or that we completely stop species-specific management (because every natural community is of course composed of the individual species represented within them), but it does imply a broader, more flexible view of what to manage for.

Given that the region is going to change and some species currently represented as part of the regional floral or faunal community may not be able to adapt to these changes, we will likely face hard decisions as to when to continue conservation efforts for a given species and when to shift focus and resources to something different. Factors that could influence continued conservation support for a species might be if the Chicago region represented the only remaining habitat, important migration routes, or the heart of the range for a species. On the other hand, if the Chicago region represented the southern range of a species distribution, or it was known that assisted migration could be implemented successfully for that species, then resources might be allocated to focus on different species. These decisions, however, will not be based on biological considerations alone, but also the societal value judgments that frame restoration and conservation priorities in this region (See Section B, I-C).

#### Questions to consider:

- If goals for this site are defined in terms of specific systems or species, how likely is it that these goals can be met over the long-term? Are there other systems or species that may be better suited to the site as climate changes? The Chicago lake plain, for example, has species and communities that are adapted to more severe drying and inundation; but how flexible they are is uncertain if changes becomes more extreme. Is there a feasible plan for transitioning toward a more viable system over time?



- If societal values suggest keeping particular species is a high priority (Section B, I-C), what extreme steps might be necessary to manage current target species under climate change, and are these steps feasible or cost effective? For example, what are the physiological tolerances of the species that are current targets of management? Are species that the target species depends upon likely to decline?
- What changes would need to be made in our policies to address a change in the key resources at this site? Would some sources of funding be lost?
- Over the long term, is the basic form of vegetation on this site likely to dramatically change under climate change (e.g., from forest to grassland) based on changes in rainfall, temperature, regional development, or hydrology? How would this change affect our mission, goals, and/or funding?
- What is a reasonable time frame for implementing a new management focus and goals? How will changes in management goals be communicated to the public?
- Given the climate change impacts and sensitivities of the site, will it be possible to meet management objectives at a reasonable cost? Are there other ways to reach these goals (by working at a different site, or adding resources to a partner's activities) that are less susceptible to negative impacts from climate change?
- How do we account for climate change as we monitor the success of our management actions? Are measures likely to be confounded by climate change? Can we incorporate changes in some climatic factors into our monitoring?

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## TOOLS/RESOURCES

- (19). CW Biodiversity Recovery Plan climate change update
- (9). Climate Change Vulnerability Index
- 37. Climate Change Adaptation Collaboratory (<http://goo.gl/sBspG>)
- 38. World Wildlife Foundation Ecoregions (<http://goo.gl/mRx4>) for identification of biome transitions

B

RETHINKING GOALS

**TABLE 1:** Means and extremes simulated in the late 20th and late 21st centuries expressed as the inter-model average of Midway, O'Hare, and the University of Chicago.

	1961 - 1990	2070-2099		Difference	
		B1	A1	B1	A1
Winter mean temperature (°C)	-3.1	-1.1	1.0	2.0	4.1
Lowest temperature per year (°C)	-24.3	-20.5	-16.3	3.8	8.0
Frequency of very cold nights/year	9.7	4.9	1.4	-4.8 (-49%)	-4.8 (-49%)
Summer mean temperature (°C)	22.4	24.8	28.2	2.4	5.8
Highest temperature per year (°C)	37.3	41.8	47.1	4.5	9.8
Frequency of hot days/year	14.8	36.3	72.2	21.5 (145%)	57.4 (388%)
Frequency of very hot days/year	2.0	8.4	30.5	6.4 (320%)	28.5 (1425%)
Intensity of heat waves (°C)	34.3	35.1	36.1	0.8	1.8
Duration of heat waves (days)	2.9	5.3	9.8	2.4 (83%)	6.9 (338%)
Length of heat wave season (days)	68.6	108.0	137.7	39.4 (57%)	69.1 (101%)
Annual precipitation (cm)	94.3	109.8	113.3	15.5 (16%)	19.0 (20%)
Frequency of very wet days/year	18.3	22.6	23.2	4.3 (24%)	4.9 (27%)
Extremely wet days/year	1.5	1.9	2.5	0.4 (27%)	1.0 (64%)

Source: Vavrus and Van Dorn, 2010

**Definitions:** Very cold nights are defined as having a minimum temperature  $\leq -18$  °C, hot days as a maximum temperature  $\geq 32$  °C, and very hot days  $\geq 38$  °C. The intensity of heat waves is the average daily maximum temperature on consecutive days over 32 °C. The length of the heat wave season is the interval between the average first and last calendar days with a maximum temperature above 32 °C. Very wet days are defined as the precipitation threshold corresponding to the wettest 5% of days during the late 20th century, while extremely wet days are those with precipitation exceeding 4 cm.

**Models:** A1 (SRES A1F1) is a high-growth emissions scenario and B1 a moderate growth emissions scenario, in which emissions peak in the mid-21st century and then fall to 1990 levels by 2100. CO<sub>2</sub> concentrations reach 940 ppm by 2100 in A1 and 550 ppm (close to double the pre-industrial value) in B1.

B

RETHINKING GOALS

## APPENDIX I:

### I. GENERAL PRINCIPLES OF ADAPTATION STRATEGIES

Consideration of how the natural environment is affected by local weather, and related conditions such as soil moisture, has always been an integral part of the planning process for natural areas and green space projects. To the extent that current actions integrate changes we are seeing, many of the conservation, planning, and management practices we already do “count” towards a goal of climate change adaptation. To maximize the chances that our actions to manage the natural environment are successful and cost effective, however, we can’t rely solely on past conditions and current experience to guide our future management plans. In order to manage these spaces so they continue providing aesthetic as well as functional benefits (e.g., stormwater capture and retention, habitat and dispersal pathways for wildlife, reduced urban heat island effect and carbon storage) the way our climate is changing has to be considered. The conceptual framework for this checklist reflects 5 main principles, adapted from a collaborative, multi-organization effort led by the National Wildlife Federation to characterize best practices in climate change adaptation that has been incorporated into Technical Input for the 2013 National Climate Assessment (Staudinger et al., 2012; Chapter 6 focuses on adaptation) and London’s guide for sustainable communities (Shaw et al., 2007):

- **Be flexible:** The climate system is dynamic and complex, as are the ecological and social systems that are responding to change in climate. While climate models suggest increases in temperature, precipitation, and extreme events, we do not know how pronounced those changes will be due to modeling uncertainties and uncertainties in future emissions. Therefore, adaptation approaches need to be flexible in order to achieve the best outcomes that are effective and efficient, as well as allow users to adapt over time.
- **Look forward:** Climate change planning focuses on shifting goals and strategies to reflect current and future ecological conditions, instead of relying on past conditions as a benchmark for judging success. While we still need to focus on implementing solutions to today’s pressing problems, being “climate-smart” also means thinking now about how to lay the groundwork for transitioning projects and management over time.
- **Maximize project success and avoid poor investments:** Consider whether project goals can be achieved given changes in climate, and anticipate and avoid actions that will make it more difficult to cope with climate risks. For example, development (or investment in flood-sensitive plant materials) in a flood risk area is likely to be even riskier in the future as storm intensities increase; culverts for road-stream crossings that are being built now should anticipate higher peak flow volumes, and provide for fish passage in lower low-flow periods. In addition to protecting people and nature, we expect that proactive investments, rather than retroactive responses, will provide the most cost savings.
- **Avoid maladaptation:** From the perspective of protecting natural resources, some actions taken by society in response to climate change may be considered “maladaptation”, in that they reduce the viability of ecosystems. For example, hard structures to control floodwaters may protect people, but interfere with natural hydrological processes. Ideally, we would like to find “win-win” opportunities, such as restoring wetlands to help manage stormwater, so that we can enhance the viability of natural systems as well as benefitting people. Another example is that while clearing away leaves in shrub and perennial beds in the fall may be a preferred for aesthetics, they will be hidden when the plants green up in the Spring and provide a natural mulch layer that can reduce watering costs during the growing season.
- **Collaborate:** As the stresses on our natural systems increase, it is even more important that we share information, collaborate on expensive necessities like testing new techniques and monitoring results, and coordinate our actions to enhance benefits, and avoid duplication of efforts or undermining each other’s work.

## APPENDIX II:

### II. WHAT DOES ADAPTATION LOOK LIKE?

“Adaptation strategies” are often thought of as separate actions that are added on to general planning or management processes. However, the ultimate goal of adaptation is to integrate knowledge regarding how patterns of rainfall, temperature, soil moisture, lake levels etc. into the decision-making process to create a holistic approach to project design. This process is known as “mainstreaming”. Adaptation can be reflected in a variety of ways, including choices made about 1) what to prioritize and how to spend resources (is there a need to allocate more toward invasive species management, water control structures, or repairing hydrologic gradients at a site?) 2) how to decide what resources to invest in (e.g., what plants to plant and where to buy seed mixes) and 3) how to prepare a site so that it maximizes a desirable outcome in the future (e.g., maximize water retention and root growth for trees). Below are some examples of current or future projects that have an adaptation component in the City of Chicago. These examples are also located on the Collaboratory (<https://adapt.nd.edu/>) where additional examples can be posted.

1. Implementing strategies to keep storm water out of the sewer system through green alleys, storm water ordinance, green roofs, sustainable streets and residential scale solutions, reducing the number of flooded basements and combined sewer overflows into local waterways.
2. Installing water control structures in Lake Calumet wetlands in order to maintain water levels needed for habitat and stormwater management in a changing climate.
3. Creating Tree Space and Soil Volume Design Standards so that trees can survive under increasing stressors including higher temperatures and drier conditions.
4. Designing curb structures so storm water can be retained and used to water parkway trees.
5. Targeting tree-planting programs in areas of the city most impacted by the urban heat island (UHI) effect. More than 6,000 trees were planted in UHI hot spots from 2005 – 2008.
6. Including invasive plants that may be a threat in warmer climate scenarios in the Invasive Species Ordinance regulated list.
7. Strategically increase the over 500 acres of natural areas in parks across the city, connecting these natural areas to other habitat.

Items 1-4 above enable the persistence of desired functions into the future. These items tend to assume that a project is immediately pending and needs to be pursued in a way that accounts for current and future climatic changes. Item 5 enables individual features to be tied together to facilitate landscape-level processes such as species movement. Item 6 ensures that future projects and investments are directed in a way that continues to be informed by climate change so as to maximize effectiveness and economic efficiencies.



C

WHAT DOES ADAPTATION  
LOOK LIKE?

## APPENDIX III:

### II. ADDITIONAL INFORMATION ON ADAPTATION APPROACHES

#### The Nature Conservancy

TNC's approach for updating projects is described in detail with suggested references and tools in "Conservation Action Planning Guidelines for Developing Strategies in the Face of Climate Change" (TNC 2009). This document is available as a pdf file at <http://conserveonline.org/workspaces/climateadaptation/documents/climate-change-project-level-guidance> (<http://goo.gl/bV10B>). The site housing this document also has links to 20 example projects from around the world (including diagrams and "hypotheses of change"), although none specifically addresses natural systems in urban settings. A journal article based on TNC's experiences with updating projects is also available (open access):

Poiani, K. A., R. L. Goldman, J. Hobson, J. M. Hoekstra, and K. S. Nelson. 2010. Redesigning biodiversity conservation projects for climate change: examples from the field. *Biodiversity Conservation* 2011:185-201. <http://www.springerlink.com/content/f0125g2575220423/> (<http://goo.gl/4w2os>)

#### "Climate Smart Conservation" Workgroup

A recent technical report developed in support of the next update of National Climate Assessment (due to be completed in 2013) provides more details on "principles" of adaptation (expanding upon the list provided in the sidebar in section A.II), and gives a slightly different, more general set of steps that can be found in Chapter 6 of Staudinger et al. (2012). This set was developed by the "Climate-Smart Conservation" workgroup convened by the National Wildlife Federation, and this group will be publishing a more detailed report in 2013. The workgroup's generalized framework identifies the following phases in an adaptation planning and implementation cycle:

1. Identify existing conservation goals and objectives
2. Assess climate change impacts and vulnerabilities
3. Review conservation goals and objectives in light of climate vulnerabilities and revise as necessary
4. Identify adaptation options (that is, strategies and actions capable of reducing vulnerabilities to achieve stated goals)
5. Evaluate and prioritize adaptation options
6. Implement priority actions
7. Track effectiveness of actions and ecological responses (that is, review and refine actions, strategies, and goals based on monitoring and other new information).

#### GeosInstitute's "ClimateWise" approach

Many other organizations have developed frameworks that illustrate a set of steps for climate change adaptation. As one example of a framework that is intended to help groups work together



toward adaptation in some sector or even across several sectors, we also include the "ClimateWise" approach, developed by the GeosInstitute. Note that this approach starts out with a focus on building partnerships, and includes an explicit step on cost-sharing and collaboration.

For more information about this approach, visit the Institute's website at <http://www.geosinstitute.org/> (<http://goo.gl/XDKgt>).

## IV. ANNOTATED LIST OF TOOLS AND RESOURCES

### TOOLS AND RESOURCES: CHICAGO REGION

1. **Chicago Region Restoration Seed Source Policies- A review** (Saari and Glisson, 2012)  
[http://muse.jhu.edu/login?auth=0&type=summary&url=/journals/ecological\\_restoration/v030/30.3.saari.html](http://muse.jhu.edu/login?auth=0&type=summary&url=/journals/ecological_restoration/v030/30.3.saari.html)
  - This report summarizes seed source policies and practices as understood and implemented by the conservation agencies and organizations of the Chicago region.
2. **Biodiversity Recovery Plan climate change update, Plants section**  
<http://climate.chicagowilderness.org/index.php?title=Plants> (<http://goo.gl/Yoo92>)
  - The information in this appendix is based on the theoretical understanding of community, behavioral and restoration ecology, as well as data published in the scientific literature on how climate is affecting plant and natural communities around in the Chicago Wilderness region and around the globe. This section is intended as a platform for managers, stewards and volunteers to contribute their qualitative and quantitative knowledge of how climate change is affecting the natural communities they work at in the decades to come.
3. **Wisconsin Initiative on Climate Change Impacts- plants and natural communities**
  - <http://www.wicci.wisc.edu/> (<http://goo.gl/e9L26>): Links to climate impacts information & overview of working groups, including the forest and wildlife working groups.
  - <http://www.wicci.wisc.edu/publications.php> (<http://goo.gl/EQlri>): Wisconsin's Changing Climate: Impacts and Adaptation. Report on climate change impacts and adaptation by sector, including business, government, agriculture, environment (including a forest chapter), and public health.
4. **Benefit Calculations Table for the Chicago Eco-structure Incentive Program (Center for Neighborhood Technology)**- Abigail will contact CNT to follow up.
5. **Benefits guide**  
[http://www.sfrpc.com/Climate\\_Change/13.pdf](http://www.sfrpc.com/Climate_Change/13.pdf) (<http://goo.gl/LQjqQ>)
  - Guide for the following strategies: sustainable drainage systems; green roofs; structures and products to improve flood resilience; cool roofs, building and pavement material; rainwater harvesting.
6. **UFORE/i-Tree Eco Analysis of Chicago's Urban Forest**  
<http://www.nrs.fs.fed.us/urban/monitoring/eco-analysis-chicago/>
  - The USDA Forest Service worked with the City of Chicago, the Chicago Park District, and WRD Environmental to conduct a UFORE (Urban FORest Effects, now called i-Tree Eco) analysis of Chicago's urban forest in the summer of 2007.
  - The UFORE/i-Tree Eco model developed by the Forest Service uses on-the-ground sampling data to understand the composition of the urban forest and calculate the forest's impacts on air pollution and energy use.
7. **The Chicago Community Climate Action Toolkit**  
<http://climatechicago.fieldmuseum.org>
  - A. Understanding people's attachments to landscapes, and their willingness to change behavior or take new action to maintain the individual and societal values of the landscape or specific species:  
<http://climatechicago.fieldmuseum.org/learn>
    - Climate Change Guide to The Field Museum's Restoring Earth Exhibition
    - The Amazing Adventures of Chicago's Climate Change Heroes
  - B. Engaging Communities in natural area stewardship by linking it to other concerns:  
<http://climatechicago.fieldmuseum.org/models>
  - C. Specific approaches to engaging communities in climate action; the model here is potentially adaptable to engagement around specific natural areas, including eliciting an understanding of the values connected to the landscape: <http://climatechicago.fieldmuseum.org/doyourown>

**8. GIV 2.0/2.1**

<http://goo.gl/Bd4Yi>

- This project provides a visionary, regional-scale map of the Chicago Wilderness region that reflects both existing green infrastructure -- forest preserve holdings, natural area sites, streams, wetlands, prairies, and woodlands – as well as opportunities for expansion, restoration, and connection.
- Working with The Conservation Fund, Chicago Metropolitan Agency for Planning and Chicago Wilderness completed a “version 2.0” of the green infrastructure network in 2012. This effort also developed a set of freely downloadable set of GIS tools for conservation partners in the region to use to identify portions of the green infrastructure network on which they wish to concentrate their efforts. Please contact Jesse Elam ([jelam@cmaphillinois.gov](mailto:jelam@cmaphillinois.gov)) for more information.

**9. NatureServe’s Climate Change Vulnerability Index**

- Implemented in Notre Dame & TNC’s Climate Adaptation Collaboratory: <http://adapt.nd.edu>
- Also available as an excel spreadsheet from NatureServe’s site <http://www.natureserve.org/prodServices/climatechange/ccvi.jsp> (<http://goo.gl/wmkqN>)
- Species-level tool to explore components of vulnerability and produce relative ratings.

**10. NatureServe Explorer Species Database:** <http://www.natureserve.org/explorer/>

- An authoritative source for information on more than 70,000 plants, animals, and ecosystems of the United States and Canada. Explorer includes in-depth coverage for rare and endangered species.

**11. Projected future temperature and precipitation extremes in Chicago** (Vavrus and Van Dorn, 2010) (<http://goo.gl/3Cknv>)

- Peer-reviewed journal article on anticipated changes in temperature and precipitation for the Chicago Wilderness region.

**12. Introduction: Assessing the effects of climate change on Chicago and the Great Lakes** (Wuebbles et al., 2010)

[http://glisa.umich.edu/great\\_lakes\\_climate/docs/Introduction-Assessing-the-Effects-of-Climate-Change-on-Chicago-and-the-Great-Lakes.pdf](http://glisa.umich.edu/great_lakes_climate/docs/Introduction-Assessing-the-Effects-of-Climate-Change-on-Chicago-and-the-Great-Lakes.pdf) (<http://goo.gl/FgUR2>)

- Peer-reviewed journal article on climate change impacts to the Great Lakes region

**13. Climate Change Impacts on Terrestrial Ecosystems in Metropolitan Chicago and Its Surrounding, Multi-State Region** (Hellmann et al., 2010)

<http://www.bioone.org/doi/pdf/10.1016/j.jglr.2009.12.001> (<http://goo.gl/uRZcy>)

- Peer-reviewed journal article on climate-related impacts to terrestrial ecosystems in the Chicago region

**14. National Wildlife Federation’s Scanning the Conservation Horizon: A guide to Climate Change Vulnerability Assessment.**

<http://www.nwf.org/~media/PDFs/Global-Warming/Climate-Smart-Conservation/ScanningtheConservationHorizon.ashx> (<http://goo.gl/LphGt>)

- Review of approaches with contributions from a wide range of NGO’s and agencies.
- A follow up document focused on best practices in adaptation is in progress.

**15. US Forest Service’s Climate Change Tree & Bird Atlas:**

<http://www.nrs.fs.fed.us/atlas/> (<http://goo.gl/jJ3Ds>)

- The Climate Change Atlas is a species distribution tool that models how ideal habitat for 134 tree species and 150 bird species may change over the next 100 years under a range of future climates.

**16. Updated urban tree planting list**

[http://www.cityofchicago.org/city/en/depts/streets/provdrs/forestry/svcs/tree\\_planting.html](http://www.cityofchicago.org/city/en/depts/streets/provdrs/forestry/svcs/tree_planting.html)

- Looks at climate-readiness of urban tree species based on hardiness zone, heat intolerance and/or poor cultivations in southern United States.

- 17. Discussion on how project managers have designed projects differently**
- 18. Discussion on coordinated plant testing and seed sourcing materials**
- 19. Chicago Wilderness Biodiversity Recovery Plan climate change update**  
[www.climate.chicagowilderness.org](http://www.climate.chicagowilderness.org) (<http://goo.gl/83BUZ>)
- Provides regional impacts, specific climate change threats to natural communities and adaptation strategies.
- 20. Focus on restoring hydrologic function to natural area**
- 21. Discussion on design storm figures**
- 22. Example of updated standards for seed use by the Ministry of Forests, Lands and Natural Resource Operations.**  
<http://www.for.gov.bc.ca/CODE/cfstandards/index.htm> (<http://goo.gl/GdKsD>)
- Province of British Columbia. Chief Forester’s Standards for Seed Use. Amendment to the Standards November 2008 and June 2010.
- 23. Climate Change Adaptation Options for Toronto’s Urban Forest**  
[http://www.cleanairpartnership.org/pdf/climate\\_change\\_adaptation.pdf](http://www.cleanairpartnership.org/pdf/climate_change_adaptation.pdf)
- This report is part of a four part project, Adapting to Climate Change in Toronto, undertaken by the Clean Air Partnership (CAP) in collaboration with the City of Toronto.
  - CAP is working with Toronto to incorporate adaptation to climate change into program planning and implementation to reduce the vulnerability of the city and its inhabitants from the impacts of climate change.
- 24. USDA Weed Factsheet: Climate change impacts on weeds**  
<http://www.climateandfarming.org/pdfs/FactSheets/III.1Weeds.pdf> (<http://goo.gl/E8Boh>)
- This resource discusses impacts to agronomic, noxious, and invasive weeds.
- 25. Hellmann et al. 2008. Five consequences of climate change for invasive species. Conservation Biology 22: 534-543.**  
(<http://goo.gl/ZpSF4>)
- Peer-reviewed journal article that examines the stages of invasion known as the “invasion pathway” to identify 5 nonexclusive consequences of climate change for invasive species.
- 26. Invasive Species, Climate Change and Ecosystem-Based Adaptation: Addressing Multiple Drivers of Global Change**  
<http://data.iucn.org/dbtw-wpd/edocs/2010-054.pdf>
- This report is targeted at policy-makers, particularly those responsible for developing climate mitigation and adaption strategies that address issues like conservation, ecosystem services, agriculture and sustainable livelihoods.
- 27. Invasive Species and Climate Change:**  
<http://www.fs.fed.us/ccrc/topics/invasive-plants.shtml> (<http://goo.gl/j2ZAZ>)
- USDA- Forest Service
- 28. Chicago’s Guide to Stormwater Best Management Practices**  
[http://www.a2gov.org/government/publicservices/systems\\_planning/waterresources/Documents/DevelopersGuide\\_4-6-05.pdf](http://www.a2gov.org/government/publicservices/systems_planning/waterresources/Documents/DevelopersGuide_4-6-05.pdf)
- Provides guidance to developers, residents, and other community members on methods to protect our water resources by reducing the amount of stormwater draining into the sewer system and local waterways.
- 29. Chicago’s Rain Harvesting Blog:** <http://chicagorainharvesting.wordpress.com/> (<http://goo.gl/QCNDI>)
- A public forum, created by Chicago’ Sustainable Backyards Program (<http://goo.gl/2dLmx>), to discuss rain harvesting questions, concerns, ideas, and innovations.

- 30. Guideline for soil volume standards** (in progress- Bureau of Forestry)
- 31. The Role of Land Use in Adaptation to Increased Precipitation and Flooding: A Case Study in Wisconsin's Lower Fox River Basin**  
LINK (<http://goo.gl/ZJ4vx>)
- Report on how the protection of natural areas and open space can improve a community's resilience to extreme events.
- 32. Hydrology Report Series (12): Climate Change and Probable Maximum Precipitation**, Australian Government, Bureau of Meteorology, Water Division, Melbourne, 2009.  
<http://www.bom.gov.au/water/designRainfalls/document/HRS12.pdf> (<http://goo.gl/8H5TZ>)
- Report on a 2-year project to investigate potential effects of climate change on estimates of Probable Maximum Precipitation (PMP) in Australia.
- 33. Plants for stormwater design manual**  
<http://www.pca.state.mn.us/index.php/view-document.html?gid=5651> (<http://goo.gl/9Qnsp>)
- Urban landscape designers, installation practitioners, and stormwater managers will find this a useful resource. Minnesota Pollution Control Agency staff worked with the authors, Daniel Shaw and Rusty Schmidt, to produce this valuable reference. The goal is to improve stormwater treatment and management practices by using native plants.
- 34. USDA Plant Hardiness Zones**  
<http://planthardiness.ars.usda.gov/PHZMWeb/> (<http://goo.gl/tcLYg>)
- 2012 USDA Plant Hardiness Zone Map (PHZM) is the standard by which gardeners and growers can determine which plants are most likely to thrive at a location. The Map is based on the average annual minimal temperature, divided into 10-degree F zones.
  - Compared with the 1990 version, zone boundaries in this edition of the map have shifted in many areas. The new PHZM is generally one half-zone warmer than the previous PHZM throughout much of the United States, in part as a result of a more recent averaging period (1974–1986 vs. 1976–2005).
- 35. Projection models for mosquitoes in the Great Lakes region** (*Aedes japonicus*, *Aedes albopictus*, and *Culex tarsalis*) (Hellmann, in progress)
- Report to the National Commission on Energy Policy
- 36. Descriptions of mosquito biology and public health risk**  
<http://www.cdc.gov/ncezid/dvbd/index.html> (<http://goo.gl/fgVMx>)
- Center for Disease Control Report
- 37. Notre Dame & TNC's Climate Adaptation Collaboratory**  
<http://adapt.nd.edu>
- Web-based resources for sharing information & tools, and for working collaboratively to identify, prioritize, and implement adaptation strategies.
- 38. World Wildlife Foundation Ecoregions**  
<http://www.worldwildlife.org/science/ecoregions/item1267.html> (<http://goo.gl/SG1am>)
- For identification of biome transitions

## GENERAL ADAPTATION RESOURCES

**39. Intergovernmental Panel on Climate Change**

<http://www.ipcc.ch/>

- Leading international body for the review and assessment of the most recent scientific, technical and socio-economic information produced worldwide relevant to the understanding of climate change. Key documents, and include thorough glossary and guidance on communicating level of uncertainty.

**40. U.S. Global Change Research Program’s Assessment Report on Climate Change Impacts in the US – Midwest Chapter** (2009). Note that new National Assessment documents are in progress.

<http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts/regional-climate-change-impacts/midwest> (<http://goo.gl/IU5qY>)

**41. TNC & partners’ Climate Wizard**

<http://www.climatewizard.org>

- A tool for visualizing and downloading historic and projected changes in climate from 16 different Global Circulation Models – you can use pre-loaded data, or create your own “custom” datasets.

**42. Climate Change Resource Center**

<http://www.fs.fed.us/ccrc/> (<http://goo.gl/a6Zei>)

- A website designed by the Forest Service for land managers, with information on climate-related tools, a library of video presentations, and topic pages on a wide variety of natural resource management issues.

**43. NOAA Coastal Services Center Digital Coast**

<http://www.csc.noaa.gov/digitalcoast/> (<http://goo.gl/GjJw4>)

- Partnership between NOAA and several other organizations to provide data, tools, and training opportunities that help coastal managers understand and respond to climate change and other management challenges. Includes tools that apply to terrestrial systems as well.

**44. DataBasin Climate Center**

<http://databasin.org/climate-center> (<http://goo.gl/yPwmK>)

- A climate-focused area of the Data Basin website, focusing on available datasets, tools, and social networks related to climate and its impacts.

**45. U.S. Fish and Wildlife Service Landscape Conservation Cooperative – Upper Midwest/Great Lakes.**

<http://www.greatlakeslcc.org/> (<http://goo.gl/Dczrw>)

- The purpose of the LCC is to share information and promote regional collaboration, and climate change is the focus of, or is incorporated in, many funded research projects.

**46. Great Lakes Regional Integrated Sciences and Assessments Center (GLISA)**

<http://glisa.umich.edu/> (<http://goo.gl/SulAi>)

- A partnership among researchers at the University of Michigan, Michigan State University, and Ohio State (funded by NOAA) to promote research and data sharing that improves decision-making, especially for Lakes Huron and Erie and their watersheds.

**47. Ontario Ministry of Natural Resources**

Climate change page <http://www.mnr.gov.on.ca/en/Business/ClimateChange/index.html> (<http://goo.gl/gCH3G>)

- Overview of climate change impacts, mitigation options, and adaptation. The publications page includes many resources related to forest impacts and adaptation (see handout as well).

**48. Ohio State University Climate Change outreach site**

<http://changingclimate.osu.edu/> (<http://goo.gl/IEfjc>)

- Resources, upcoming events, and links to archived 1-hour webinar topics include presentations on stormwater management, forests, water quality, working lands, impacts on Great Lakes ports, etc.

**49. Michigan Climate Coalition** – sharing information in Michigan on impacts and responses to climate change. <http://www.mclimatecoalition.org/> (<http://goo.gl/TK22F>)

- Includes working groups focused on forests (led by Stephen Handler and Amy Clark-Eagle) and wildlife (led by Chris Hoving and Katie Kahl).

**50. Minnesota Forest Resources Council:** <http://www.frc.state.mn.us/> (<http://goo.gl/C5ZC8>)

- The Minnesota Forest Resources Council is a state council established by the Sustainable Forest Resources Act (SFRA) of 1995 to promote long-term sustainable management of Minnesota’s forests.
- Information on sustainable forestry, including forest policy, biofuels, and carbon management.

**51. The National Park Service’s Apostle Islands** web page on climate change and sustainability (which has many great additional links)

<http://www.nps.gov/apis/naturescience/climate-change-and-sustainability.htm> (<http://goo.gl/OJMeV>)

- The Park’s General Management Plan is one of the first in the National Park Service to address climate change. See <http://www.nps.gov/apis/upload/APIS-GMP-short-version.pdf> (<http://goo.gl/3mVT0>), pages 18-19, 115-18.

## ASSESSING VULNERABILITY

**52. Forest Ecosystem Vulnerability Assessment for northern Wisconsin**

<http://www.nrs.fs.fed.us/pubs/38255> (<http://goo.gl/xMvCx>)

- The Ecosystem Vulnerability Assessment and Synthesis is one of the initial products from the Northwoods Climate Change Response Framework and provides information relevant to all of northern Wisconsin.

**53. The ForeCASTS Project**

[http://www.geobabble.org/~hnw/global/treeranges3/climate\\_change/](http://www.geobabble.org/~hnw/global/treeranges3/climate_change/) (<http://goo.gl/ozuCz>)

- The ForeCASTS project has generated an atlas of maps showing future suitable habitat under two climate change models. The maps also show which parts of the tree ranges might be under the greatest climate change pressure.

**54. The LANDIS-II Forest Landscape Model**

<http://www.landis-ii.org/> (<http://goo.gl/2PFih>)

- LANDIS-II simulates forest succession, disturbance (including fire, wind, harvesting, insects), climate change, and seed dispersal across large (typically 10,000 - 20,000,000 ha) landscapes.

**55. The MC1 Dynamic Global Vegetation Model**

<http://www.fsl.orst.edu/dgvm/> (<http://goo.gl/MvqpH>)

- MC1 is a dynamic global vegetation model that uses monthly climate data (Tmin, Tmax, VPR, and PPT) as well as soils information (bulk density, texture, depth) to project vegetation distribution, carbon stocks and fluxes, hydrological flows, and wildfire occurrence and impacts.

**56. LANDFIRE**

<http://www.landfire.gov/>

- LANDFIRE products are designed to be used at a landscape-scale in support of strategic vegetation, fire, and fuels management planning to evaluate management alternatives across boundaries. LANDFIRE data products also facilitate national-and-regional-level strategic planning and reporting of wildland fire and natural resource management activities.

## ADAPTATION RESOURCES AND TRAINING/WORKSHOP FACILITATION

(See also many of the reports in the impacts sections – especially for IPCC & WICCI)

**57. Climate Change Response Framework**

[www.climateframework.org](http://www.climateframework.org)

- The Climate Change Response Framework is a collaborative approach to incorporating climate change considerations into forest management. Three regional Framework projects are occurring across the eastern US, including the Northwoods Climate Change Response Framework.

**58. TNC’s Climate Change Adaptation work**

- Great Lakes Project Climate Change website: [www.nature.org/greatlakesclimate](http://www.nature.org/greatlakesclimate)  
This site introduces our staff & work, houses case studies, and describes partnerships.
- The Great Lakes project connects to many resources within the TNC as a global organization – the Global program gateway can be found at <http://NaturePeopleFuture.org>. The site includes:
  - Guidance for regional scale assessments: <http://conserveonline.org/workspaces/climateadaptation/documents/incorporating-cc-adaptation-into-regional/view.html> (<http://goo.gl/n4DW7>)
  - Guidance for revising a Conservation Action Plan: <http://conserveonline.org/workspaces/climateadaptation/documents/climate-change-project-level-guidance/view.html> (<http://goo.gl/WbD9O>)
  - Open Access journal article describing TNC’s original climate clinic, including a Great Lakes team. Poiani et al. 2011. Biodiversity Conservation 20: 185-201. <http://www.springerlink.com/content/f0125g2575220423/> (<http://goo.gl/joQVs>)

**59. Model Forest Policy Program:** Building forest and water adaptation capacity at the community level.

- Main site: <http://www.mfpp.org/>
- Direct link to the Climate Solutions University: <http://www.mfpp.org/csu/>

**60. GEOS Institute**

<http://www.geosinstitute.org/>

- The ClimateWise Program of the GEOS Institute specializes in helping communities conduct risk assessments and initiate climate change adaptation planning.

**61. Trust for Public Land Northwoods Initiative**

<http://www.tpl.org/what-we-do/where-we-work/minnesota/Northwoods-Initiative.html> (<http://goo.gl/U3Lms>)

- The Trust for Public Land designed a focused program to protect important landscapes in Minnesota, Wisconsin, and Michigan. TPL’s goal is to protect water quality, prevent forest fragmentation, and continue to manage resources sustainably to benefit local economies.

**62. EcoAdapt’s Climate Adaptation Knowledge Exchange**

<http://www.cakex.org/>

- Aimed at building a shared knowledge base for managing natural systems. Also see “Climate Savvy” EcoAdapt’s book on adaptation (L. Hansen and J. Hoffmann).

**63. U.S. Climate Change Science Program’s Preliminary Review of Adaptation Options for Climate-Sensitive Ecosystems and Resources** (source of 7 R’s)

<http://www.climatescience.gov/Library/sap/sap4-4/final-report/> (<http://goo.gl/8WCU8>)

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