Literature Review for Evaluation Criteria and Candidate Best Practices for Michigan Coastal Wetlands Adaptation

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Background

Michigan coastal wetlands provide habitat for numerous species of plants and animals, and help maintain water quality for Michigan and the entire Great Lakes basin. Based on the Great Lakes Coastal Wetland Consortium inventory of coastal wetlands, Michigan has approximately 275,748 acres of Great Lakes coastal wetlands.[1] These wetlands are managed by the Department of Environmental Quality (DEQ) and supported by state and federal partnerships. Four aspects of wetland management identified by the state include monitoring, preservation, restoration, and climate change.[2] Given the recognition by the state of the importance of considering climate change adaptation in wetland management, the Michigan Department of Environmental Quality Coastal Management Program awarded the Great Lakes Commission (GLC) a grant to identify, through a collaborative process, best practices for coastal wetland adaptation. The National Wildlife Federation (NWF) was a subcontractor for the project and led the preparation of this literature review, which summarizes the process and associated literature used to develop candidate best practices for climate change adaptation in Michigan wetlands.

Given the many functions and values provided by coastal wetlands, their survival and health is important, including in changing climatic conditions such as warmer air and water temperatures, extreme and variable precipitation patterns and attendant changes in water levels, changing soil conditions, wildlife phenology, and migration patterns.[3] In addition to their importance as habitats, coastal wetlands have other key functions and values as well, including helping to protect water supply, enhancing water quality (e.g., through retaining nutrients), and supporting economic activities such as recreation and tourism. Actual responses of wetlands to climate change will depend on a number of factors, including wetland type and factors affecting runoff and evapotranspiration (e.g., vegetation type and extent, land use).[4]

Concerning climate change adaptation of coastal wetlands, there has been significant work on marine systems, and a number of case studies have been reported.[5] The importance of freshwater coastal wetlands in broader ecosystem health has long been recognized, including in the Great Lakes.[6] However, there have been relatively few efforts at identifying issues specific to coastal wetland adaptation in the Great Lakes, and limited site-specific work, in particular having research components.

Defining what it means to focus on climate change adaptation in a coastal wetland context – and in adaptation in general – requires accounting for multiple issues of scale, complexity, multidisciplinarity, and societal values.[7] Concerning scale, work can include using scientific understanding obtained at a larger scale and applying it at the local level. It requires a general understanding of vulnerabilities to climate change (amongst other stressors) and finding actions that reduce these vulnerabilities. For example, a manager might begin with strategies such as develop restoration projects that are resilient to a wider range of future lake levels and then develop actionable items that are appropriate for a particular location, given the ecological conditions,

specific vulnerabilities, management objectives, and perhaps social constraints on that system. Indeed accounting for plausible future conditions in goal- and objective-setting regarding wetlands management is a key principle characterizing sound climate adaptation in general.[8] In addition, the possibility of significant impacts of future climate change (including beyond recent historic variability) highlights the need for potentially increased human intervention (e.g., in water control, expanded buffer areas, increased protected areas) to ensure particular wetlands can be optimally protected and restored.

This literature review was intended to help identify candidate best practices and criteria by which to evaluate those practices that could be used by the core team (working with the Project Review Committee) ultimately to select those practices which are "best" at supporting adaptation of Michigan's coastal wetlands to climate change. The literature review was not intended to be a comprehensive review of all peer-reviewed and grey literature related to wetlands adaptation, but rather focus on representative work readily available and deemed relevant to adaptation of Michigan coastal wetlands. The effort targeted both peer-reviewed publications (including available through Web of Science) and grey literature (including from government agencies, nongovernmental organizations, and other entities). In addition, solicitation of input from the Project Review Committee was also conducted. For this project, it was understood that coastal wetland adaptation could include both incorporating adaptation considerations into restoration actions as well as altering other practices or actions in the watershed (such as local land use planning, agricultural practices) to reduce vulnerability of particular wetlands to climate change.

Evaluation Criteria

Evaluation criteria were identified to assess the extent to which wetland management programs and practices—candidate best practices—actually enhance the ability of Michigan wetlands to adapt to climate change—are actually "best". Robust criteria will account for uncertainty by embracing multiple principles within adaptive management and scenario planning.[9] After examining a number of criteria and more specific aspects, our team concluded that the criteria we use to evaluate a "best practice" should include measures such as importance, effectiveness, urgency, sustainability, co-benefits and side effects, reversibility, flexibility, resilience, robustness as well as political and cultural acceptability. These measures drew heavily on a technical paper developed to guide adaptation in Europe.[10]In addition, the consideration of optimal measure and criteria specific to Michigan wetlands adaptation drew heavily on earlier drafts of a recently published report reviewing adaptation considerations in the U.S.[11]

Understanding that wetland responses to climate change can be site-specific,[12] we recognized the importance of developing project level (site-specific criteria) for candidate best practices. A key element of effective climate change adaptation is that managers clearly link proposed actions to likely impacts based on some level of analysis or logic model (whether quantitative or conceptual).[13] This approach was carried out in developing the project level criteria.

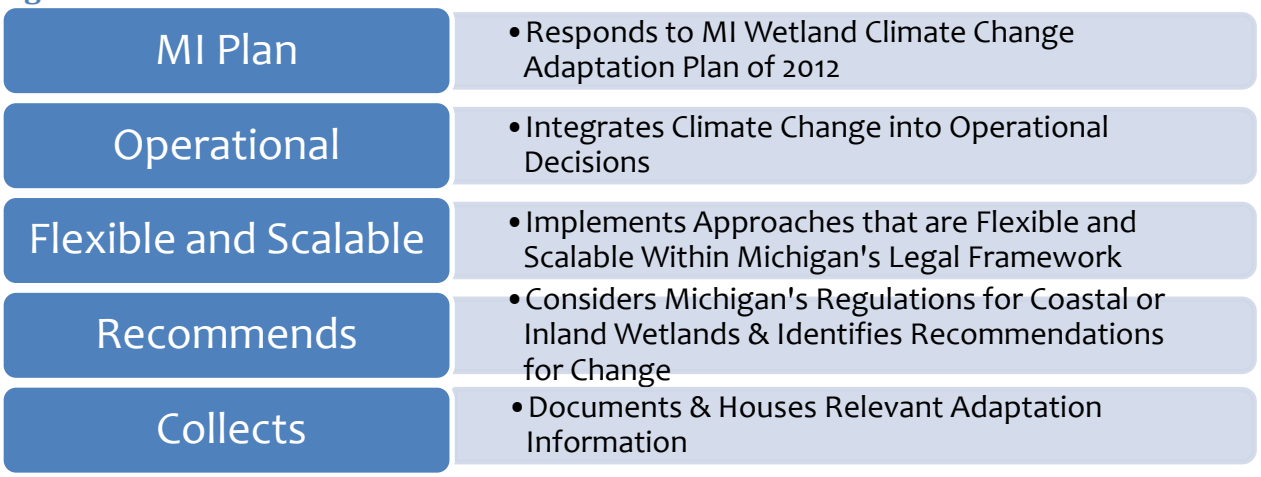
Climate change adaptation will also include addressing programmatic and other institutional constraints and enabling conditions such as existing institutional frameworks, laws and regulations or lack thereof and obsolete or ineffective management or operational procedures (e.g., requirements regarding historical data to inform future decisions).[14] Accordingly, institutional level evaluation criteria were also developed for the potential to enhance governance and institutional capacity around wetlands management to anticipate and respond to climate change. Institutional level evaluation criteria, in this case, were specific to Michigan, but the process also considered local and federal requirements. And it is assumed the types of criteria developed would be applicable in other jurisdictions.

In sum, criteria were developed for evaluating and selecting best practices at both the project/site level as well as the institutional level. We also considered criteria that would enable a determination as to whether a best practice is transferrable to other areas within the Great Lakes region, or other states throughout the country. Figures 1 and 2 summarize the project level and institutional level evaluation criteria used in the end.

Figure 1. Project Level Criteria

Links	• Links Restoration/Management Actions to Climate Impacts/Vulnerability
Decisions	• Integrates Climate Change into Decision-Making Framework
Future Goals	• Develops Goals & Objectives That Learn from Past, Look to Future
Measures and Monitors	• Incorporates Climate Change Into Performance Measures and Monitoring
Broadly Evaluates	• Evaluates Benefits and Impacts at Multiple Spatial Scales
Plans for Variation	• Examines and Plans for Range of Greater Variation or Decision-relevant Uncertainties

Figure 2. Institutional Level Criteria



Candidate Best Practices

In climate change adaptation, "best practices" transpire at multiple levels. Concerning coastal wetland adaptation as envisioned in this project, a best practice can occur at either the project or institutional levels. The project level is site-specific, using the Michigan DEQ definition of site, but expanding out to the adjacent area, migratory pathway, or riverine system, when assessing climate change vulnerability. At the institutional level, best practices are Michigan state-level specific, but as noted above, allow for consideration of local and federal requirements as well.

The term "best practice" generally describes a method or technique that has consistently shown results superior to those achieved with other means. At this point in adaptation of Michigan's wetlands, we do not have enough information to determine whether all individual practices deliver consistent, superior results. Instead, through the literature review (see annotated bibliography at end), and iterative consultations with the Project Review Committee, the team generated a list of "good" or "emerging" practices, or "candidate best practices." Again, some of these are formally cited in the literature while others are suggestions from experience among the PRC members or are inferred in reports that address wetlands or climate change adaptation more generally but not necessarily both. The candidate best practices were evaluated and ranked by PRC members using the selected evaluation criteria described above and a simple numeric scoring system, leading to a shorter list of practices deemed by the group to be most promising in wetland adaptation efforts. Our selected list of "best practices" exemplify different approaches for responding to climate change impacts for various situations. They highlight courses of adaptation actions that are expected to be most efficient and effective by taking into account relevant measures of successful adaptation, as noted above.

Annotated Bibliography

This section highlights references and resources (with citations, summaries, and relevance to criteria and/or individual best practices) identified by core team members and Project Review Committee members during the literature review phase of this project as relevant to coastal wetlands adaptation in Michigan.

Title: Adaptation Collaboratory
Full Citation: University of Notre Dame and The Nature Conservancy, Adaptation Collaboratory, available from https://adapt.nd.edu/.
Summary: The website is a resource for research, education, and collaboration in the area of adaptation and climate change. It incorporates a multitude of tools, which take several forms including modeling, searchable clearinghouses of legal information, and dissemination of emerging opinion from experts on the benefits and challenges with adaptation implementation. These tools can be used individually and in an integrative way to inform decision-making, research, and awareness.
Relevance to Criteria or Best Practices: As with CAKE, this clearinghouse provides publication, tools, and other information relevant to this project, and individual components are relevant to multiple criteria and several best practices in general. However, one issue is the relatively limited number of wetland adaptation case studies compiled to date.

Title: Adaptation of Shoreline Best Management Practices
Full Citation: EOR, Inc. (undated) EOR - Helping to Address Climate Change, available from http://www.eorinc.com/EOR-ClimateChangeGrant.php.
Summary: A multi-agency effort involving EOR, Inc. and the University of Minnesota, with funding from the Minnesota Pollution Control Agency, investigated the impacts of climate change on shoreline processes (including vegetation condition) and how policies and shoreline best management practices (BMPs) can be modified to address climate change. The project was to entail modeling, field experimentation, and monitoring, with results to be made available to local units of government and firms engaged in BMP installation.
Relevance to Criteria or Best Practices: The case study is relevant to several project level criteria as well as several best practices, including consideration of climate in wetland and shoreline restoration.

Title: Adapting to Climate Change: A Planning Guide for State Coastal Managers

Full Citation: National Oceanic and Atmospheric Administration (NOAA), 2010. Adapting to Climate Change: A Planning Guide for State Coastal Managers, NOAA Office of Ocean and Coastal Resource Management, available from http://coastalmanagement.noaa.gov/climate/docs/adaptationguide.pdf.

Summary: The guide was developed by NOAA to assist state and territorial coastal managers in developing and implementing adaptation plans to reduce the impacts and consequences of climate change and variability. The guide discusses the planning process, development of a vulnerability assessment, development of an adaptation strategy, and implementation and maintenance of the plan. Appendices include information on federal funding sources, federal laws and executive orders related to climate change, and brief regional climate impact overviews.
Relevance to Criteria or Best Practices: The guide is relevant to several criteria and several best practices, including climate vulnerability assessments.

Title: Building Capacity for Climate-Resilient Communities and Water Conservation in the Huron River Watershed
Full Citation: Gregg, R. M. 2012. (Updated 2013). Building Capacity for Climate-Resilient Communities and Water Conservation in the Huron River Watershed [Case study on a project of the Huron River Watershed Council], available from http://www.cakex.org/case-studies/building-capacity-climate-resilient-communities-and-water-conservation-huron-river.
Summary: This case study involves climate adaptation efforts of the Huron River Watershed Council (HRWC), a nonprofit in Ann Arbor, MI engaged in protecting and sustaining resources in the Huron River Watershed. The HRWC has been engaged in climate change work for some time, including developing an adaptation project entitled Making Climate-Resilient Communities. The project has involved multiple funders and partnership with the Great Lakes Integrated Sciences and Assessment program, and has included multiple workshops with local community members, with work divided among three workgroups: water infrastructure, in-stream flows, and natural infrastructure (with the latter including wetland restoration). A number of strategies have come out of the workshops, including related to water infrastructure improvements, broadening of education and outreach efforts, and incorporating climate change in to regulations and permitting.
Relevance to Criteria or Best Practices: The case study is relevant to several of the criteria in this project (in both project and institutional groups), including around decisionmaking, and informed several best practices related to partnerships, convening workshops, and development of local ordinances considering climate change.

Title: Climate Adaptation Knowledge Exchange (CAKE)
Full Citation: EcoAdapt, Climate Adaptation Knowledge Exchange (CAKE), available from http://www.cakex.org/.
Summary: The Climate Adaptation Knowledge Exchange (CAKE) was founded by EcoAdapt and Island Press in July 2010, and is managed by EcoAdapt. It aims to build a shared knowledge base for managing natural and built systems in the face of rapid climate change. Just as importantly, it is intended to help build an innovative community of practice. It helps users to get beyond the limitations of their time and the unwieldy thicket of books, papers and articles by:

- Vetting and organizing the best information available, including providing summaries of individual efforts,
- Building a community via an interactive online platform,
- Creating a directory of practitioners to share knowledge and strategies, and
- Identifying and explaining data tools and information available from other sites.

Users desiring more information on summarized case studies can go to original source materials, linked from the site.
Relevance to Criteria or Best Practices: Given the numerous case studies (and original research and other work) available in the system, this source in aggregate is relevant to multiple criteria as well as a number of best practices.

Title: Climate Change Adaptation: A Priorities Plan for Canada
Full Citation: Feltmate, B., Thistlethwaite, J., 2012. Climate Change Adaptation: A Priorities Plan for Canada; Report of the Climate Change Adaptation Project (Canada), available from http://uwaterloo.ca/environment/sites/ca.environment/files/uploads/files/CCAP-Report-30May-Final.pdf.
Summary: This project aimed to identify and prioritize solutions to address climate change threats to Canada, in particular around adaptation approaches. The effort entailed examining climate change projections for the country, utilizing experts to identify key climate challenges, utilizing an advisory committee to rank sectors, and utilize experts to identify actions addressing challenges in priority sectors identified. One of the top sectors was freshwater, and the resulting action was to "establish a national priority to identify, preserve, and/or restore wetlands that are 'key capacitors' within watersheds across Canada…" The report notes the importance of wetlands in several Canadian regions, threats they are under, several wetland initiatives underway, and the importance of developing new wetland restoration policies as an adaptation measure.
Relevance to Criteria or Best Practices: The effort overall is relevant to several criteria and several best practices, including regarding partnering with experts, engaging stakeholders, and incorporating climate change in land protection decisions.

Title: Climate Change Adaptation Plan for Coastal and Inland Wetlands in the State of Michigan
Full Citation: Christie, Jeanne, P. Bostwick. 2012. Climate Change Adaptation Plan for Coastal and Inland Wetlands in the State of Michigan. The Association of State Wetland Managers, Inc.: Windham, ME, available from http://www.michigan.gov/documents/deq/Michigan_Wetlands_and_Climate_Change_Report_Final_Final_403251_7.pdf.
Summary: The report presents general information about climate change impacts to Michigan's wetlands, a synthesis of various local workshops on coastal adaptation, state strategic approaches on climate change, case studies of adaptation planning in

other states, and recommendations. The purpose of this plan is to give background information on coastal wetland adaptation in Michigan and to make recommendations for state wetland management in a changing climate. The Handbook also is not intended as legal or environmental advice or as a best practices manual. This handbook is intended to facilitate navigation of a wide array of statutory and regulatory programs, especially those of which that have relevance to adaptation.
Relevance to Criteria or Best Practices:: Because this is a Michigan-focused plan on adaptation, it was highlighted in the form of a separate criterion.

Title: Climate Ready Great Lakes
Full Citation: National Oceanic and Atmospheric Administration, Great Lakes Region, Climate Ready Great Lakes, available from http://www.regions.noaa.gov/great-lakes/index.php/resources/climate-ready-great-lakes/.
Summary: The National Oceanic and Atmospheric Administration (NOAA) Great Lakes Regional Collaboration Team, working with the Great Lakes Sea Grant Network and University of Michigan School of Natural Resources and Environment produced training modules to inform adaptation efforts in the region. The approach consists of three modules, each of which has a slide presentation and supplemental materials (including handouts, worksheets, and evaluation forms). The modules address three aspects of adaptation, including predicted climate impacts in the region (including discussion on variability), approaches to adaptation (including in relation to stormwater management, infrastructure, and ecosystems), and tools to assist in the entire process, including on vulnerability assessments and adaptation planning.
Relevance to Criteria or Best Practices: Because the modules were developed for the Great Lakes region, they are particularly suited to adaptation in Michigan coastal areas, address several of the criteria considered in this process, and also informed several best practices, in particular on continuing education and cross-training.

Title: Climate-Smart Restoration of the Black River.
Full Citation: Inkley, D. 2013. Climate-Smart Restoration of the Black River, National Wildlife Federation. Also see summary in Koslow, M., J. Berrio, P. Glick, J. Hoffman, D. Inkley, A. Kane, M. Murray and K. Reeve. 2014. Restoring the Great Lakes' Coastal Future - Technical Guidance for the Design and Implementation of Climate-Smart Restoration Projects with Seven Case Studies. National Wildlife Federation, Reston, VA and National Oceanic and Atmospheric Administration, Silver Spring, MD, available from http://www.nwf.org/What-We-Do/Energy-and-Climate/Climate-Smart-Conservation/Adaptation-on-the-Ground/Great-Lakes-Projects.aspx.
Summary: As part of a broader project funded by National Oceanic and Atmospheric Administration and the Kresge Foundation to advise on adaptation restoration, NWF was involved in advising restoration efforts in the lower Black River draining to the

central basin of Lake Erie in Ohio. The area saw significant impacts from industrial development, and design addressed several issues, including slag debris removal, streambank stabilization and revegetation, and other habitat restoration. A vulnerability assessment identified several modifications to pursue in the project, including regarding choices of tree species in planting efforts, prioritizing streambank revegetation to address projected variable streamflow conditions, and install variable height fish habitat shelves to better accommodate both low and high river flows.
Relevance to Criteria or Best Practices: The case study entailed work with a number of partners, and is particular relevant to the best practice concerning climate change vulnerability assessments.

Title: Climate-Smart Restoration of Little Rapids
Full Citation: Haven, C. 2013. Climate-Smart Restoration of Little Rapids. National Wildlife Federation, Ann Arbor, MI. Also see summary in Koslow, M., J. Berrio, P. Glick, J. Hoffman, D. Inkley, A. Kane, M. Murray and K. Reeve. 2014. Restoring the Great Lakes' Coastal Future - Technical Guidance for the Design and Implementation of Climate-Smart Restoration Projects with Seven Case Studies. National Wildlife Federation, Reston, VA and National Oceanic and Atmospheric Administration, Silver Spring, MD, available from http://www.nwf.org/What-We-Do/Energy-and-Climate/Climate-Smart-Conservation/Adaptation-on-the-Ground/Great-Lakes-Projects.aspx.
Summary: In another NOAA-funded project, Eastern U.P. Regional Planning & Development Commission led a grant to restore habitat in the Little Rapids area of the St. Mary's River Area of Concern (near Sault Ste. Marie, MI), with NWF advising on climate adaptation. The project entailed hydraulic flow modeling to assess the potential impacts of restoration of 70 acres of habitat and associated ecosystem processes. Potential climate change impacts considered included ensuring consideration of potential regional precipitation changes in modeling, and considering ice formation and other impacts of removal of a causeway in the channel.
Relevance to Criteria or Best Practices: The case study is relevant to several project level criteria, as well as several best practices, including on vulnerability assessments and considering multiple climate scenarios.

Title: Climate-Smart Restoration of the Maumee Area of Concern
Full Citation: Koslow, M. 2013. Climate-Smart Restoration of the Maumee Area of Concern, National Wildlife Federation, Ann Arbor, MI. Also see summary in Koslow, M., J. Berrio, P. Glick, J. Hoffman, D. Inkley, A. Kane, M. Murray and K. Reeve. 2014. Restoring the Great Lakes' Coastal Future - Technical Guidance for the Design and Implementation of Climate-Smart Restoration Projects with Seven Case Studies. National Wildlife Federation, Reston, VA and National Oceanic and Atmospheric Administration, Silver Spring, MD, available from http://www.nwf.org/What-We-

Do/Energy-and-Climate/Climate-Smart-Conservation/Adaptation-on-the-Ground/Great-Lakes-Projects.aspx.
Summary: As part of the same broader NOAA- and Kresge Foundation-funded project, NWF was involved in this ongoing project with an emphasis on wetlands restoration in the Maumee Area of Concern (AOC) in western Lake Erie. The overall project goal was to restore 600 acres of coastal wetlands in four tracts, with separate goals and approaches for each of the sites. NWF involvement included general literature review, working with project partners (including the Nature Conservancy, U.S. Fish and Wildlife Service, and others) to identify key climate drivers in the area, and carrying out a screening level vulnerability assessment. Outcomes of the effort included recommendations on approaches specific to individual restoration sites related to reforestation, fish passage, and wetland restoration.
Relevance to Criteria or Best Practices: The report has relevance to several project criteria as well as informing the selection of the best practices involving partnering with experts on climate change adaptation, conducting climate change vulnerability assessments, and monitoring to establish baseline conditions.

Title: Coastal Change Analysis Program
Full Citation: National Oceanic and Atmospheric Administration, Coastal Change Analysis Program, available from http://coast.noaa.gov/digitalcoast/data/ccapregional; H. Stirratt (NOAA), personal communication.
Summary: NOAA's Coastal Change Analysis Program (C-CAP) has developed a nationally standardized database of land cover and change information for U.S. coastal regions. The land cover maps (including intertidal areas, wetlands, and adjacent uplands) are updated every five years, allowing an assessment of locations and extent of changes occurring with time. The tool has been used to assess changes at Oconto Marsh on lower Green Bay (WI). The program showed that as water levels decreased, new wetlands developed. A related tool, Coastal County Snapshots, is also useful in highlighting and tracking wetland changes with time. Both tools can potentially be useful in the context of wetland mitigation (including in scenarios with wetland loss and gain in the same general region following water level changes.)
Relevance to Criteria or Best Practices: This program is relevant to several project level criteria, and also formed the basis for the best practice on using land cover/land use data to inform wetland planning and management at various jurisdictional levels.

Title: Edgewater Beach Overlay District, St. Joseph, Michigan
Full Citation: Edgewater Beach Overlay District, City of St. Joseph, Michigan, Zoning Ordinance, Section 9.7, available from http://www.sjcity.com/images/departments/planning_zoning/pdfs/Zoning_ordinance_amended_041414_eff_042414.pdf.
Summary: The ordinance, adopted in 2012, had the intent to "preserve the character of the public trust land" along the Lake Michigan shoreline, in particular in light of changing conditions. As noted in the ordinance, periods of low water levels can lead

to sand accretion, and the enlarged beach can be a target for development by local property owners. In contrast, periods of high water levels lead to submergence and erosion, and existing state and federal development standards do not ensure that damages to land during these periods will not occur. In addition, a natural reaction of property owners in such situations often being construction of a seawall, and these types of shore protection structures pose their own problems for public trust and other lands. In response to these types of problems, the ordinance prohibits construction shoreward of a fixed demarcation north of the St. Joseph River, highlighting the benefits that will accrue in both low and high-water situations.
Relevance to Criteria or Best Practices: Though the ordinance does not explicitly reference climate change, key impetus for it is clearly relevant to climate change (and the potential for changes in water level regimes, including extremes), and the ordinance is relevant implicitly to several criteria, and offers lessons for best practices related to zoning decisions in light of climate change (in particular concerning variable water levels).

Title: Flood Protection and Ecosystem Services in the Chehalis River Basin
Full Citation: Batker, D., Kocian M., Lovell, B, & Harrison-Cox, J. 2010. Flood Protection and Ecosystem Services in the Chehalis River Basin, Earth Economics, available from http://www.eartheconomics.org/FileLibrary/file/Reports/Chehalis/Earth_Economics_Report_on_the_Chehalis_River_Basin_compressed.pdf.
Summary: The report was developed to inform decisions on flood policy in the Chehalis River Basin in southwestern Washington, following severe flooding and establishment of the Chehalis River Basin Flood Authority. The study noted climate change projections for the region, noting predicted increases in total precipitation would mostly be in winter months, with the potential for increasing water supply concerns in summer months. The study had an emphasis on quantifying ecosystem services in the river basin, identified the many functions and values provided by wetlands (including regarding water supply), and identified freshwater wetlands as providing the greatest monetary value in the river basin.
Relevance to Criteria or Best Practices: The report is relevant to best practices related to quantifying ecosystem services in support of wetland protection and restoration, as well as potentially the consideration of climate change in wetland and shoreline restoration measures.

Title: Great Lakes Coastal Wetland Communities: Vulnerabilities to Climate Change and Adaptation Strategies
Full Citation: Mortsch, L., J. Ingram, A. Hebb, and S. Doka (eds.). 2006. Great Lakes Coastal Wetland Communities: Vulnerability to Climate Change and Response to Adaptation Strategies. Final report submitted to the Climate Change Impacts and Adaptation Program,
Natural Resources Canada. Environment Canada and the Department of Fisheries and Oceans, Toronto, Ontario. 251 pp. + appendices, available from

http://www.env.uwaterloo.ca/research/aird/aird_pub/Great_Lakes_Coastal_Wetlands_Report_2006.pdf.
Summary: Coastal wetlands in the Great Lakes region will be impacted by climate change. Namely, changes in water level could have dire consequences for existing wetlands and dependent bird and fish communities. This project entailed a review of potential impacts of climate change to Great Lakes coastal wetlands, assessed vulnerabilities, and identified evaluated adaptation options. Their approach included utilizing GIS to analyze shoreline vulnerabilities, develop and apply bird and fish habitat suitability models to projected climate change scenarios, and evaluate feasibility and effectiveness of adaptation strategies.
Relevance to Criteria or Best Practices: The approach is relevant to several criteria and best practices, including on data acquisition, modeling, and vulnerability assessments.

Title: Great Lakes Dashboard Project; Lake Level Viewer: United State Great Lakes
Full Citation: National Oceanic and Atmospheric Administration, U.S. Army Corps of Engineers, Great Lakes Environmental Research Laboratory, Great Lakes Commission, Cooperative Institute for Limnology and Ecological Research, Great Lakes Restoration Initiative, Great Lakes Dashboard Project. Available from http://www.glerl.noaa.gov/data/dashboard/portal.html; National Oceanic and Atmospheric Administration, Digital Coast, Office for Coastal Management (and other collaborators), Lake Level Viewer: United State Great Lakes. Available from http://coast.noaa.gov/digitalcoast/tools/llv.
Summary: National Oceanic and Atmospheric Administration and other partners have been involved in development of tools relevant to coastal wetlands. The Great Lakes Dashboard Project provides graphical display of a number of physical parameters, including water levels (monthly, annual, and period of record averages), wind speed, air and water temperature, ice cover, and other parameters, and output format is customizable (e.g. time scales, vertical axes). The Lake Level Viewer Great Lakes module was recently released, and allows for visualizing changes in lake levels in the lakes (up to six feet below and above historical long-term averages), as well as coastal and shoreline impacts. The tool provides images of each Great Lake, showing areal change in shoreline with user-selected changes in water levels, and also allows examining potential impacts via photographic images at specific locations around the Basin. Other tools are also linked from Lake Level Viewer. Given the importance of lake levels in wetland extent and condition, these tools and others can assist in adaptation planning, in examining impacts of historical changes and potential future changes with climate change.
Relevance to Criteria or Best Practices: These tools are relevant to several criteria and informed the best practice on coastal wetland monitoring.

Title: Lake Superior National Estuarine Research Reserve

Full Citation: National Oceanic and Atmospheric Administration, Lake Superior National Estuarine Research Reserve, available from http://lsnerr.uwex.edu/; B. Schleck (NOAA), personal communication.
Summary: As part of planning efforts at the Lake Superior National Estuarine Research Reserve, near Superior, WI, significant stakeholder work has been carried out. This included outreach with three different focus groups in support of Sentinel Site development at the NERR. Outreach by NOAA staff targeted a diverse audience, including other federal agencies, state and tribal agencies, academic researchers, and others to characterize ongoing monitoring of vegetation and climate parameters in the region, as well as to determine the extent of stakeholder needs in these and related areas.
Relevance to Criteria or Best Practices: The effort is relevant to several project criteria, and also informed the best practice on engaging multiple stakeholders and interest groups.

Title: Metro Beach Metropark and St. John's Marsh
Full Citation: Michigan Sea Grant, 2011. Metro Beach Metropark and St. John's Marsh, available from http://www.miseagrant.umich.edu/explore/restoration/marsh-restoration-project/; L. Vaccaro (MI Sea Grant), personal communication.
Summary: A cooperative effort of Michigan Sea Grant, Michigan Department of Natural Resources, Ducks Unlimited and other partners has been involved in a project to restore coastal marshes in the St. Clair watershed, with an emphasis on this case in controlling invasive *Phragmites*. The invasive plant with the potential to outcompete most other marsh plants is threatening marsh biodiversity in much of Michigan and throughout the region, impairing wildlife habitat, views, and recreational access. Treatment in this case has included herbicide application and controlled burns. Though not explicitly an adaptation measure, controlling *Phragmites* and improving wetland plant biodiversity can contribute to increased resiliency to climate change, and climate change considerations can help inform selection of areas to prioritize for *Phragmites* control.
Relevance to Criteria or Best Practices: The case study is relevant to the first project level criteria, and also the best practice consideration of climate in wetland and shoreline restoration.

Title: Municipal Adaptation & Resiliency Service (MARS)
Full Citation: Great Lakes and St. Lawrence Cities Initiative, Great Lakes & St. Lawrence Cities Initiative Municipal Adaptation & Resiliency Service (MARS), available from https://www.ccadaptation.ca/en/mars.
Summary: The Municipal Adaptation & Resiliency Service (MARS) was created by the Great Lakes & St. Lawrence Cities Initiative, the Ontario Centre for Climate Impacts and Adaptation Resources, and the Climate Action Partnership, with the goal of increasing climate change adaptation and resiliency in the over 100 cities represented in the Cities Initiative. The MARS service includes a "Call to Action" pledge (on adaptation commitments), the provision of adaptation training Webinars, and a

community of practice portal with a number of resources, including reports, case studies, fact sheets, and tools to assist in adaptation project implementation.
Relevance to Criteria or Best Practices: The resource is directly tied to the institutional criterion on collecting information, and informed several best practices, including on continuing education and processes for information access.

Title: New York City Wetlands Strategy
Full Citation: Mayor's Office of Long-Term Planning & Sustainability, 2012. New York City Wetlands Strategy, available from http://www.nyc.gov/html/planyc2030/downloads/pdf/nyc_wetlands_strategy.pdf.
Summary: Like many other parts of the country, the New York City region has seen significant wetlands losses, with over 85% of coastal wetlands and 90% of freshwater wetlands lost through development and other activities. The city Wetlands Strategy was developed to address these losses and ongoing pressures on wetlands, and address issues such as regulatory gaps, information limitations, funding limitations, and threats from climate change. The Strategy proposed work in four areas – protection, mitigation, restoration, and assessment. Individual initiatives were identified in each area, and climate change would be considered across a number of initiatives, including in monitoring and assessing potential impacts of sea level rise, ensuring climate change is considered in further research on wetlands in the area, and incorporating understanding of climate change impacts into local education programs.
Relevance to Criteria or Best Practices: The Strategy has relevance to institutional criteria (in particular related to decisionmaking), and offers lessons concerning regulatory best practices (e.g., compliance/permitting), including in implementation of the Waterfront Revitalization Program (in lieu of any local wetland statutes or regulations).

Title: Pristine Lands Protected at Bete Grise Preserve.
Full Citation: Michigan Office of the Great Lakes, Coastal Zone Management Program, Pristine Lands Protected at Bete Grise Preserve, available from www.michigan.gov/deq/0,4561,7-135-3313_3677_3696-311958--,00.html.
Summary: A multi-phase land purchase project was undertaken to protect wetlands at Bete Grise in Keweenaw County along Lake Superior in Michigan's Upper Peninsula. Funding provided through the Great Lakes Restoration Initiative, the NOAA Coastal and Estuarine Land Conservation Program, and other partners enabled the Houghton-Keweenaw Conservation District to purchase over 1,000 acres of land in 2012-13 adjacent to the existing preserve. Though not explicitly an adaptation effort, partners recognized the increased protected areas should provide benefits in the context of a changing climate (and potential wetland movement).
Relevance to Criteria or Best Practices: This effort is directly related to best practice involving consideration of climate in land protection decisions.

Title: Criteria for Evaluation of Wetland Permits
Full Citation: Michigan Natural Resources and Environmental Protection Act (Act 451) of 1994, Section 30311, as amended.. Available from www.legislature.mi.gov/doc.aspx?mcl-Act-451-of-1994
Summary: This section of Michigan law describes requirements for issuance of a permit under state and federal law. Some provisions that have been needed to protect wetlands from historic or ongoing threats can in some cases hinder restoration efforts, if the broader habitat restoration and enhancement goals are not considered. Additionally, it is important that climate change be considered in permit applications, including to ensure that projects are designed to enhance wetland adaptation.
Relevance to Criteria or Best Practices: These issues are related in particular to several institutional level criteria (including on changes needed to regulations) as well as the wetland permitting best practice.

Title: Rein in the Runoff: Michigan's Spring Lake Stormwater Management Project
Organization: **Publishing Date**: 2013
Citation: Feifel, K. M. 2012. Rein in the Runoff: Michigan's Spring Lake Stormwater Management Project [Case study on a project of Michigan Sea Grant], available from http://www.cakex.org/case-studies/rein-runoff-michigans-spring-lake-stormwater-management-project.
Summary: Over the past few decades, stormwater has increased pollutant loads in Spring Lake, Michigan. In 2007, a collaborative team of researchers began working with the community of Spring Lake to develop an integrated assessment of Best Management Practices (BMPs) to reduce local stormwater impacts. The integrated assessment process involved a detailed assessment of natural, economic, and social issues, future population growth scenarios, and an analysis of potential BMPs. The final report, Rein in the Runoff, was released in 2009 and decision-makers are using it to help guide the development and implementation of local ordinances and structural improvements to reduce stormwater impacts. The current and future state of the Spring Lake watershed was assessed using the following research tools:

- a regional wetlands and shoreline assessment,
- a systematic comparison of potential stormwater solutions (both structural and nonstructural-ordinance based BMPs),
- economic analyses of different BMP alternatives, and
- forecasts of future land use and land cover change related to population growth.

Relevance to Criteria or Best Practices: This project was relevant to several criteria, and though the effort did not have an emphasis on climate change, the scenario planning concerning land use/land cover changes could be expanded to consider impacts of different climate change scenarios.

Title: Soft Shoreline Engineering in the Detroit River and Western Lake Erie

Full Citation: University of Windsor, Soft Shoreline Engineering, available from http://web4.uwindsor.ca/units/stateofthestraight/softs.nsf/inToc/D27D2ED7AB6CBCE48525775F00726983?OpenDocument.
Summary: The Huron-Erie Corridor, including the Detroit River, has witnessed some of the greatest shoreline alterations (in particular hardening) in all the Great Lakes. Through a project involving researchers at the University of Windsor, a number of soft shoreline engineering case studies in the region were compiled. The projects, most located along the Detroit River, included a range of technologies to achieve varying degrees of shoreline softening, including use of flexible plastic revetments; dam removal and standard stream restoration; replacement of concrete shore protection structure with diversity of stone types; and removal of invasive Phragmites and native planting.
Relevance to Criteria or Best Practices: The case studies are relevant to several best practices related to mitigation and restoration, including climate considerations in wetland and shoreline restoration.

Title: South Bay Salt Pond Restoration Project, Adaptive Management Plan
Full Citation: Trulio, L., D. Clark, S. Ritchie, A. Hutzel, and the Science Team, 2007. Science Team Report for the South Bay Salt Pond Restoration Project, Adaptive Management Plan, Final Environmental Impact Statement/Report, Appendix D, available from http://www.southbayrestoration.org/pdf_files/SBSP_EIR_Final/Appendix%20D%20Final%20AMP.pdf. Also, summarized in Kershner, J. 2010. South Bay Salt Pond Restoration Project, case study, available from http://www.cakex.org/case-studies/south-bay-salt-pond-restoration-project.
Summary: The South Bay Salt Pond (SBSP) Restoration Project has been identified as the largest tidal restoration project on the West Coast, with a goal of transforming 15,100 acres of former leveed salt ponds to tidal wetlands and managed pond habitats. In addition, it is anticipated that the restored tidal wetland system will provide a natural buffer against sea level rise, coastal flooding, and erosion, all with potential to increase with climate change. The project included earlier development of an Adaptive Management Plan, with an emphasis on learning from restoration and management actions, and the plan itself being adaptive, with key uncertainties, applies studies, and institutional structure potentially changing over time. Given the numerous uncertainties, managers determined that project activities would be implemented in phases, utilizing adaptive management to determine the extent to which the system can move toward full tidal action (and associated habitats).
Relevance to Criteria or Best Practices: This project is relevant to a number of project level criteria, and in its approach, can offer suggestions relevant to several institutional best practices.

Title: State Hazard Mitigation Plans & Climate Change: Rating the States
Full Citation: Babcock, M., 2013. State Hazard Mitigation Plans & Climate Change: Rating the States. Available from

http://web.law.columbia.edu/sites/default/files/microsites/climate-change/files/Publications/Students/SHMP%20Survey_Final.pdf
Summary: Federal law requires that states can only receive disaster mitigation funding from the federal government if they have an approved hazard mitigation plan in place, though there are no requirements that such plans include discussion of potential climate change implications for natural hazards. A survey was conducted to assess the extents to which state hazard mitigation plans address climate change. The analysis grouped states in four categories, ranging from 1 (no or inaccurate discussion of climate change) to 4 (thorough discussion of potential impacts on hazards and adaptation options). The survey found that coastal states in general were more likely to address climate change. Michigan ranked in group 3, with limited discussion of climate change, but emphasis on the need to more systematically consider it in future plans. The report also noted that lessons from states with some type of consideration of climate change in their plans could potentially be applied to other states.
Relevance to Criteria or Best Practices: This document informed the best practice on including analysis of climate change in state hazard mitigation plans.

Title: Terrestrial Carbon Sequestration Monitoring Networks and Demonstration Sites
Full Citation: Nater, E.A., C. Miller, 2008. Terrestrial Carbon Sequestration Monitoring Networks and Demonstration Sites, Report to the Minnesota Department of Natural Resources. Available from http://files.dnr.state.mn.us/aboutdnr/reports/legislative/terrestrial_carbon.pdf.
Summary: The report summarizes findings on a study carried out by University of Minnesota researchers upon request by the Minnesota State Legislature on the potential of terrestrial carbon sequestration in the state. The request included identification of a network of monitoring sites to measure the large-scale, long-term potential capacity of carbon sequestration of various land types, as well as identify potential demonstration projects to measure the impact of deliberate sequestration practices. Though not focused on wetlands, two of the proposed demonstration project sites included wetland complexes, with proposals to quantify carbon stock changes of conversion from agriculture back to wetlands. The project did not appear to have an emphasis on coastal wetlands, though some lessons learned would presumably be transferable to coastal wetland ecosystems. In addition, if any carbon credit system were developed, carbon sequestration achieved via wetland restoration would presumably be part of such a system.
Relevance to Criteria or Best Practices: The concept is directly related to a potential best practice including consideration of carbon sequestration potential of wetlands restoration projects (as an additional ecosystem service provided by restoration).

Title: Updating the Illinois Wildlife Action Plan: Using a Climate Change Vulnerability Assessment to Inform Conservation Priorities

Full Citation: Kahl, K., Hall, K., Walk, J., Hagen, S., Lange, A., & Doran, P. (2011). Updating the Illinois Wildlife Action Plan: Using a Climate Change Vulnerability Assessment to Inform Conservation Priorities. [Case study on a project of The Nature Conservancy, Ed. Rachel M. Gregg], available from http://www.cakex.org/case-studies/5241.
Summary: The Nature Conservancy's vision of "climate-smart" conservation seeks to anticipate human responses to climate change, and considers the benefits to people that result from our actions to protect and restore nature. One key area for engagement and partnership has been work on state Wildlife Action Plans. This case study describes a vulnerability assessment of 163 species comprising eight taxonomic groups from Illinois' list of "Species in Greatest Need of Conservation" designated in the state's Wildlife Action Plan. High priority action items include: 1) As a strategy for reducing sediment and nutrient loads in waters draining from agricultural and developed areas, engineering standards for constructed wetlands need to be revised to account for more frequent high-precipitation events to avoid failure; 2) Chicago Wilderness' vulnerability assessments, already underway, will help prioritize species and habitat within their regional long term conservation strategies; and 3) Locations for endangered species reintroductions are being reconsidered based on the potential for long-term viability and stewardship, rather than only locations of historical occurrence.
Relevance to Criteria or Best Practices: This plan is relevant to several best practices, in particular climate vulnerability assessments.

Title: Visualizing Coastal Flooding and Lake Level Changes
Full Citation: Stone, J.D., Johnson, S. 2012. Visualizing Coastal Flooding and Lake Level Changes, available from http://greatlakesresilience.org/case-studies/land-use-zoning/visualizing-coastal-flooding-and-lake-level-changes; H. Stirratt (NOAA), personal communication.
Summary: Storm surges and coastal flooding can be issues in the Great Lakes, as was witnessed in Green Bay, WI on several occasions, both during high and low water levels.To help understand and prepare for such events, the NOAA visualization tool CanVis was used in a case study involving Brown County and the City of Green Bay. The tool includes descriptions of the short-term (e.g. wind-driven waves) and long-term factors (e.g. precipitation, ice cover) affecting water levels, and allows users to see potential impacts of different development and water level scenarios. The effort in Brown County and Green Bay is part of a larger effort involving development of an interactive mapping tool to assist public officials and private individuals in understanding coastal flooding hazards and consider management options.
Relevance to Criteria or Best Practices: The case study is relevant to several criteria and best practices, including on vulnerability analysis, land protection decisions, and considering multiple climate scenarios.

Title: Wetland Mitigation Banking

Full Citation: Michigan Department of Environmental Quality, Wetland Mitigation Banking, available from http://www.michigan.gov/deq/0,4561,7-135-3313_3687-10426--,00.html.

Summary: Wetland mitigation is required for many wetland permits issued under state or federal law, with a goal of replacing wetland functions lost as a result of some permitted activity. Wetland mitigation banking provides a mechanism for creating new wetland areas ("banks"), and the resulting "credits" can be sold to permit applicants or used by the bank sponsor to meet wetland permit conditions. In the context of climate change, mitigation banking has the potential to offer some benefits, through for example, by considering the broader area consisting of a number of smaller projects, and integrating mitigation projects with watershed based resource planning.

Relevance to Criteria or Best Practices: The program is potentially relevant to the best practice involving use of purchases and conservation easements in wetland protection and restoration.

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