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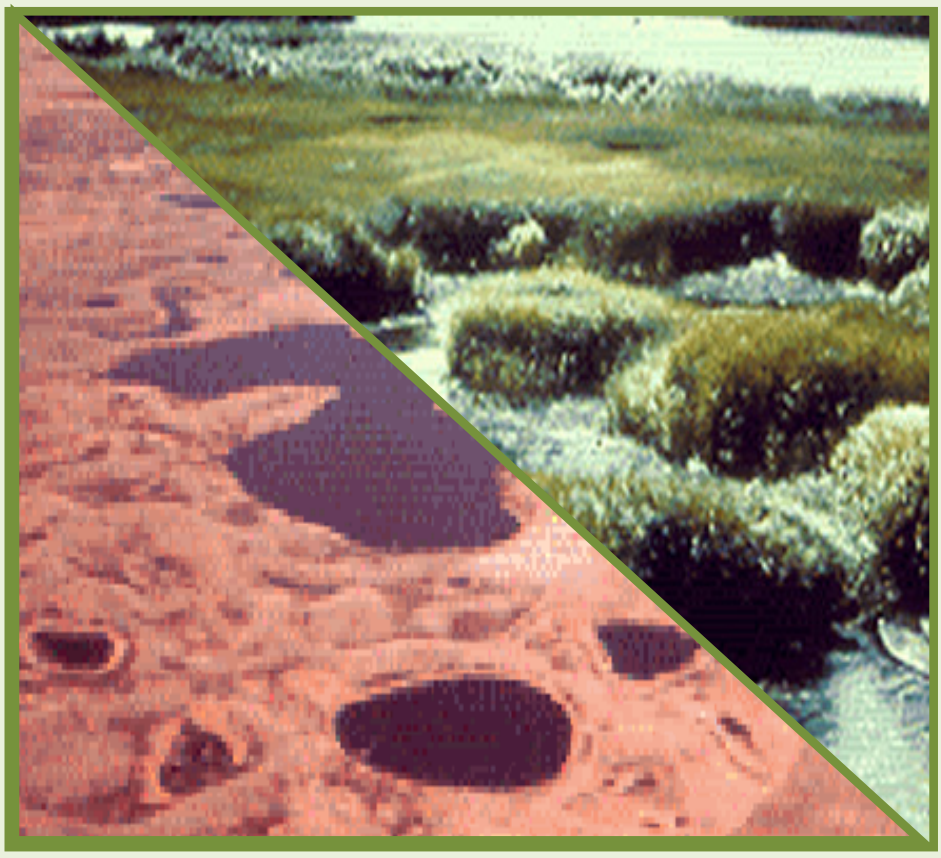
Recommendations for a National Wetlands and Climate Change Initiative



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PREFACE

The following recommendations have been prepared to stimulate discussion and build state/tribal/federal, local and private sector consensus on actions which may be taken to address a critical topic—the impact of climate change on wetlands and measures which may be taken to reduce or compensate for those impacts.

The recommendations are based upon speaker presentations at Wetlands 2008: Wetlands and Global Climate Change, conducted by the Association of State Wetland Managers and a broad range of cooperating parties September 16-18, 2008 in Portland, Oregon. More than 100 speakers made presentations at this meeting. There were 375 total attendees. See http://www.aswm.org/calendar/wetlands2008/agenda.htm for the PowerPoint presentations from this meeting.

This meeting was hosted by the Northwest Chapter of the Society of Wetland Scientists. Sponsors included the U.S. Environmental Protection Agency (EPA) Headquarters and Regions 8, 9, 10; U.S. Fish and Wildlife Service, Federal Highway Administration, Bureau of Land Management and the National Wildlife Federation. Cooperating parties included the U.S. Army Corps of Engineers, City of Eugene, Climate Impacts Group ad the University of Washington, the Coos Watershed Association; Duke University Wetland Center, Nicholas School of the Environment, Sierra Club and the Nature Conservancy. This support is gratefully acknowledged.

The recommendations also draw upon a series of five earlier scientific workshops concerning wetlands and climate change conducted by the Association of State Wetland Managers with support from the U.S. Geological Survey. However, the opinions expressed are those of the Association and not necessarily those of the cooperating parties or sponsoring agencies.

The recommendations were submitted in October 2008 for review to attendees at the September Wetlands and Climate Change Symposium in. Portland. We received many excellent suggestions. These have been incorporated into this report. We want to thank particularly the suggestions from Suzanne Marr and the staff of Region 9 EPA. We also thank Rachael Fertik and the EPA Office of Wetlands, Oceans, and Watersheds staff in Washington, D.C.; James Powell, University of Fairbanks; Pat Parenteau, Vermont Law School; Allison Aldous, the Nature Conservancy; and Scott Bridgman, University of Oregon.

Cover photos:
Climate change may dry millions of prairie pothole wetlands.
Sea level rise.

TABLE OF CONTENTS

INTRODUCTION

Although scientific uncertainties exist with regard to magnitude of climate change, there is ample scientific evidence to suggest that climate change is now having and will have significant impacts on millions of coastal, estuarine, and freshwater wetlands throughout the Nation. Wetlands serve a broad range of functions including flood loss reduction, pollution control, endangered species habitat, and recreation. These functions will be diminished. Wetlands are also more sensitive to small changes in precipitation and temperature than other ecosystems and as a result many may be destroyed.

What actions could States, Tribes, federal agencies and local governments cooperatively take to reduce or mitigate the impact of climate change on wetlands? compensate for such impacts? How can wetland resource managers "adapt"[1] wetlands to climate change? What are the priority management-oriented research needs?

We believe that a cooperative national Wetlands and Climate Change Initiative is needed with action by all levels of government and the private sector.

We recognize that many of the recommendations set forth below are already being implemented (to a greater or lesser extent) by federal and State agencies, local governments, and the private sector. We applaud these actions. These actions, however, are fragmented and uncoordinated. We believe that, given the complexity of wetland ecosystems and breadth of needs, a new, national "big picture" effort is needed

The recommendations which follow begin with why we think that a National Wetlands and Climate Change Initiative is needed. Suggested actions by States and Tribes, federal agencies and local governments are next considered. More specific measures to reduce the impacts of climate change on wetlands and to adapt wetlands to climate change are then listed separately for coastal/estuarine wetlands and then for freshwater wetlands. The recommendations conclude with collaborative research needs.

The recommendations will be posted on the ASWM wetlands and climate change web site and will broadly distributed once the review and revisions are completed. See Association of State Wetland Managers Wetlands and Climate Change webpage, http://www.aswm.org/science/climate_change/climate_change.htm/

WHY IS A NATIONAL WETLANDS AND CLIMATE CHANGE INITIATIVE NEEDED?

A National Wetlands and Climate Change Initiative involving all levels of government and the private sector (NGO's, academic institutions, land trusts, other) is needed for a number of reasons:

[1] We use the term "adaptation" here to mean actions pertaining to wetland processes, practices, or functions to reduce or offset potential damages from climate change.

- **Severe climate change impacts to wetlands.** Increased temperatures, increase or decrease in precipitation, and sea level rise will have severe impacts on wetland ecosystems. Impacts will be particularly great for coastal and estuarine wetlands, which cannot migrate inland due to steep topography, levees, sea walls, or other development. They will also be great for small, shallow wetlands such as vernal pools and prairie potholes, where temperatures and evaporation rates may substantially increase without corresponding increases in precipitation. They will be great for montane wetlands with temperature-sensitive plant and animal species and little opportunity for such species to migrate. They will be great for permafrost wetlands due to melting.

- **Release of stored carbon and methane.** Much of the carbon stored in wetland soils in the U.S. and world may be released if wetlands are drained or if permafrost wetlands melt. Bacteria which live in aerated conditions will oxidize the carbon and return it to the atmosphere. Fires will add to releases. Peat lands in the Northern U.S. (e.g., Minnesota, Maine) and Alaska and some other types of wetlands continue to sequester small quantities of carbon. The release of carbon will exceed sequestering if temperatures rise, precipitation levels fall, or if wetlands are drained.

  Wetlands globally emit significant amounts of methane. This total has been estimated to be in the 15-22% range of total global methane emissions and may be even greater. Most of these emissions are at lower latitudes rather than in the U.S., for example the Amazon floodplain. However, because methane is a very active greenhouse gas, the climate change "forcing" function of methane may exceed the gains from carbon sequestering, particularly on short term basis. In the long term (500-1000 years), methane has a decreasing effect.

- **Reducing the impacts of climate change on wetlands and "adapting" wetlands to climate change will require an effort by all levels of government and the private sector.** No single action or measure will be sufficient to reduce the impact of climate change on wetlands or to adapt wetlands to climate change. Many actions will be needed. See recommendations below.

- **Lack of coordination and leadership between programs and efforts.** At the present time there is a great deal of interest at all levels of government and in the private sector concerning the impacts of climate change on wetlands and measures which might be taken to better protect wetlands from impacts and adapt wetlands to climate change. There is also a fair amount of management-oriented wetland and climate change research taking place in universities, agencies, and nonprofit organizations in the U.S. and abroad. However, federal, state, tribal, local government and private sector efforts (academic, NGO) are not coordinated. Agencies here in the US often are not aware of work underway in other countries or with international organizations (e.g., Ramsar). Even within the US, one state does not know what another state is doing. Limited research is taking place with regard to some of the most critical issues such as evaluation of carbon storage and methane generation in wetland sediments and the implications of various management practices upon carbon stores, sequestering and methane generation.

WHAT SHOULD A NATIONAL WETLANDS AND CLIMATE CHANGE INITIATIVE INCLUDE?

A national wetlands and climate change initiative should include the following elements. Note, this list is not exhaustive and would be revised by a National Wetlands and Climate Change Initiative coordinating committee.

- **Form a National Wetland and Climate Change Coordinating Committee.** The Council for Environmental Quality, U.S. Environmental Protection Agency (EPA), U.S. Fish and Wildlife Service (FWS), U.S. Geological Service, National Oceanic and Atmospheric Administration, U.S. Army Corps of Engineers, U.S. Forest Service, U.S. Park Service, Bureau of Land Management and National Science Foundation should, in cooperation with other federal agencies, States, Tribes, local governments, and the private sector (not-for-profit, academic institutions, business groups) convene a National Wetlands and Climate Change Coordinating Committee. Such a Coordinating Committee should build upon existing federal, state and local climate change coordination efforts and should involve a broader range of partners. The goals of the committee should be to reduce the impacts of climate change on wetlands, to help adapt wetlands to climate change, and to better understand and communicate the importance of protecting wetlands with large carbon stores to reduce future increases in climate change (i.e., carbon storage).

- **Improve cooperation between climate change, watershed and coastal zone programs.** Since the health of watersheds and the supply of water flowing down a watershed has great impact on the health of wetlands, improved coordination should take place between climate change, nonpoint source control, watershed protection, and coastal zone programs. The National Coordinating Committee should:

    - Cooperate with broader watershed and coastal zone health protection and climate change partners, and
    - Coordinate planning and actions with organizations and agencies that work with upland issues (NRCS, resource conservation districts, ranchers and farmers, land trusts, USFS, EPA nonpoint source and watershed program).

- **Conduct a survey of wetlands and climate change efforts including policies and programs, publications, webpages, and research.** The Committee should undertake a survey of wetland and aquatic ecosystem-related efforts underway throughout the nation. Such a survey should be a cooperative effort of all levels of government and the private sector. The results of this survey should be posted to the web.

- **Create and update a national wetlands and climate change website.**[2] The Committee should create a national website focusing on wetlands, with links to other relevant sites, publications, reports and activities throughout the nation and world. A portion of the site should be geared towards providing information to the public.

[2]See for an initial effort to develop such a web page http://www.aswm.org/science/climate_change/climate_change.htm/.

- **Create a coordinated, multiagency wetlands and climate change research program.** The Committee should develop a priority list of wetland and climate change research needs and help fund priority studies. See list of priority research needs below.

- **Implement measures to help reduce (mitigate) the impacts of climate change on wetlands and adapt wetlands to change at all levels of government and the private sector.** Measures should be tailored to different regions of the country such as the Gulf Coast, Prairie Potholes, arid Southwest, the islands (Pacific and Caribbean), and the snow fall dependent areas. For examples of more specific measures for coastal/estuarine and freshwater wetlands (see below).

- **Establish cap and trade programs.** Regional cap and trade programs need to be formed to certify offset credits for wetland restoration and sequestration.

- **Broaden international cooperation.** Much wetland and climate change scientific research is taking place on the international scene. Policies are being adopted and tested. Strengthened cooperation and information exchange is needed between domestic and international efforts.

WHAT ROLES COULD FEDERAL AGENCIES AND CONGRESS, STATES AND LOCAL GOVERNMENTS PLAY IN IMPLEMENTING AN INITIATIVE?

Federal leadership is needed to implement a National Wetlands and Climate Change Initiative. Suggested federal, State, Tribal and local roles include the following items:

Action Items for Federal Agencies

The **Administration and federal agencies** should take the following actions. (Note, agencies have already initiated some of these actions.)

- **Federal agencies (see list above) should convene a joint federal, state, tribal and local Wetlands and Climate Change Initiative** building upon existing formal and informal coordinating mechanisms. See discussion above. Goals and priorities established by the initiative should be broadly communicated to other federal agencies and entities.
- **Identify key statutory obligations and opportunities under the purview of these agencies that can be periodically updated to incorporate consideration of climate change into programs.**
- **Adopt goals and plans.** All agencies should incorporate wetland and climate change protection and adaptation goals into agency missions, strategic plans.
- **Identify wetlands most threatened on public lands.** Land management agencies such as the U.S. Forest Service, Corps of Engineers, Park Service and Bureau of Land Management should not only identify wetlands but devise protection and adaptation policies and implement these policies.
- **Establish a coordinated system of reference sites.** Federal agencies should, in cooperation with the States/Tribes and academic institutions, establish and operate a coordinated, national system of wetland and climate change reference sites including

Long Term Ecological Research sites, National Estuarine Research Reserve sites, and National Estuary Program sites. These sites would be used to monitor climate change and development and test various protection and adaptation strategies. Agencies should make data widely available.

- **Incorporate adaptations to climate change in water projects to add safety factors for floods and erosion and added ecosystem protection and adjustment goals reflecting anticipated climate changes such as low flow protection for fish and other wildlife.**
- **Survey state, tribal, federal, local climate change and wetland/water ecosystem programs; publish results.** EPA in cooperation with the Fish and Wildlife Service other agencies should survey federal, state, tribal, and local wetland ecosystem protection and adaptation efforts, post results to the web.
- **Prepare and widely distribute a wetlands and climate change best management practices handbook.** EPA and the FWS should in cooperation with other agencies, prepare or fund the preparation of a handbook or handbooks setting forth measures for protection of wetlands and adaptation of wetlands to climate change. The information should be made readily accessible online.
- **Carry out or fund demonstration projects** illustrating various measures to protect and adapt wetlands to climate change.
- **Add protection of wetland carbon stores as an explicit goal of the Section 404 permitting program;** require impact reduction and compensation.
- **Determine key questions to be answered and fund and/or carry out priority management-oriented research.** See below.
- **Actively foster communication links** between US efforts (at national, regional and local levels) and those in other countries.

Action Items for Congress

Congress should:

- **Establish a National Wetland Climate Initiative** as part of broader climate change legislation.
- **Include protection and adaptation of wetlands** as part of national climate change legislation (e.g., the Lieberman/ McCain of 2003 or Lieberman/Warner bill of 2007).
- **Fund wetland and climate change related research.**
- **Provide funding to support accurate wetland mapping nationwide.** In most areas of the country wetlands maps are 20-30 years old.

Action Items for States, Tribes

States and Tribes should:

- **Document current changes in wetlands and underlying conditions** (i.e., changes in precipitation, temperature, species composition) that may be related to climate change.
- **Identify anticipated direct and indirect threats to wetlands (e.g., watershed hydrologic regimes)** due to climate change.
- **Document and communicate to others the successes or failures of protection and adjustment strategies and techniques**.

- **Work with local agencies to implement watershed actions** that will better protect wetlands, their water supply and water quality (i.e., low impact development strategies allowing precipitation to soak into groundwater, nonpoint source pollution control with buffer strips in urban and agricultural areas).
- **Broaden state climate change programs beyond emission controls to include** ecosystem adaptation, specifically wetland and watershed adaptation**.** States and Tribes should incorporate wetland protection and adaptation goals into climate change efforts**.** Watershed adaptation should be incorporated into wetland adaptation.
- **Identify wetlands most threatened by climate change on state lands.** Develop protection and adjustment strategies.
- **Factor climate change into existing state wetland regulatory efforts.**
- **For States/Tribes that don't have wetland regulatory statutes, adopt legislation** that is protective of wetlands, including adaptation to climate change.
- **Require local governments to factor climate change into land use planning and regulatory efforts** where state statutes require state standard-setting for local planning and regulations (e.g., Washington State).
- **Integrate wetland protection and restoration into state flood hazard and climate change initiatives** such as protection of wetland flood storage and conveyance, increased freeboard in state floodplain and regulations, prohibition of fills in wetlands, adoption of zero rise floodways, and adoption of a no adverse impact standard for floodplain management.
- **Establish regulatory buffers for all wetlands and waters.** This will allow wetlands room to migrate up slope**.** Wider and more protected buffers will provide more protection to riparian areas during the more intense storm events that are predicted. More extensive riparian buffers will also better control cold stream habitat for aquatic species.
- **Create and protect multiobjective corridors for migration of species** as part of state fish and game management efforts.
- **Work with partners such as land trusts, local governments and federal agencies to protect wetlands with significant carbon stores.**
- **Work with local governments and federal agencies to update wetland maps.**
- **Determine key questions to be answered and fund and/or carry out priority management-oriented research** in cooperation with the federal government, academic institutions and land trusts including the creation of systems of reference sites. See below.

<u>Action Items for Local Governments</u>

Local governments should:

- **Adopt wetlands and climate change protection and adaptation goals and regulations as part of comprehensive land management and watershed management.** This should include **adoption of** conservation zoning, sensitive lands, and critical area ordinances to protect wetlands.
- **Identify wetlands most threatened by climate change within the community and watershed.** Plan, prioritize and implement actions that will protect wetlands and help them adapt to climate change. Begin with actions that are easiest to implement, provide outreach to the community.

- **Work with other jurisdictions throughout the watershed to protect wetlands both upstream and downstream of their own borders.**
- **Factor climate change into "smart growth," "sustainable cities," similar land and water planning and management efforts.**
- **Work with other agencies to implement watershed actions** that will better protect wetlands, their water supply and water quality (i.e., low impact development strategies allowing precipitation to soak into groundwater, nonpoint source pollution control with buffer strips in urban and agricultural areas).
- **Factor climate change into watershed plans, infrastructure planning and ~~plan~~ implementation strategies** (e.g., establishing robust buffers, "over-sizing" culverts and other structures to better accommodate extreme events).
- **Better protect wetlands as part of flood hazard reduction efforts including those adopted to anticipate increased intensity of storm events.** These include measures such as zero rise floodways, restrictions on fill in wetlands, and no adverse impact floodplain management policies.
- **Restore, create or enhance wetland types most threatened by climate change,** in a manner that will be sustainable.
- **Establish buffers to protect wetlands and other resources.**
- **Adopt "development rights" regulations to promote clustering of development on uplands and protection of wetlands.**
- **Control drainage of wetlands to prevent oxidation of wetland soils** and the resulting release of carbon into the atmosphere.
- **Create multiobjective greenways** with wetlands as one component to provide corridors for migration of species.
- **Work with land trust, state, tribal and federal partners** to protect and manage wetlands and wetland carbon stores including establishment of wetland carbon banks.
- **Determine key questions that should be answered** by increased monitoring and/or research, and work with other levels of government and with private organizations to accomplish the monitoring and/or research.

WHAT MORE SPECIFIC MEASURES ARE NEEDED TO BETTER PROTECT AND ADAPT COASTAL/ESTUARINE WETLANDS?

What, more specifically, may be done by States, Tribes, local governments and federal agencies to protect and adapt coastal wetlands to climate change as part of a National Wetlands and Climate Change Initiative?

Climate Impacts on Coastal/Estuarine Wetlands

Projected sea level rises of 2/3 of a meter to 2 meters (differences reflecting, in part, assumptions concerning ice sheet melting) by 2100 combined with coastal subsidence will have severe impact coastal and estuarine wetlands, particularly on the Atlantic and Gulf coasts. There will be wetland losses, where there is insufficient plant growth and sediment deposition to equal sea level rise and coastal or estuarine wetlands cannot migrate inland. This is a particular problem for deltaic systems such as the Mississippi Delta, where sediment-trapping reservoirs have been constructed along inflowing rivers and subsidence is occurring due to compaction of sediments, oil and gas removal, and isostatic adjustments. Loss of many of these wetlands can be expected

with release of the carbon contained the peats and soils to the atmosphere. In other instances, the carbon will be redeposited in new marshes or transported to the open ocean.

States, federal agencies, local governments and the private sector could take a variety of actions to reduce the impact of climate change on coastal and estuarine wetlands. These actions may be divided into two overlapping categories—protection and adaptation.

Protection (Mitigation) Strategies for Coastal/Estuarine Wetlands

Strategies for reducing or mitigating the impact of climate change of coastal/estuarine wetlands include:

- **Incorporate wetland ecosystem protection and adaptation goals into coastal zone regulatory, infrastructure development, watershed management and land planning management programs.**

- **Implement "low risk" regulatory and nonregulatory impact reduction and adaptation options.** Low risk actions are actions which are justified whether or not climate change occurs. These options typically serve a broad range of independent objectives in protecting and restoring wetland functions and values (e.g., flood storage, erosion control, pollution control). Examples of low risk protection options include building setbacks for coastal/estuarine wetlands, more stringent control of drainage, the attachment of conditions to permits to help protect carbon stores, and government or NGO acquisition of wetlands with the largest carbon stores to protect them from drainage and filling.

- **Implement "resilient" wetland strategies as part of "resilient estuary" and other climate change impact reduction or adaptation efforts.**

- **Develop and document coastal/estuarine protection and adjustment tools through the use of demonstration "pilots."** Work with the National Estuary Projects, National Estuarine Research Reserves and National Marine Sanctuaries to carry out projects and to identify and communicate their successful projects. Monitor success and failures. Make the results of studies broadly available.

- **Work with coastal planning and management entities using agreed on protocols to consolidate their wetland, sea level rise, subsidence, flooding and other types of maps (using GIS and other methods) to identify coastal and estuarine wetlands and wetland species most at risk from climate change within a locality, state, or particular region.** This will require identification of plant and animal species with greatest vulnerability such as species with poor distribution and limited range.

- **Establish on the ground priorities for protection and adaptation.** For example wetlands best able to keep up with sea level rise could be identified and targeted for acquisition or more stringent regulations. Similarly, wetland types with strong restoration potential despite sea level rise should be identified**.**

- **Establish buffers for coastal/estuarine and freshwater wetlands.** Buffers will allow coastal/estuarine wetlands to migrate as sea level rises**,** if the landward slope is not too steep. Buffers will also reduce pollutant loads**.**

- **Consider the impact of proposed activities on carbon stores in regulatory permitting.** Regulatory agencies at all levels of government should amend regulations to better protect wetland carbon stores. Permittees should be required to estimate carbon impacts in seeking permits. Mitigation and compensation measures should be required.

- **Strengthen control of** draining of wetlands. Control of drainage of wetlands is a particularly high priority to protect carbon stores and carbon sequestering. It is also a high priority to better protect wetland functions and values since drainage is only partially regulated at federal, state and local levels.

Adaptation Strategies for Coastal/Estuarine Wetlands

Strategies for adapting coastal/estuarine wetlands to climate change (and thereby reducing impacts to wetlands and wetland functions) include:

- **Control invasive species in climate-stressed wetlands.** This will require the ability to distinguish between climate change induced range shifts and species invasion.

- **Study and better understand species that are expected to migrate north and up-slope in order to determine which ones are most likely to support wetland functions and values given climate change.**

- **Acquire upland buffers to permit coastal/estuarine wetlands to migrate when sea level rise occurs, where slopes are sufficiently shallow to allow for migration.**

- **Divert sediments (e.g., the Davis diversion in Louisiana) to nourish wetlands that are subsiding.** Study different methods of wetlands nourishment to determine which methods work best in different regions and under different conditions.

- **Undertake restoration, creation, enhancement for wetland types most threatened by climate change in contexts where restored, created, or enhanced wetlands may also be sustainable.** Wetland restoration, creation and enhancement including the establishment of mitigation banks or more specific, multiobjective "wetland carbon banks" may, in some instances, help reduce the impact of climate change on wetlands, protect existing carbon stores and carbon sequestering,[3] and reduce methane emissions.

- **Establish wetland reference sites (see above) to monitor the impact of climate change and determine the effectiveness of management and adjustment strategies.**

[3]Some management options to enhance carbon sequestering and storage such as stabilization of water levels, control of fires and replanting wetlands may be inconsistent with broader ecosystems goals, depending how they are carried out. They should be approached with caution.

- **Undertake long term wetland planning with the goal of protecting and increasing the resiliency and adaptability of wetland ecosystems in the face of climate change (e.g., National Wildlife Refuges).**

- **Undertake priority research. See discussion below.**

WHAT MORE SPECIFIC MEASURES ARE NEEDED TO BETTER PROTECT/ADAPT FRESHWATER WETLANDS?[4]

Climate Impacts on Freshwater Wetlands

Climate change will also seriously affect freshwater wetlands due, principally, to temperature rise, increased evaporation, reduced precipitation (for some areas)**,** and increased intensity of storm events. Projected temperature rise of 2-8 degrees F by the end of the century without comparable increases in precipitation will dry out or lower water levels in wetlands in many areas of the nation. Northerly shifts in vegetation and animal species will take place where migration pathways are adequate and there is sufficient time for such migration. Otherwise, temperature sensitive species will be destroyed or their numbers seriously reduced by shifts in temperature and/or shifts in precipitation. Species changes are also expected where growing seasons are elongated, allowing for some insect populations to grow substantially. Plant and animal species that are stressed by draught or warmer temperatures may be further stressed by insects and pathogens that thrive in the changed climate (i.e., bark beetle, spruce budworm). Die off of major plant species (i.e., conifers) can dramatically increase the incidence of wildland fires, which can lead to increased erosion and the degradation of wetlands.

Impacts will be particularly great where precipitation decreases. Increases in temperatures and evapotranspiration combined with reductions in precipitation will likely reduce surface and ground water levels in northern latitude wetlands, destroying or reducing in the size many wetlands.

Protection Strategies for Freshwater Wetlands

States, Tribes, federal agencies, local governments, academics, NGO's, and the private sector could take a variety of actions to reduce the impact of climate change on wetlands although total protection of wetlands is impossible. Recommendations for actions which could be taken to reduce impacts on freshwater wetlands are in many respects similar to those for coastal and estuarine wetlands:

- **Identify (map, identify through GIS) wetlands and wetland species most at risk from climate change within a locality, state, or particular region.** This will require identification of plant and animal species with greatest vulnerability such as species with

[4]We recognize that there is considerable overlap in protection and adaptation strategies for coastal/estuarine and freshwater wetlands and that a single list of actions could be provided for both. However, reviewers of this report suggested that actions for coastal and freshwater wetlands be separated for clarity purposes despite some redundancy.

poor distribution and limited range. Formulate protection plans and strategies for these wetlands or classes of wetlands.

- **Incorporate wetland and climate change ecosystem protection goals into watershed management, water planning, and comprehensive land planning including smart growth, and infrastructure development programs.**

- **Increase regulatory protection for wetlands most threatened by climate change to reduce stresses, provide opportunity for wetlands to migrate, and protect carbon stores:**

    - More stringently control drainage,
    - Prevent fragmentation of wetland/aquatic ecosystems; more fully protect migration corridors, and
    - Consider the impact of activities on wetland carbon stores in regulatory permitting; require impact minimization and compensation measures; attach conditions to permits, and

- **Adopt buffers to reduce potential for erosion and pollution, to keep water temperatures low, and to allow migration of plants and animals.**

- **Establish wetland reference sites to track changes in wetlands due to climate change, determine the effectiveness of management and adjustment strategies.**

- **Acquire and protect wetlands with the largest carbon stores.**

<u>Adaptation Strategies for Freshwater Wetlands</u>

Strategies for adapting freshwater wetlands to climate change (and thereby reducing impacts to wetlands and wetland functions) include:

- **Prevent fragmentation of wetlands.** Prevention of fragmentation in wetlands and reestablishment of corridors is needed to permit migration of plant and animal species.

- **Prioritize wetlands with regard to management and adaptation.** Establish "on the ground" priorities for the most cost effective application of protection and adaptation strategies. For example wetlands with deep carbon deposits could be identified and targeted for acquisition or more stringent regulations. Similarly, wetlands with strong restoration potential under climate change conditions should be identified**.**

- **Study and better understand and address invasive species in climate-stressed wetlands.** This will require the ability to distinguish between range shifts and species invasions. More specifically, this will require deciding whether plant or animal species migrating into an area due to increased temperatures, sea level rise or other climate change factors are to be considered "invasive."

- **Study and better understand species that are expected to migrate north and up-slope in order to determine which ones are most likely to support wetland functions and values given climate change.**

- **Install water control structures at the outlets of freshwater wetlands.** Such structures can, in some instances, help maintain water levels during dry periods. However, structures may be quite expensive, require maintenance, and interrupt natural successional cycles.

- **Re-establish and maintain corridors.** Re-establishment and management of wildlife corridors is needed to permit plant and animal species to migrate. This is particularly important for river corridors which permit, under natural conditions, the migration of fish, reptiles, birds, and other animals and plants.

- **Divert sediments (e.g., the Davis diversion in Louisiana) to nourish wetlands** that are degraded due to sediment loss or inundation.

- **Undertake restoration, creation, and enhancement.** Wetland restoration, creation and enhancement including the establishment of mitigation banks or more specific, multi-objective "wetland carbon banks" may, under certain conditions, help reduce the impact of climate change on wetlands, protect existing carbon stores and carbon sequestering, and reduce methane emissions. However, climate change may also destroy or degrade wetland restoration, creation, and enhancement projects.

- **Establish wetland reference sites to document the impacts of climate change and to determine the effectiveness of management and adjustment strategies.**

- **Beginning with existing watershed plans and other land use planning, determine the processes and actions needed to increase the resiliency of wetlands and watersheds in the face of climate change.**

- **Develop protection and adjustment tools through the use of "pilots."** Monitor success and failures. Actively make the results of studies broadly available to the public and other practitioners.

- **Consider the impact of proposed activities on carbon stores in regulatory permitting.** Regulatory agencies at all levels of government should amend regulations to better protect wetland carbon stores. Permittees should be required to estimate carbon impacts in seeking permits. Mitigation and compensation measures should be required.

- **Strengthen control of drainage of wetlands.** Control of the drainage of wetlands is a particularly high priority to protect carbon stores and carbon sequestering. It is also a high priority to better protect wetland functions and values since drainage is only partially regulated at federal, state and local levels.

- **Undertake priority research. See discussion below.**

As with coastal/estuarine wetlands, some protection and adaptation options such as options to enhance carbon sequestering and storage in freshwater wetlands through stabilization of water levels, control of fires and replanting wetlands may be inconsistent with broader ecosystems goals, depending how they are carried out. They also should be approached with caution.

WHAT ARE PRIORITY MANAGEMENT-ORIENTED AND BASIC RESEARCH NEEDS?

A National Wetlands and Climate Change Initiative should include a coordinated research agenda. Initiative members should define priority research needs and either help undertake or fund priority research. Some priority management-oriented research topics include the following items. We have divided them into several categories:

Predicting Climate Change

- **Refine climate change models reflecting soils, geology and topography to provide more accurate predictions regionally concerning changes in temperature, precipitation, extreme meteorological events, sea level rise and other aspects of climate change**. Actions to protect and adapt wetlands need to be based upon sound and specific predictions of change.

Impacts of Climate Change on Wetlands

- **Document more fully the impacts of climate change on wetland ecosystems** through the use of reference sites and research projects. This should include but not be limited to the impacts of increased CO_2, increased temperatures, sea level rise, increases or decreases in precipitation, and increased precipitation intensity. Examples of relevant topics include:

    - **Photosynthesis, plant types, shifts in vegetation.** How will climate change affect rates of photosynthesis, shifts in vegetation (e.g., what trees will grow where?), changing surface and ground water regimes, and other features?
    - **Species sensitivity.** Field studies and experiments are particularly needed to document the sensitivity of specific wetland plants/animals and types of wetland ecosystems to small changes in temperature, precipitation patterns, changes in hydroperiod, changes and rates of change in CO_2, etc.
    - **Possible benefits from shifts.** Are some of the plant and animal species that are likely to move north and up-slope of benefit to wetlands? Can wetland functions still be maintained with these new species?
    - **Sea level rise.** What are the impacts of rising sea levels upon coastal and estuarine wetlands including rates of sedimentation and other deposition, carbon sequestering and storage in sediments, and the pathways and fate of carbon in wetland sediments, which may be dislodged by sea level rise and flooding?
    - **Intensified precipitation events.** What is the impact of intensified precipitation events on wetlands and their buffers? How would these events impact anadromous fish habitat?
    - **Hydrology.** How will climate change affect surface and ground water regimes? Can wetlands help capture surface water and move it to groundwater?

- **Snow dependent systems.** What are the impacts of snow-dependent systems when the snow fall decreases due to temperature increases and snow runoff occurs earlier in the year? Can wetlands help store surface waters where winter rains replace snow, reducing spring runoff in rivers and streams and resulting impacts upon fisheries?
- **Arid and semi-arid region impacts.** What is the impact of decreased precipitation and increased temperatures on the wetlands of the US southwest (i.e., springs and riparian wetlands)? How would changes in the wetlands of the southwest impact the indigenous human communities?

Carbon Storage and Methane

- **Determine how much carbon is stored in U.S. wetlands.** How significant is this carbon to climate change? How much carbon continues to be sequestered? What factors affect sequestration? What measures might be taken to reduce this production? What impact would this have upon wetland functions and values? More specific topics include:

  - **Carbon deposition in riverine, estuarine, lacustrine, other sediments.** Some studies suggest that large amounts of carbon may be contained in sediments deposited in wetlands. Is this correct? If so, how much? Does sequestration continue? At what rate? How soon is this carbon returned to the atmosphere?
  - **In situ versus upland carbon sequestering**. What is the relationship of in-situ wetland carbon storage and sequestering in wetlands to upland carbon fixing, erosion, runoff and wetland deposition by upland activities such as agriculture and forestry?
  - What is the impact of **fire upon carbon cycling** in wetlands? What is the impact of fires in different types of watersheds (desert, Mediterranean, temperate climates) and its subsequent vegetative cover loss, erosion, sedimentation, habitat loss? What measures can be taken to reduce the impact of increased wildland fires on wetlands?
  - How significant are **"catastrophic" events** such as hurricanes and major rain storms to carbon sequestering and storage in wetlands?

- **Determine with greater specificity how much methane is produced by wetlands.** What factors affect this production? What are the methane fluxes in all types of wetlands and at various levels within wetland sediments? How significant is this amount? What measures might be taken to reduce this production? What impact would this have upon wetland functions and values?

- **Determine the impact of a various land and water management practices upon carbon storage and sequestering and methane emissions** (and, in some instances, NO2) including draining wetlands, water level manipulation, various forestry practices, various agricultural practices, burning and suppression of fire, plantings with various species, control of exotics, etc.?

- **Determine the compatibility of water and land and water management practices to sequester and store carbon and/or reduce methane emissions be with broader biodiversity and other wetland functions and values.** What will be the impacts of

various management techniques upon flood storage and conveyance, wave attenuation, erosion control, pollution control, food chain support, biodiversity, recreational values, other functions and values? How compatible will land and water management strategies to enhance wetland carbon sequestering and to reduce methane production (e.g., water level manipulation) be with protection of biodiversity and with protection and restoration of other wetland functions and values? More specifically:

- **What will be the impacts of controlling fire** upon habitat and ecosystems functions such as flood conveyance, biodiversity, and endangered species and upon long- term serious burns?
- **What will be the impacts of controlling (stabilizing) water levels** upon successional sequences and various wetland plant and animal species?
- **What will be the impacts of using fertilization** to increase carbon production and deposition upon eutrophication and wetland plant and animal species including accelerated demise of wetlands?
- **What will be the impacts of diverting sediments** into wetlands to increase carbon sequestration upon fisheries, waterfowl, and other plant and animal species and upon the accelerated demise of wetlands?

- **Investigate the use of various remote sensing techniques combined with field surveys to identify wetlands with significant** carbon stores, to calculate the amounts of wetland carbon stores and to determine methane emissions.

- **Investigate the roles wetland restoration, creation and enhancement can play in protecting wetland functions and values including protection of wetland carbon stores and the adjustment of wetlands to climate change.** What project designs will are most successful? What wetland management techniques should be used?

- **Investigate the dynamics of c-sequestration and storage and methane production in restored, created, and enhanced wetlands.** Investigate how various restoration, creation, and enhancement strategies (e.g., flooding, water level stabilization) affect c-sequestering and storage, and methane production. More specifically, can enhanced, restored or created wetlands sequester carbon at rates which exceed those of natural wetlands? Release methane? If so, with what designs and management practices?

  a. Rates vs. age
  b. Rates vs. strategies
  c. Rates vs. system types
  d. Watershed interactions

<u>Management</u>

- **Evaluate the effectiveness of various land and water management practices in reducing the impact of climate change on wetlands, adapting wetlands to such impacts, or compensating for losses of acreage or function.**

- **Evaluate the impact on biodiversity and wetland functions and values of wetland management measures taken to protect carbon stores, sequester carbon, or protect other functions. Investigate approaches for creating wetland "carbon banks" to protect wetlands with large stores of carbon and to sequester additional carbon.** What management practices are needed to not only protect existing stores but to enhance sequestering and reduce methane production? Are wetland "carbon farms" or "carbon banks" practical? If so, how might they be established? What sorts of management practices are needed? How are credits and debits to be calculated?

- **Evaluate the impact of combined climate change and population changes.** How will we protect wetlands given potential indirect population impacts of climate change? For example, how are wetlands likely to be impacted by shifts in population and resulting water demands if people move north in response to climate change.

- **Evaluate the impact of climate change on water supplies.** How are wetlands likely to be impacted, if water supplies become more scarce and competition for water grows?

- **Develop model regulations and policies including monitoring protocols** to protect carbon stores, promote carbon sequestration, and reduce methane production.

- **Develop economic and other incentives** for land and water management practices which can help protect carbon stores (e.g., peat lands), protecting and enhancing sequestering, and reducing methane production.

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SOME USEFUL WEB PAGES

Science

www.dieoff.org/page129.htm
The Carbon Bomb: Climate Change and the Fate of the Northern Boreal Forests.

www.epa.gov/globalwarming/ *Global Warming.* U.S. Environmental Protections Agency.

www.ipcc.ch/ *Intergovernmental Panel on Climate Change*. See this site for copies of the IPCC documents and many other excellent links concerning climate change.

www.iisd.org/wetlands/wandcs/scienceofwetlands/index.htm *Physical and Biotic Processes Affecting Carbon Cycling in Prarie Wetlands.* Results of a workshop. 1/15/99.

http://www.pewclimate.org/docUploads/aquatic.pdf Report: Aquatic Ecosystems and Global Climate Change Potential Impacts on Inland Freshwater and Coastal Wetland Ecosystems in the United States. Prepared for the Pew Center on Global Climate Change, January 2002, N. LeRoy Poff, Mark M. Brinson, and John W. Day, Jr. Much of this excellent report concerns wetlands. Good bibliography.

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http://www.aswm.org/calendar/wetlands2008/agenda.htm PowerPoint presentations from Wetlands 2008 conducted by the Association of State Wetland Managers with many cooperating parties in Portland, Oregon on September 16-18, 2008.

United States

General Contacts

USGS Global Climate Change webpage http://biology.usgs.gov:80/ecosystems/global_change/index.html

www.gcrio.org/ U.S. Global Change Research Information Office. General information.

USGS, Global Climate Change & Wetlands, National Wetlands Research Center

http://www.nwrc.usgs.gov/about/web/climate.htm

http://www.iisd.org/wetlands/ Ducks Unlimited, Wetlands & Climate Change

http://www.uaf.edu/accap/ Alaska Center for Climate Assessment and Policy, University of Alaska,

Sequestering

http://www.ducks.org/Conservation/EcoAssets/1306/CarbonSequestration.html Duck's Unlimited Carbon Sequestration Program

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International

http://www.unep.org/themes/climatechange/ United Nations Environment Program, Climate Change

http://www.ipcc.ch/ Intergovernmental Panel on Climate Change

www.ramsar.org Ramsar Convention on Wetlands. This overall Ramsar Convention Bureau web site contains or references many reports available dealing with wetlands and climate change.

http://www.worldclim.org/futdown.htm IPPC 3rd Assessment data. Future climate projections, calibrated and statistically downscaled using the WorldClim data for 'current' conditions.

http://www.unfccc.int United Nations Framework Convention on Climate Change [UNFCC]

http://www.ramsar.org/res/key_res_x_index_e.htm Ramsar resolution concerning climate change and wetlands.