USACE CLIMATE CHANGE ADAPTATION PLAN AND REPORT 2011

SUBMITTED TO THE EXECUTIVE OFFICE OF THE PRESIDENT'S COUNCIL ON ENVIRONMENTAL QUALITY / OFFICE OF THE FEDERAL ENVIRONMENTAL EXECUTIVE ON 30 SEPTEMBER 2011

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Assistant Secretary of the Army for Civil Works

US Army Corps of Engineers®

USACE CLIMATE CHANGE ADAPTATION PLAN AND REPORT 2011

EXECUTIVE SUMMARY

The US Army Corps of Engineers (USACE) understands that climate change is among the major challenges of the 21st century, and can impact all areas of our missions and operations. Since 2006, USACE has embarked on a comprehensive approach to climate change that incorporates new knowledge and changing conditions into our missions, operations, programs, and projects. Our approach enhances the capacity of our planning, design, construction, operations, and maintenance to adapt to changing climate and other global changes.

Our goal is to develop practical, nationally consistent, legally justifiable, and cost effective measures, both structural and nonstructural, to reduce vulnerabilities and improve the resilience of our water resources infrastructure impacted by climate change. We are taking a collaborative approach that embodies a new attitude to partnering between agencies. This collaboration takes advantage of our different perspectives and expertise so that our progress on adaptation reflects the best available and actionable science. But in turn, we are working to help guide the science to better meet our needs and the needs of other land and water resources agencies. We are taking a phased approach that allows us to identify uncertainties, whether in climate projections or in system responses, so that we begin adaptation in areas where uncertainties are relatively smaller and the risk of adverse or unintended consequences is lower. We are developing and implementing plans, policies, and infrastructure adaptation in parallel, rather than sequentially, so that adaptation begins soonest for projects that are most vulnerable. We are pilot-testing adaptation methods, sharing lessons learned within and outside the agency, and refining our adaptation based on the new knowledge. Working within a risk-informed framework that considers all of the challenges facing us will enable USACE to implement integrated water resources management solutions to the impacts of climate change.

This USACE Climate Change Adaptation Plan provides the information requested by the Council on Environmental Quality in their *Implementing Instructions for Federal Agency Climate Change Adaptation* issued on 4 March 2011. An overarching policy statement about climate change is presented. Answers to the guiding questions posed by the *Implementing Instructions* about climate change impacts to USACE strategic missions and goals support a high-level vulnerability analysis. The top priorities for the next fiscal year are identified, as requested for the September 2011 submittal.

This report also provides additional information on current USACE adaptation planning and implementation progress. The scope, collaboration, and resources we have applied to climate change adaptation planning demonstrate the importance placed on this critical challenge to the long-term sustainability of our mission, operations, programs and projects that oversee and administer public water resources and associated infrastructure in every state, as well as several international river basins, and support military operations worldwide that promote peace and stability.

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USACE CLIMATE CHANGE ADAPTATION POLICY STATEMENT

As the Nation's largest and oldest manager of water resources, the US Army Corps of Engineers (USACE) has long been successfully adapting its policies, programs, projects, planning, and operations to impacts from important drivers of global change and variability. Climate change and variability, both observed and as projected for the future, are among those important drivers of global change having significant impacts to the management of US national water resources and infrastructure.[1] The Nation's water-resource infrastructure managed by USACE both protects public health and human life and annually provides billions of dollars of economic, social, and environmental benefits crucial to the continued progress of the Nation.

It is the policy of USACE to integrate climate change adaptation planning and actions into our Agency's missions, operations, programs, and projects. USACE shall continue undertaking its climate change adaptation planning, in consultation with internal and external experts and with our Districts, Divisions, and Centers, and shall implement the results of that planning using the best available – and actionable – climate science and climate change information. USACE shall also continue its efforts with other agencies to develop the science and engineering research on climate change information into the actionable basis for adapting its Civil Works and Military Programs missions to climate change impacts. Furthermore, USACE shall consider potential climate change impacts when undertaking long-term planning, setting priorities, and making decisions affecting its resources, programs, policies, and operations.

These actions which USACE is now conducting and has outlined for the future are fully compatible with the guiding principles and framework of the US Federal Interagency Climate Change Adaptation Task Force and the Implementing Instructions for Federal Agency Climate Change Adaptation issued on 4 March 2011 jointly by the Executive Office of the President's Council on Environmental Quality / Office of the Federal Environmental Executive (CEQ/OFEE) and the Office of Management and Budget.[2]

Together with CEQ, USACE recognizes the very significant differences between climate change adaptation and climate change mitigation in terms of physical complexity, fiscal and material resources, level of knowledge and technical readiness, and temporal and geographic scale. Because of these differences, understanding and implementing climate adaptation policies and measures requires very different knowledge, skills, and abilities than implementing mitigation measures. Relatedly, USACE understands and is acting to integrate climate adaptation (managing the unavoidable impacts) with mitigation (avoiding the unmanageable impacts). It is the policy of USACE that mitigation and adaptation investments and responses to climate change shall be considered together to avoid situations where near-term mitigation measures might be implemented that would be overcome by longer-term climate impacts requiring adaptation, or where a short-term mitigation action would preclude a longer-term adaptation action.

The successful implementation of this USACE adaptation policy will help enhance the resilience of the built and natural water-resource infrastructure USACE manages and reduce its potential vulnerabilities to the effects of climate change and variability. This success will allow USACE to continue fulfilling its missions using Integrated Water Resource Management to safeguard the Nation's tremendous investment in the built and natural water-resource infrastructure by mainstreaming climate change adaptation in all USACE activities.

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[1] USGS Circular 1331 "Climate Change and Water Resources Management: A Federal Perspective", available at http://pubs.usgs.gov/circ/1331/, a joint document by the USACE, Bureau of Reclamation, US Geological Survey, and National Oceanic and Atmospheric Administration.

[2] http://www.whitehouse.gov/administration/eop/ceq/initiatives/adaptation

Mainstreaming climate change adaptation means that it will be considered at every step in the project life cycle for all USACE projects, both existing and planned, through a logical, rational, legally justifiable process that develops practical, nationally consistent, and cost-effective adaptation measures, both structural and nonstructural, to reduce vulnerabilities and enhance the resilience of our water-resource infrastructure.

This work to understand and adapt to the impacts of climate and global change is already underway at USACE, and the policy enunciated here is closely aligned with the USACE Campaign Plan[3] and the USACE Civil Works Strategic Plan.[4] USACE has several integrated programs directed at parts of climate change adaptation; in addition, many coordinated elements from other programs support the development of approaches to understand and implement climate change adaptation for implementing the USACE mainstreaming effort.[5]

The magnitude and complexity of climate change impacts facing water-resource managers in the US has spurred USACE to embark on closer, more fruitful interagency cooperation for developing methods supporting climate change adaptation. Close collaboration, both nationally and internationally, is the most effective way to develop the measures to identify and reduce the USACE mission vulnerabilities to potential future climate changes. USACE has demonstrated its commitment to engage and lead such collaboration through efforts including the "Building Strong Collaborative Relationships for a Sustainable Water Resources Future Initiative"[6] and the Federal interagency Climate Change and Water Working Group (CCAWWG).[7] It is the policy of USACE that these and other productive collaborative efforts around climate and global change adaptation shall continue.

This policy establishes the Assistant Secretary of the Army for Civil Works as the Agency official responsible for ensuring implementation of all aspects of this policy. This policy does not alter or affect any existing duty or authority. Through this Policy, USACE establishes the USACE Climate Change Adaptation Steering Committee to oversee and coordinate agency-wide climate change adaptation planning and implementation. The Steering Committee is chaired by the USACE Chief, Engineering and Construction, and will include appropriate representation from throughout USACE.

This policy statement shall be effective beginning 3 June, 2011, for all USACE missions, operations, programs and projects and shall remain in effect until it is amended, superseded, or revoked.

Signed

Ms. Jo-Ellen Darcy

Assistant Secretary of the Army for Civil Works

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[3] See http://www.usace.army.mil/about/campaignplan/Pages/Home.aspx

[4] *Sustainable Solutions to America's Water Resources Needs* (Department of the Army, Corps of Engineers, Civil Works Strategic Plan 2011-2015) approval pending from OMB as of 1 June 2011.

[5] See http://corpsclimate.us for more information.

[6] See http://www.building-collaboration-for-water.org/ for more information.

[7] See http://corpsclimate.us for more information.

INTRODUCTION

For more than 230 years, the USACE has supplied engineering solutions to water resources needs, including navigation, flood and coastal storm damage reduction, protection and restoration of aquatic ecosystems, hydropower, water supply, recreation, regulatory, and disaster preparedness and response. The USACE military support mission is even older, providing key support to the Revolutionary War beginning in 1775.

As the largest and oldest federal water resources management and military support agency in the nation, the U.S. Army Corps of Engineers (USACE) oversees and administers public water resources and associated infrastructure in every state, as well as several international river basins (Fig 1). Approximately 12 million acres of land and water resources are under the jurisdiction of the USACE as part of its Civil Works (CW) portfolio of more than1600 water resources projects, programs, and systems. USACE also applies water resources management expertise to support military program (MP) operations worldwide that promote peace and stability.

Water resources management has evolved over time to support economic development, life safety, and ecosystem restoration in a cross-jurisdictional and multi-scale manner that reflects the wide variety of water users and their differing requirements. This process has resulted in management policies and procedures designed to respond to changing needs and balance competing needs.

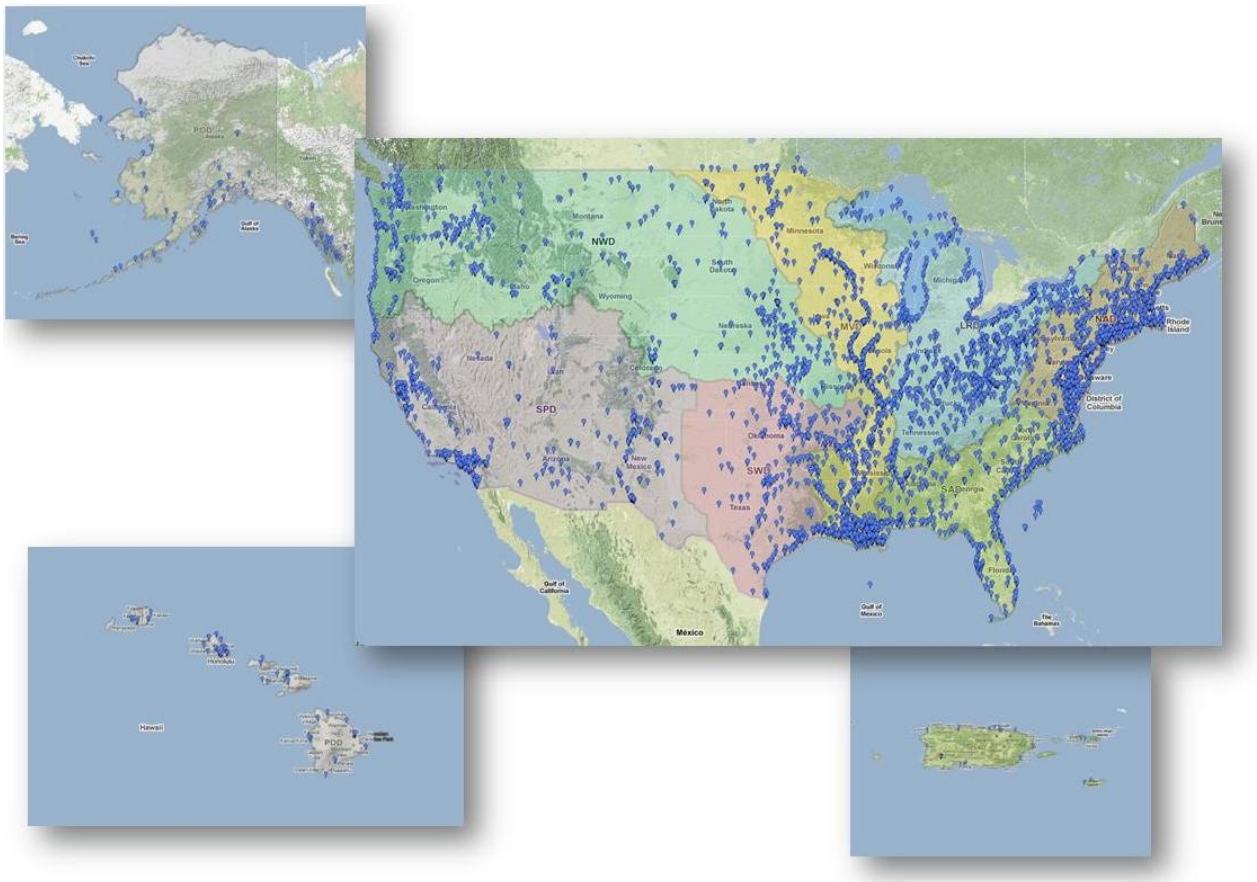

Figure 1. Locations of USACE projects in the US (blue pins). USACE Division boundaries are shown by shaded areas.

These policies and procedures improve the capacity of water managers to absorb change and disturbances without unduly impacting basic functions (Olsen et al. 2010a). Water resources management managers thus provide a potential reservoir of resilience and adaptive capacity in the face of climate change, whether at home or abroad (White et al. 2010).

Climate change and variability impacting water resources management became apparent in the early 2000's following a number of influential scientific studies of western snowmelt-dominated watersheds (Gleick 1986; Lettenmaier and Gan 1990; Dettinger and Cayan 1995; Service 2004; Reganda et al. 2004, Stewart et al. 2005; Mote et al. 2005). In 2006, the USACE CW program embarked on the Western States Watershed Study (WSWS, USACE 2009) to evaluate climate and other global changes, and in 2007, began an interagency effort addressing climate change impacts and adaptation in Federal water resources management. At the same time, the Department of Defense (DoD) was considering how climate might impact its mission. In 2008, the Defense authorization bill required DoD to explicitly address climate change considerations in its Quadrennial Defense Review (QDR), which is undertaken every four years, thus spurring USACE MP to consider climate change impacts and adaptation as well. The 2010 QDR Report (US DoD 2010) notes that "Climate change and energy will play significant roles in the future security environment."

This report presents information required by the Implementing *Instructions for Federal Agency Climate Change Adaptation* (CEQ 2011) issued jointly on 4 March 2011 by the Executive Office of the President's Council on Environmental Quality / Office of the Federal Environmental Executive (CEQ/OFEE) and the Office of Management and Budget. In addition to the USACE Adaptation Policy Statement, we also address the Guiding Questions, and present progress on USACE assessments of vulnerability to climate change, and adaptation planning and implementation, including extensive interagency collaboration.

21ST CENTURY CHALLENGES

The USACE considers global changes that result in local impacts and responses as the major challenges of the 21st century.

Climate change is but one of these 21st century challenges; the others include demographic shifts and related land use/land cover, world population, aging infrastructure, persistent conflict, declining biodiversity, globalization, and changing social values and economic conditions (USACE 2011). These global changes can interact and combine in unpredictable ways, resulting in potentially surprising or abrupt changes that threaten public health and safety, the performance of water resources infrastructure, and the functioning of ecosystems. USACE recognizes that global changes are part of a complex system that cannot effectively be dealt with by piecemeal or sequential problem-solving.

We also recognize that close collaboration, both nationally and internationally, is the most effective way to develop practical, nationally consistent, and cost-effective measures to reduce potential vulnerabilities resulting from global changes (Stockton and White 2011). That's why we are working closely with other agencies having aligned mission areas. And it's also why we have provided support to the Council on Environmental Quality's Federal Interagency Climate Change Adaptation Task Force working groups in the form of a number of our senior engineers and scientists.

GUIDING QUESTIONS FOR HIGH-LEVEL VULNERABILITY ASSESSMENT

USACE MISSION AND STRATEGIC GOALS: BACKGROUND

The USACE mission, shown in the inset box at right, reflects both its CW and MP missions, and is achieved through activities supporting four USACE Campaign Plan Goals:

U.S. Army Corps of Engineers' Mission: Provide vital public engineering services in peace and war to strengthen our Nation's security, energize the economy, and reduce risks from disasters.

Goal 1: Deliver USACE support to combat, stability and disaster operations through forward deployed and reach back capabilities.

Goal 2: Deliver enduring and essential water resource solutions through collaboration with partners and stakeholders.

Goal 3: Deliver innovative, resilient, sustainable[8] solutions to the Armed Forces and the Nation.

Goal 4: Build and cultivate a competent, disciplined, and resilient team equipped to deliver high-quality solutions.

The CW mission statement is: "Serve the public by providing the Nation with quality and responsive development and management of the Nation's water resources; promotion of sustainable marine transportation systems; protection and management of the natural environment; restoration of aquatic ecosystems; flood risk management and emergency management; and engineering and technical services in an environmentally sustainable, economic, and technically sound manner with a focus on public safety and collaborative partnerships."

The MP mission statement is: "Provide premier engineering, construction, real estate, stability operations, and environmental management products and services for the Army, Air Force, other assigned U.S. Government agencies and foreign governments."

These Campaign Plan Goals highlight collaboration and resilience to potential destabilizing influences of wars, and economic and natural disasters. Sustainability and risk management in a holistic and environmentally sound manner is also stressed.

Further, the CW mission is accomplished through five strategic goals.

- Assist in providing for safe and resilient communities and infrastructure.
- Help facilitate commercial navigation in an environmentally and economically sustainable fashion.
- Restore degraded aquatic ecosystems and prevent future environmental losses.
- Implement effective, reliable, and adaptive life-cycle performance management of infrastructure.
- Build and sustain a high quality, highly dedicated workforce.

[8] Sustainability in this context refers to the capacity to endure and remain productive over time, which is very well aligned with the concept of adaptation, which is "Adjustment in natural or human systems to a new or changing environment that exploits beneficial opportunities or moderates negative effects." (CEQ 2010).

Over the past several years, the global changes identified above are impacting the Nation and the USACE CW and MP, and are likely to continue in the future. Climate change is of particular importance, and its impacts have highlighted for us the need to consider a dynamic, rather than an equilibrium future. This dynamic future includes multiple plausible futures that can impact our missions, operations, programs and projects in a variety of ways.

Climate adaptation undertaken as part of the MP engineering services or other support provided to facilities, operations, and programs of the Army, Air Force, other assigned U.S. Government agencies and foreign governments lies within the purview of the agency being supported. These agencies will set policies and mandates, plan, resource, implement, and report on climate change adaptation activities with their area of responsibility. USACE MP will transfer any lessons-learned to the CW program.

Climate change adaptation strategies and plans undertaken in support of the CW program yields valuable information for all USACE activities, and lessons learned can be transferred to MP and their customers and stakeholders. Therefore, this high-level assessment of climate change impacts primarily deals with the USACE CW program.

HOW CLIMATE CHANGE IMPACTS USACE MISSION AND STRATEGIC GOALS: BACKGROUND

In response to the challenges posed by climate change, and recognizing the need for an integrated and collaborative approach to water resources management, the USACE and its major water resources management partners Bureau of Reclamation (Reclamation), U.S. Geological Survey (USGS), and the National Oceanic and Atmospheric Administration (NOAA) began working together in 2007 to assess climate change impacts to federal water resources management, reviews strategies to improve water management by tracking, anticipating, and responding to climate change, and provides case studies.

This report, "Climate Change and Water Resources Management: A Federal Perspective" (Brekke et al. 2009) was published in February 2009 (Fig 2). USGS Circular 1331 provides the high-level assessment of vulnerability required to describe how climate change impacts the USACE missions and strategic goals identified above. In particular, Key Point 2 states that ***climate change could affect all sectors of water resources management,*** *since it may require changed design and operational assumptions about resource supplies, system demands or performance requirements, and operational constraints. The assumption of temporal stationarity in hydroclimatic variables should be evaluated along with all other assumptions.*

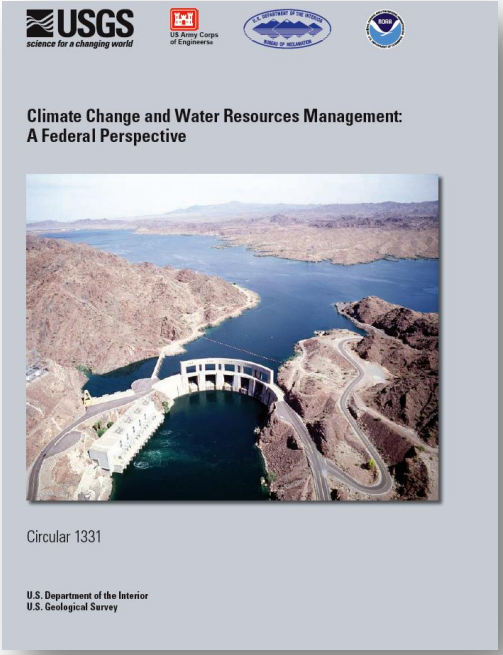

Figure 2. USGS Circular 1331, the fundamental assessment of climate change impacts to water resources management. (See http://pubs.usgs.gov/circ/1331/Circ1331.pdf).

GUIDING QUESTIONS: STRATEGIC MISSIONS AND GOALS

The USACE achieves the strategic goals identified above through implementation of strategic objectives in nine business areas representing the diversity of the Nation's resource requirements:

- *Navigation*
- *Flood and Coastal Storm Damage Reduction*
- *Environment*
- *Hydropower*
- *Regulatory*
- *Recreation*
- *Emergency Management*
- *Water Supply*
- *Support for Others.*

While these business areas provide a framework for executing the CW, the associated Civil Works activities transcend individual business areas, often addressing multiple water resource purposes. The nine business program managers continually seek comprehensive, collaborative, and sustainable solutions that often involve multiple business programs. For the purpose of this submittal, CEQ requests information on three to five areas.

Our high-level assessment of climate change impacts and vulnerabilities for this submittal addresses the following five business areas (all areas will be complete by March 2012):

- *Navigation*: Primary navigation responsibilities include planning and constructing new navigation channels and locks and dams, and dredging to maintain channel depths at U.S. harbors and on inland waterways. USACE operates and maintains 12,000 miles of inland and intra-coastal waterway navigable channels, including 192 commercial lock and dam sites, and is responsible for ports and waterways in 41 states. In partnership with local port authorities, Corps personnel oversee dredging and construction projects at hundreds of ports and harbors at an average annual cost of over $1.3 billion.

- *Flood and Coastal Storm Damage Reduction*: The primary responsibility of the flood risk management program purpose is to reduce flood risk by saving lives and reducing property damage in the event of floods and coastal storms. USACE is responsible for the construction and operation of 383 major lake and reservoir projects, construction of over 8,500 miles of levees and dikes, construction of about 90 major shoreline protection projects along 240 miles of the Nation's 2,700 miles of shoreline, building of hundreds of smaller local flood risk reduction projects that have been turned over to non-Federal authorities for operation and maintenance, and implementation of several non-structural projects to reduce susceptibility to flood damages. This business area is closely tied to Emergency Management, especially with respect to assessing changes to the frequency, intensity, and location of extreme events.

- *Environment*: The environmental program has two major focus areas: protection and restoration, and stewardship. Efforts in both areas are guided by the Corps environmental operating principles, which help us balance economic and environmental concerns. The

protection and restoration program reflects the lessons we've learned as a society in recent years about the importance of re-establishing the natural functions of our Nation's rivers, lakes, wetlands and coasts. The stewardship program focuses on the ongoing care and protection of the 12 million acres of rivers, lakes and wetlands for which we are directly responsible.

- *Hydropower*: The USACE is the largest operator of hydroelectric power plants in the United States and one of the largest in the world. Our 75 plants have a total installed capacity of 23,764 megawatts and produce nearly 68 billion kilowatt-hours a year. This is 24% of the Nation's total hydropower output.

- *Water Supply*: Careful management of the Nation's water supply is critical to limiting water shortages and lessening the impact of droughts. As one of the Nation's largest water supply agencies, the USACE plays a major role in ensuring that Americans have enough water to meet their needs through management of 136 multiple purpose projects that contain storage for water supply in 25 states and Puerto Rico. These projects are capable of providing almost 5 billion gallons of water per day for use by local communities and businesses.

The remaining business areas will be addressed in our 2011-2012 high-level vulnerability assessment to be completed by March 2012, as well as our nationwide screening-level vulnerability assessment.

GUIDING QUESTIONS: CLIMATE CHANGE IMPACTS TO STRATEGIC MISSIONS AND GOALS

Next we consider major climate change impacts that may significantly impact our ability to meet the requirements of the five selected business areas listed above. Assessments of vulnerability to climate change often use the framework driver-impact-response or adaptation to describe the big picture. We need to keep in mind that it is not so much the change in the physical effects drivers (temperature, precipitation), but the impacts to our mission, operations, programs, and projects that are associated with this these changes will guide our responses and adaptation.

DRIVERS

The primary drivers of climate change impacts to the business areas of navigation, flood and coastal storm damage reduction, environment, hydropower and water supply are changing temperature and precipitation regimes, and increasing global sea level and associated physical processes (Brekke et al. 2009).

Changing temperatures impact the form of precipitation, evapotranspiration, and sea-surface temperatures. Changes from snow to rain, or from rain on snow to rain on frozen ground, can affect the origin and timing of runoff. Altered evapotranspiration from vegetation and land surfaces can impact the amount of water reaching streams, lakes, and reservoirs. Changes in sea-surface temperatures can alter ocean and atmospheric circulation and affect the intensity and frequency of coastal storms.

Precipitation changes are expected to differ across the country, with some areas receiving more and others receiving less. There may also be changes in seasonal patterns and extremes of precipitation.

Depending on location, precipitation changes could lead to more climate variability and more frequent occurrence of extreme events such as droughts and floods. The most important issue related to precipitation as a driver of climate change is the potential for nonstationarity, which would overturn a fundamental assumption of hydrologic and hydraulic engineering design.

Global sea level varies over time and regionally. Sea-level change has been the focus of intense interest by the U.S. water resources science agencies (NOAA and USGS), along with other agencies contributing to the US Global Change Research Program (USGCRP, 2009). The Intergovernmental Panel on Climate Change (IPCC), particularly working groups 1 (Physical Science) and 2 (Impacts and Adaptation), have also expended considerable effort researching sea-level change. Finally, agency reports and peer review literature contain on the order of 10,000 citations in the area of sea-level change (or sea-level rise). Relative local sea-level changes are a combination of global sea level and dynamic land changes such as subsidence or glacial rebound. Local relative sea-level changes can affect wave, tide, surge heights, and saline intrusion into groundwater. Changes in local relative sea level increase the potential risks associated with any change in coastal storm frequency, intensity, or storm track.

It is important to note that any or all of these changes could occur abruptly (National Research Council, 2002, 2006; Climate Change Science Program, 2008).

IMPACTS

Potential water resources management sector impacts identified and discussed in USGS Circular 1331 include changing water availability, variability, demand, and quality; wild-land fires; ecosystem or species transitions or alterations; coastal and estuarine conditions; and energy production and demand. NRC (2010) provided a comprehensive list of climate changes and their associated impacts to ecosystems, based on a wide variety of sources.

For the purpose of this high-level vulnerability assessment, we have outlined potential climate change impacts associated with the drivers discussed above that could impact the selected USACE business areas of Navigation, Flood and Coastal Storm Damage Reduction, Environment, Hydropower, Water Supply. These impacts are shown in Table 1, along with the business areas they are expected to impact.

GUIDING QUESTIONS: MANAGING IMPACTS TO STRATEGIC MISSIONS AND GOALS

We believe that by understanding the drivers and impacts associated with climate and other global changes, and their impacts to our strategic mission and goals, USACE will enhance its capacity to endure and remain productive over time. This expectation is clearly aligned with the concept of adaptation, which is "Adjustment in natural or human systems to a new or changing environment that exploits beneficial opportunities or moderates negative effects." (CEQ 2010).

USGS Circular 1331 found that there would be short- and long-term climate impacts to all areas of our water resources management mission. We already knew from our internal program set up to deal with changes in response to Hurricane Katrina (the IPET-HPDC Lessons Learned Implementation Team) that we must have methods, technologies, processes, and policies to incorporate the effects of new and changing conditions into our projects and programs, over the entire lifecycle, using a risk-informed, comprehensive systems approach. Our immediate concerns

were with those areas of our mission that have a life-safety component, such as floods and coastal storms. We're also very concerned about drought issues, since the impact several of our mission areas. Changes in sedimentation resulting from altered precipitation patterns can impact both reservoir storage capacity and dredging to support navigation.

Table 1. Climate Change Impacts to Selected Strategic Missions and Goals (after NRC 2010).

Climate Change	Impact	Strategic Mission/Goal Impacted*
Increasing average air temperature	Change in form of precipitation (snow vs. rain)	N, F, E, H, W
	Changes in water temperatures → water quality, lake stratification	E
	Effects on crops and growing season → changing water demand	H, W
	Changes in ecosystem structure and function	E
	Changes in invasive species or pest distribution	N, F, E, H, W
	Changes in river ice regimes	N, F, E, H
	Changes to glacial processes	N, F, E
	Changes to ocean ice regimes	N, F, E
	Changes to permafrost	E
	Changes in energy demand	N, E, H, W
	Altered ocean circulation → changing tide & surge regimes	N, F, E
	Increased extreme events → heat waves, cold waves, ice storms, blizzards, dust storms	N, F, E, H, W
	Changing persistence of large-scale atmospheric features	N, F, E, H, W
	Changes in evapotranspiration	N, E, H, W
Changing precipitation: increasing variability, altered seasonality, and changing intensity or frequency of extremes (flood and drought)	Changing or more variable municipal & industrial water supplies	N, W
	More variable stream flow and lake levels	N, F, E, H, W
	Changing water conditions for ecosystems	N, E, H, W
	Changing frequency of coastal and riverine flooding	N, F, E, H, W
	Changes in stormwater runoff	N, F, E, W
	Changes in drought frequency and intensity	N, F, E, H, W
	Changing sediment regimes	N, F, E, H, W
	Changing levels of pollutants in runoff	E, W
	Changes in snowmelt onset and volume	N, F, E, H, W
Sea-level and costal storm changes and associated tides, waves, and surges	Increased shoreline erosion and changes to barrier islands & inlets	N, F, E
	Loss of or changes to coastal wetlands	N, F, E
	Increased storm waves, surges, tides	N, F, E
	Changes in estuarine structure and processes	N, F, E
	Altered saline intrusion into coastal aquifers	E
	Inundation of low-lying land	N, F, E
	Increased depth in harbors and channels	N, F, E
	Altered coastal sedimentation	N, F, E
	Changes in wind regimes	N, F, E
	Changes in ecosystem structure and species distributions, including invasive species and pests	E
	Altered frequency & extent of harmful algal blooms & coastal hypoxia events	E

* N=Navigation, F=Flood and Coastal Storm Damage Reduction, E=Environment, H=Hydropower, W=Water Supply

In response to the water-related risks posed by climate change, the Corps has embarked on a comprehensive approach to climate change that is flexible enough to incorporate new knowledge and changing conditions. Our goal is to develop practical, nationally consistent, legally justifiable, and cost effective measures, both structural and nonstructural, to reduce vulnerabilities and improve the resilience of our water resources infrastructure.

We are taking a collaborative approach. This has required a new attitude to partnering between agencies that recognizes the value of our different perspectives and expertise so that guidance reflects the best available – and actionable – science, and in turn, the science is guided to support our needs. We are developing and implementing plans, policies, and infrastructure adaptation in parallel, rather than sequentially, so that adaptation begins soon for projects that are most vulnerable.

We are taking a phased approach that allows us to identify uncertainties, whether in climate projections or in systems responses, so that we begin adaptation in areas where uncertainties are relatively smaller. Thus, risk of adverse consequences is lower. We are pilot-testing adaptation methods, sharing lessons learned within and outside the Corps, and refining our adaptation based on the new knowledge. As we conduct our evaluations and formulate management plans, we must be careful that we do not prematurely down-select to one future, in a way that reduces our ability to manage risks, and especially that increases residual risk.

So we need to be aware that the future is nonstationary, that we need to describe the future in ways that are compatible with our need for economic and engineering analyses, and that encompass all of the processes affecting our projects and systems, including socio-economic and environmental. Finally, our adaptation planning and implementation must be credible, relying on logical, rational, and legally justifiable methods, processes, and policies. In keeping with the questions-based approach of the flexible framework, Table 2 contains some of the priority questions we faced as we began to manage climate change impacts.

COORDINATION AND COLLABORATION TO BETTER MANAGE CLIMATE CHANGE ADAPTATION

Water resources management agencies have a special incentive to collaborate on water data, science, engineering, and operations, because strong collaboration around water quantity and quality can result in a more secure and stable environment (Wolf 2005). On the other hand, loose collaboration or competition over water can result in conflict and instability (Ravenborg 2004). The same skills used to handle 20th century challenges of changing land use, demographics, and climate provide a reservoir of institutional knowledge and experience that can help to de-escalate conflict related to 21st century challenges (Stockton and White 2011). Dalton et al. (2011) suggested that collaboration is key if water resources managers are to develop and implement adaptively managed solutions to achieve positive outcomes through managing risks proactively rather reacting to prevailing crises and conflicts as climate changes.

Table 2. Priority Questions Driving USACE Approach to Manage Climate Change.

Priority Questions Driving USACE Approach	Business Area Impacted*	How These Questions Relate to Business Areas
How do we respond to increasing variability of precipitation with climate change?	N, F, E, H, W	Increasing variability impacts our capacity to: • Provide navigation services • Manage reservoirs as authorized to provide flood risk reduction, and prepare, respond and recover from floods and coastal storms • Effectively plan, design, and manage ecosystem restoration project • Provide reliable hydropower • Manage reservoirs for authorized water supply
How to account for nonstationarity in hydrologic analyses?	N, F, E, H, W	Nonstationarity undermines a fundamental assumption of hydrologic and coastal design, requiring new methods, processes, and technologies supporting updated planning, design, and operations of our projects and programs supporting navigation, flood and coastal storm risk reduction, environment, hydropower, and water supply.
How to perform flood-related and other hydrologic analyses?	N, F, E, H, W	Climate change and variability have revealed: • The need to consider multiple plausible futures • That there are many approaches to obtain climate information – which approaches are suitable for which decision? • Gaps in knowledge and lack of established methods of performing hydrologic analyses required to adequately plan, design, and operate our projects and programs supporting navigation, flood and coastal storm risk reduction, environment, hydropower, and water supply.
How to address the potential for increased drought?	N, F, E, H, W	Use of novel and innovative techniques to monitor, plan for, and forecast drought are required to adequately plan, design, and operate our projects and programs supporting navigation, flood and coastal storm risk reduction, environment, hydropower, and water supply.
How do we account for sea-level change and changes in waves, tides, surges, and storms?	N, F, E, W	Changes in sea level, tides, surges, and coastal storms must be accounted for to adequately plan, design, and operate our projects and programs supporting navigation, flood and coastal storm risk reduction, environment, and water supply.

* N=Navigation, F=Flood and Coastal Storm Damage Reduction, E=Environment, H=Hydropower, W=Water Supply

With these ideas in mind, beginning in 2008, USACE began the "Building Strong Collaborative Relationships for a Sustainable Water Resources Future Initiative" to identify and leverage opportunities for collaborative efforts and to create a joint national dialogue for water priorities between states, tribes and the federal resource agencies (Fig 3). The initiative collected and analyzed state water plans and brought together a variety of stakeholders to discuss critical water resources needs and potential response strategies with the goal of developing a comprehensive picture of water resources planning throughout the U.S. that identifies:

- Areas of water resource planning and management where states and regional entities feel their priority water needs are not being met.
- Regions or sectors where more integrated or comprehensive water resources planning and management within and across states is possible and advantageous.
- Topics for which the federal government might provide enhanced support to states and regions, especially for more integrated water resources planning and management.
- Opportunities for partnerships among states, regional entities, federal agencies, and NGOs to more effectively address comprehensive and integrated statewide and regional water resource and planning needs.

The initiative is summarized in a national report (USACE 2010) as shown in Figure 3.

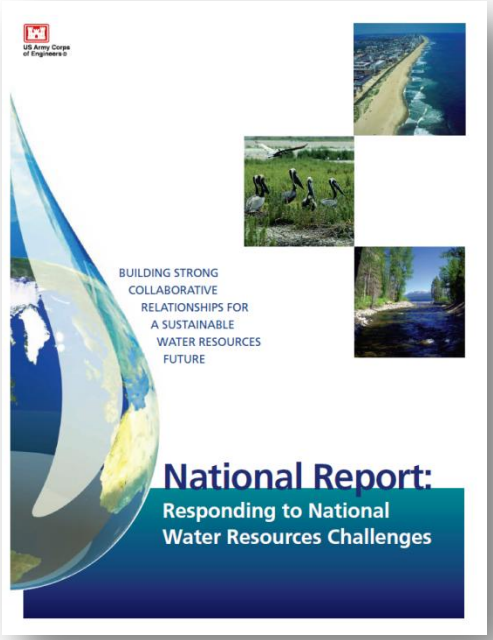

Figure 3. Summary report for Building Strong Collaborative Relationships For A Sustainable Water Resources Future Initiative. See http://www.building-collaboration-for-water.org/.

The following sections illustrate how USACE has actively engaged its fellow water resources management agencies in facing the challenges of the 21st century.

GUIDING QUESTIONS: AGENCIES WITH SIMILAR CLIMATE CHANGE IMPACTS AND MANAGEMENT CHALLENGES

As a land and water resources management operating agency with inland and coastal, national and international responsibilities, USACE has numerous mission components aligned with other Federal agencies. This section describes some of the agencies facing climate change impacts and challenges similar to those facing USACE; others are listed in Table 3.

Table 3. Agencies with Similar Climate Change Impacts and Management Challenges.

Agency	How Climate Change Management Challenges are Similar
Department of Agriculture, US Forest Service	Similar needs to monitor and track changes to water resources impacted by climate change, especially sedimentation and agricultural runoff
Department of Commerce, National Oceanic and Atmospheric Administration	Similar needs to monitor and track changes to water resources impacted by climate change Provides water resources science support to USACE
Department of Commerce, US Coast Guard	Similar impacts to navigation and disaster response
Department of Defense	Similar impacts to land and water resources management & national security
Department of Homeland Security, Federal Emergency Management Agency	Similar impacts to disaster preparedness, response, recovery and flood risk reduction
Department of the Interior, Bureau of Reclamation	Water resources management operation agency Similar impacts to land and water resources management
Department of the Interior, National Park Service	Similar impacts to land and water resources management
Department of the Interior, US Geological Survey	Similar needs to monitor and track changes to water resources impacted by climate change Provides water resources science support to USACE
Department of Transportation, Federal Highway Administration	Similar impacts to infrastructure
Environmental Protection Agency	Similar impacts to water quality
National Aeronautics and Space Administration	Similar needs to monitor and track changes to water resources impacted by climate change Provides water resources science support to USACE

US DEPARTMENT OF INTERIOR

BUREAU OF RECLAMATION

The two largest water managers in the U.S. are the US Army Corps of Engineers (USACE) and the Department of Interior's Bureau of Reclamation (Reclamation). Collectively, the agencies have 350 years of similar but complementary land and water resources management experience. The common missions of the two agencies are hydropower, dam safety and critical infrastructure, water supply, ecosystem restoration and protection, and recreation.

Hydropower is perhaps the most similar mission area for USACE and Reclamation, which together provide a little more than half the hydropower in the U.S. The agencies share hydropower production within the Columbia and Missouri River Basins at multipurpose dams with different authorizations and purposes, but otherwise operate in different basins with different purposes (Figure 4).

With regard to dam safety and critical infrastructure, USACE has more than 600 dams nationwide and Reclamation has approximately 500. They have begun standardizing their approaches to dam safety through development of similar risk-based tools and approaches for assessing downstream consequences from natural hazards. Water supply is a primary mission for Reclamation, but a secondary mission for USACE. Reclamation is the largest wholesaler of water in the U.S., supplying water to more than 31 million people. Water supply is an authorized use for the USACE as part of multipurpose projects, but is not currently authorized as a primary or single purpose for a project. Recreation is a major economic benefit associated with the water resources managed by both USACE and Reclamation Recreation relies on adequate water quality, quantity, and ecosystem health. Ecosystem restoration and protection is part of planning for Reclamation's water and power operations, but is a primary business area for USACE, with specific guidance dating to 1990.

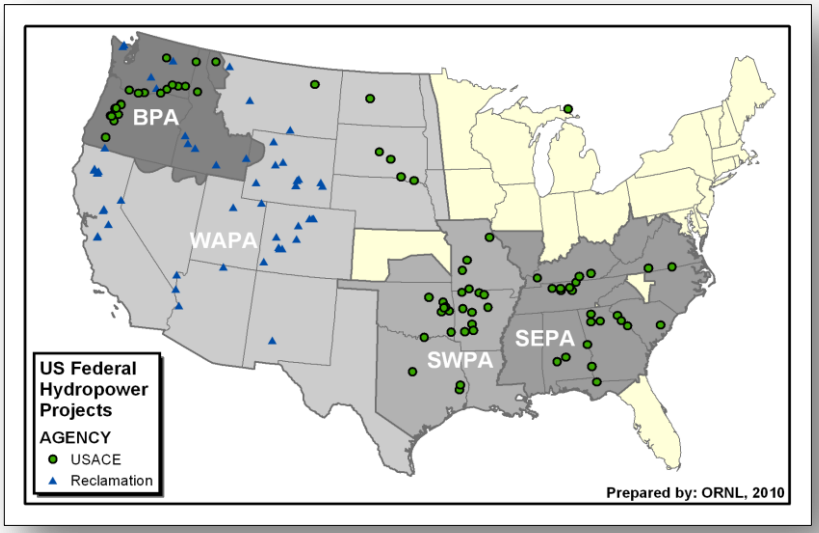

Figure 4. Existing federal hydropower projects at Reclamation and USACE projects. Four power market administration areas are shown: Bonneville Power Administration (BPA), Southeastern Power Administration (SEPA), Southwestern Power Administration (SWPA), and Western Area Power Administration (WAPA). (Prepared by National Hydropower Asset Assessment Project Team, Oak Ridge National Laboratory).

The differing missions of the two agencies are navigation (USACE), flood and coastal storm risk reduction (USACE), regulatory (USACE), irrigation (Reclamation), disaster preparedness and response (USACE), and war-fighter support (USACE). The differing missions all have a strong water resources management component, and thus still share many of the challenges and needs of the common missions.

From the working level to the leadership, both agencies understand that an unprecedented level of collaboration is necessary to meet the combined challenges of climate and global change to water resources management. Together, the agencies are working to develop and implement consistent strategies to "manage the unavoidable" climate change effects through planning, engineering, and design of climate change adaptation measures that can also protect against adverse effects of other global changes. This collaboration brings together two operating agencies with long experience in adjusting to meet new water resource-related challenges, and since 2006, the relationship has proved beneficial to these water managers, their partners and stakeholders, and presents a model for other agencies.

US GEOLOGICAL SURVEY

The mission of the US Geological Survey (USGS) is to provide reliable, impartial information to describe and understand the Earth for use in minimizing loss of life and property from natural disasters; managing water, biological, energy, and mineral resources; enhancing and protecting the quality of life; and contributing to wise economic and physical development.

USACE and USGS share a symbiotic relationship around water resources management, where the operating capabilities required by USACE could drive the direction of science inquiries for USGS, which in turn may result in improved knowledge and processes for USACE operations (Fig 5). Similarly, the data collected and compiled by one agency for a specific purpose can be used by the other agency to supplement other data and information for an entirely different purpose.

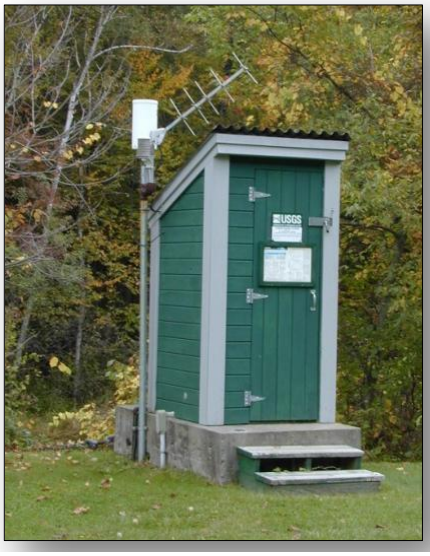

Figure 5. USGS cooperative stream gage at USACE Union Village Dam, Thetford, VT (Gage # 0114500, Ompompanoosuc River at Union Village, VT). (Photo courtesy USACE New England District).

Figure 6. 11 May 2011: Dr. Jane Lubchenco, NOAA administrator (left), The Honorable Terrence (Rock) Salt, principal deputy assistant secretary of the Army for Civil Works (middle), and Dr. Marcia McNutt, director of the USGS (right) shake hands after signing an MOU to form an innovative partnership to address America's growing water resources challenges. This was during a ceremony at Georgetown Waterfront Park, near the Potomac River stream gage in Washington, DC. (Photo courtesy USGS).

Since 1978, USACE and USGS have shared a Memorandum of Understanding (MOU) to exchange information about to geology, seismology and hydrology. A later partnership agreement was signed in 2004 to support working together to provide information for science-based management of this Nation's water, geological, and biological resources through the collection, analysis, interpretation, modeling, information management and reporting of biological, hydrological, geologic, geographic and other natural resource information of mutual interest.

The USACE and the USGS also participate together in the Cooperative Stream Gaging Program (CSGP). The CGSP was established in about 1940 to meet special USACE data needs pertaining to water quality and quantity for water resources management activities such as planning studies, monitoring river conditions during construction, and water control management of completed projects. Under this program, arrangements were made for the USGS to operate specific gaging stations for the USACE, subject to adjustments to conform to current data requirements and the availability of funds. The

water data acquired by the USACE from these stations are also available for use by all Federal, state, and private agencies, as well as individuals interested in water data.

On 11 May 2011, USACE and USGS, together with the National Atmospheric and Oceanic Administration (NOAA), signed a Memorandum of Understanding to form an innovative partnership of federal agencies to address America's growing water resources challenges (Fig 6). These agencies, with complementary missions in water science, observation, prediction and management, are partnering to unify their commitment to address the Nation's water resources information and management needs. This MOU, titled "Collaborative Science, Services and Tools to Support Integrated and Adaptive Water Resources Management," will facilitate addressing water information needs including the creation of high-resolution forecasts of water resources showing where water for drinking, industry and ecosystems will be available, and integrated water information to support stakeholders in managing water resources.

DEPARTMENT OF COMMERCE, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

The mission of NOAA is to understand and predict changes in the Earth's environment and conserve and manage coastal and marine resources to meet our Nation's economic, social, and environmental needs. Critical elements of this mission that are aligned with USACE include monitoring and analyzing water resources, issuing predictions and warnings for all hydrologic conditions from floods to droughts, and providing information supporting projections and analyses of climate change and variability.

USACE and NOAA share a symbiotic relationship around water resources management, where the operating capabilities required by USACE could drive the direction of science inquiries for NOAA, which in turn may result in improved knowledge and processes for USACE operations. Similarly, the data collected and compiled by one agency for a specific purpose can be used by the other agency to supplement other data and information for an entirely different purpose. USACE and NOAA NWS River Forecast Centers commonly share information during periods of flood, and there is interest in expanding this collaboration with the signing of the USACE-USGS-NOAA MOU described above.

Figure 7. Cooperative NOAA Real-Environmental Real-Time Observation Network (NERON) station located at USACE's Union Village Dam in Thetford, VT. (Photo courtesy USACE New England District).

USACE and NOAA's National Weather Service (NWS) cooperate together under an interagency agreement participate in Data Collection Networks that collect liquid precipitation and river stage data using precipitation and river stage measuring equipment and observers. The networks provide the USACE with hydrologic information that is unavailable from other NWS networks. Data are recorded, quality controlled,

archived, and published for use by USACE and other agencies. Measured data are commonly available in near real-time, including river stages and precipitation, and snow depth. Data from NWS/USACE Data Collection Networks are collected and transmitted using automated equipment or observed manually and communicated daily via telephone, Internet, or computer programs to NWS Forecast Offices. Data are subsequently reformatted into computer code and electronically transmitted to NWS River Forecast Centers and USACE offices. The NWS/National Operational Hydrological Remote Sensing Center satellite-derived snow cover maps and alphanumeric products are distributed via direct file transfer or over the Internet to NWS and USACE offices. These maps incorporated measured snow surveys from USACE project sites. Similar to the cooperative weather stations, NOAA's Real-Environmental Real-Time Observation Network (NERON) has begun placing observation equipment at USACE sites in New England (Fig. 7). These stations often take advantage of existing USACE telemetry to transmit data to NWS and NOAA.

In view of their shared interest in water resources data collection and integration of this information, USACE, NOAA, and USGS have also recently partnered in developing "Integrated Water Resoruces Science and Services," known as the IWRSS consortium. This collaborative venture is intended to support an evolutionary approach towards an integrative water resources information system that knits together water resources information, products and services across geographic and organizational scales. Early activities are aimed at increased cooperation around emergency situations to reduce vulnerabilities; these activities have value under nonstationary conditions resulting from climate and other global changes, as well as stationary conditions.

GUIDING QUESTIONS: EXISTING FEDERAL AGENCY COLLABORATION AND COORDINATION

USACE has engaged in extensive collaboration with other Federal Agencies, academia, international experts, and the private sector to address impacts and vulnerabilities associated with climate change and variability. Several of the more important collaborative activities are described in this section; others are listed in Table 4.

CLIMATE CHANGE AND WATER WORKING GROUP (CCAWWG)

For the past several years, the two major water resources operating agencies, the US Army Corps of Engineers (USACE) and the Bureau of Reclamation (Reclamation), together with the two major water science agencies, the US Geological Survey (USGS) and the National Oceanic and Atmospheric Administration (NOAA) have been exploring climate change, its impacts, and potential adaptation measures related to eater resources management. These agencies, along with the Federal Emergency Management Agency (FEMA), the Environmental Protection Agency (EPA), and the National Aeronautics and Space Agency (NASA) formed a group called the Climate Change and Water Working Group (CCAWWG) to enhance collaboration and leverage our mission-related interests in climate change and water resources management.

One common goal of the CCAWWG partners is to assess climate impacts to water resources, identify user needs and their associated knowledge and technology gaps, and develop plans to respond to the identified needs and gaps. As previously discussed, beginning in 2007, the group began work on a report presenting the federal perspective of climate change impacts to water resources

Table 4. Existing USACE Collaboration and Coordination with Federal Agencies.

Agency	Existing Collaboration/Project
Department of Commerce, National Oceanic and Atmospheric Administration	Climate Change and Water Working Group member Participation in updating USACE guidance on vertical datums & sea-level change
Department of Commerce, US Coast Guard	Participation in updating USACE guidance on sea-level change
Department of Defense	Climate Change and Water Working Group member Participation in updating USACE guidance on sea-level change USACE support to Strategic Environmental Research and Development Program
Department of Homeland Security, Federal Emergency Management Agency	Climate Change and Water Working Group member Participation in updating USACE guidance on vertical datums and sea-level change USACE participation in review of FEMA Climate Change Impacts Study
Department of the Interior, Bureau of Reclamation	Climate Change and Water Working Group member Participation in updating USACE guidance on vertical datums and sea-level change
Department of the Interior, National Park Service	Participation in updating USACE guidance on sea-level change
Department of the Interior, US Geological Survey	Climate Change and Water Working Group member Participation in updating USACE guidance on sea-level change
Department of Transportation, Federal Highway Administration	Participation in updating USACE guidance on sea-level change Invited attendees at CCAWWG workshops
Environmental Protection Agency	Climate Change and Water Working Group member
National Aeronautics and Space Administration	Climate Change and Water Working Group member USACE and NASA co-host Interagency Forum on Climate Change Impacts & Adaptations
Office of Science and Technology Policy	USACE active in Interagency Climate Change Adaptation Task Force working groups USACE active in National Climate Assessment support activities USACE active in US Global Research Program science working group

management (Brekke et al. 2009). At that time, the CCAWWG agencies identified two high priorities: how to deal with nonstationary hydrology resulting from climate change (and other global changes) and how to select from the portfolio of approaches to develop climate information for use in water resources decision-making. Two interagency CCAWWG workshops hosted by USACE were held in 2010 to address these issues.

NONSTATIONARITY

As highlighted by USGS Circular 1331 and discussed previously in this report, the issue of nonstationarity is of primary importance to USACE and others in the engineering community who have long relied on the assumption of stationarity. The USACE-hosted and CCAWWG-sponsored, "Workshop on Nonstationarity, Hydrologic Frequency Analysis, and Water Management," was held in January 2010. The workshop provided a forum for national and international experts to present and discuss proposed operational alternatives to the assumption of stationarity in hydrologic frequency analysis, including transitional and new methods. The workshop objectives were (1) to discuss in detail how water management agencies should plan and manage water resources in the face of nonstationarity, and (2) to form a coordinated action plan to help the agencies move forward. The first product from this workshop was the proceedings (Olsen et al. 2010b). The second product is a special collection of papers on the topic of nonstationarity in the *Journal of the American Water Resources Association* to provide peer review of the ideas and potential methods[9].,. The agencies are now beginning to develop a coordinated action plan to deal with nonstationarity.

PORTFOLIO OF APPROACHES

The second priority issue identified by Brekke et al. (2009), and reinforced during numerous formal and informal discussions before, during and after the nonstationarity workshop, was the need to develop best practice guidelines for producing and using climate change information for water resource adaptation. This was the topic of the second CCAWWG-sponsored workshop in 2010, "Assessing a Portfolio of Approaches for Producing Climate Change Information to Support Adaptation Decisions." As summarized by Arnold[10], the portfolio of potential approaches is large and varied, and each method or analytical technique in this portfolio brings with it uncertainties and particular deficiencies, some of which are large or only partly characterized and poorly quantified.

The CCAWWG member agencies are in the process of evaluating the workshop outcomes, and will develop a plan for products in 2011, with the goal of working toward best practice guidelines. This workshop made clear that the CCAWWG operating agencies require "actionable science" to improve decision-making to adapt to climate change and variability. Therefore, it is incumbent on the operating agencies to carefully describe their own user needs and information gaps to the science agencies to help shape the science and place a higher priority on filling gaps and developing information deemed useful in decision-making.

Developing best practices around the portfolio of approaches has direct implications to the updated Principles and Guidelines for Water and Land Related Resources Implementation Studies (P&G), which are the rules that govern how Federal agencies evaluate proposed water resource development projects. CEQ is leading the development of the new Principles, Requirements, and Guidelines (PR&G)[11]. Especially important will be the new agency-specific guidelines that are to be

[9] See http://onlinelibrary.wiley.com/doi/10.1111/jawr.2011.47.issue-3/issuetoc
[10] See http://www.corpsclimate.us/assessingportfolioworkshop.cfm
[11] See http://www.whitehouse.gov/administration/eop/ceq/initiatives/PandG

developed. These should address both nonstationarity and decision-driven approaches to developing climate information appropriate to water resources development projects.

SEA-LEVEL CHANGE GUIDANCE

The USACE has long recognized the potential of changing sea levels to impact our projects. We published our first guidance on the subject in 1986 - even before the publication of the influential 1987 National Research Council study "Responding to Changes in Sea Level: Engineering Implications" (NRC 1987). Our most recent update was in 2009 in the form of Engineer Circular 1165-2-211, "Incorporating Sea-Level Change Considerations in Civil Works Programs" (USACE 2009).

Figure 8. Interagency and international team developing USACE guidance for sea-level change, including USACE, USGS, NOAA, Reclamation, Navy, Coast Guard, Federal Highway Administration, Federal Emergency Management Agency, National Park Service, US Naval Academy, HR Wallingford (UK), University of Southampton (UK), and Moffat and Nichol Engineers.

We developed that guidance with help from top sea-level science experts at NOAA's National Ocean Service and the USGS. We also considered the approaches being taken by our stakeholders. This guidance will be updated by July 2011 with new information, again with assistance from NOAA experts.

We are now working on USACE district-led guidance for adaptation to sea level, this time collaborating both internally, through the use of virtual teams at all levels of the organization, and externally by inclusion of national and international experts. We want to make sure our work is consistent with other Federal agencies, so we've invited agencies such as NOAA, USGS, Reclamation, Navy, Federal Highway Administration, and Federal Emergency Management Agency (FEMA) to take part in our guidance update teams. We've also included the private sector and two experts from the UK in our guidance development. This collaborative process supports rapid incorporation of new and changing information and provides rapid knowledge transfer between agencies.

INTERAGENCY FORUM ON CLIMATE CHANGE IMPACTS AND ADAPTATIONS

USACE and NASA co-host an informal forum[12] on climate change impacts and adaptations. The forum is attended by numerous agencies. It provides a venue for presentations and discussions on issues common across agencies relating to the impacts of climate change on agency resources and operations and adaptations of agency activities, facilities or lands to respond to these impacts. Relevant new publications and reports from participating agencies and from sources such as the U.S. Global Change Science Program Office, the Government Accountability Office, the Council on Environmental Quality, and the Pew and Heinz Centers are regularly presented and discussed at

[12] See http://www.fedcenter.gov/programs/greenhouse/ccforum/

this forum. Meetings are held periodically in the Washington, DC, area. Interested parties can join forum sessions in person or by telephone.

INTERAGENCY TASK FORCE ON CLIMATE CHANGE ADAPTATION

In April 2009, the Interagency Climate Change Adaptation Task Force (Task Force) began meeting in under the leadership of CEQ, NOAA, and the Office of Science and Technology Policy (OSTP). More than 20 Federal agencies and Executive branch offices participated in working groups to consider the capabilities of the Federal Government to respond to the impacts of climate change. The Task Force also asked its Federal agency participants to assist in developing a report to the president (CEQ 2010) describing progress on agency actions in support of the national adaptation strategy. USACE has vigorously supported the Task Force, including four members of the Task Force itself (Ms. Jo Ellen Darcy, Mr. Terrance "Rock" Salt, Mr. Robert Pietrowsky, and Dr. Joe Manous).

USACE engineers and scientists have supported virtually all of the numerous working groups, including Agency Adaptation Processes, Water, Fish Wildlife and Plants, and Coasts. USACE staff provided material support by conducting project-scale adaptation pilots to test the proposed flexible framework, in conducting and evaluating listening sessions, in the drafting of written products, and in developing and presenting information at the required CEQ FY11 climate change workshops during summer 2011.

GUIDING QUESTIONS: NEW OR ADDITIONAL COLLABORATIVE OPPORTUNITIES

As USACE updates future guidance related to climate change adaptation, we will use the same collaborative approach as we have taken with the sea-level change adaptation guidance. Future guidance update opportunities include broad hydrology guidance, methods to deal with nonstationary hydrology, guidelines for selecting from the portfolio of approaches to develop climate information, and simple approaches to assessing the impacts of tides, surges, and waves, among others. We will take the same approach to integrating regulations to be consistent with our planning and engineering for climate change adaptation.

USACE will continue to take active roles in the CCAWWG and the Task Force Working Groups, the US Global Change Research Program (USGCRP), the National Climate Assessment (NCA), and other interagency groups. We hope to expand the CCAWWG to include some of our more informal partners such as the Department of Transportation's Federal Highway Administration (FHWA). There is a great opportunity to include state agencies, professional organizations (e.g., American Society of Civil Engineers), non-governmental organizations (NGOs, e.g., Water Utility Climate Alliance and The Nature Conservancy), academia, and the private sector (Table 5).

Table 5. New or Potential USACE Collaboration and Coordination Opportunities.

Agency	Potential Collaboration/Project
Department of Commerce, National Oceanic and Atmospheric Administration and Coast Guard Department of Defense Department of Homeland Security, Federal Emergency Management Agency Department of the Interior, Bureau of Reclamation; National Park Service; Bureau of Land Management; USGS; and Fish and Wildlife Service Department of Transportation, Federal Highway Administration Environmental Protection Agency Department of Housing and Urban Development States, Professional Organizations, NGOs , Academia, and Private Sector	Broad USACE guidance on hydrology, methods to deal with nonstationary hydrology, guidelines for selecting from the portfolio of approaches to develop climate information
Department of Commerce, National Oceanic and Atmospheric Administration and Coast Guard US Naval Academy Department of Defense Department of Transportation, Federal Highway Administration Department of the Interior, National Park Service and USGS States, Professional Organizations, NGOs , Academia, and Private Sector	New USACE guidance on simple approaches to assessing the impacts of tides, surges, and waves on constructed and natural infrastructure
CCAWWG agencies, Task Force, USGCRP, NCA, other interagency forums	Continued interagency activities

USACE CLIMATE CHANGE ADAPTATION PLANNING AND IMPLEMENTATION

The Nation's water-resource infrastructure managed by USACE both protects public health and human life and annually provides billions of dollars of economic, social, and environmental benefits crucial to the continued progress of the Nation. USACE has long been successfully adapting its policies, programs, projects, planning, and operations to impacts from important drivers of global change and variability. Climate change and variability both observed and as projected for the future, are among those important drivers of global change having significant impacts to the management of US national water resources and infrastructure. In this section, we describe the state of USACE climate change adaptation planning and implementation as of June 2011.

PROGRAMMATIC EFFORTS

Support for USACE activities related to climate change adaptation to date has been primarily provided by two programs: the IPET/HPDC Lessons Learned Implementation Team and Responses to Climate Change, with a third program (Global Change Sustainability) implementing lessons learned from these two programs (Fig 9).

IPET/HPDC LESSONS LEARNED IMPLEMENTATION TEAM

A major impetus driving USACE to prepare for climate change came from internal and external reviews following Hurricane Katrina. These reviews were provided by the Interagency Performance Evaluation Team (IPET)[13], the Hurricane Protection Decision Chronology (HPDC)[14] the American Society of Civil Engineers (ASCE 2009)[15] and the National Academies of Engineering and Public Administration (NRC 2009, NAPA 2009), among others.

The results of these were a clear indication to us that we need to

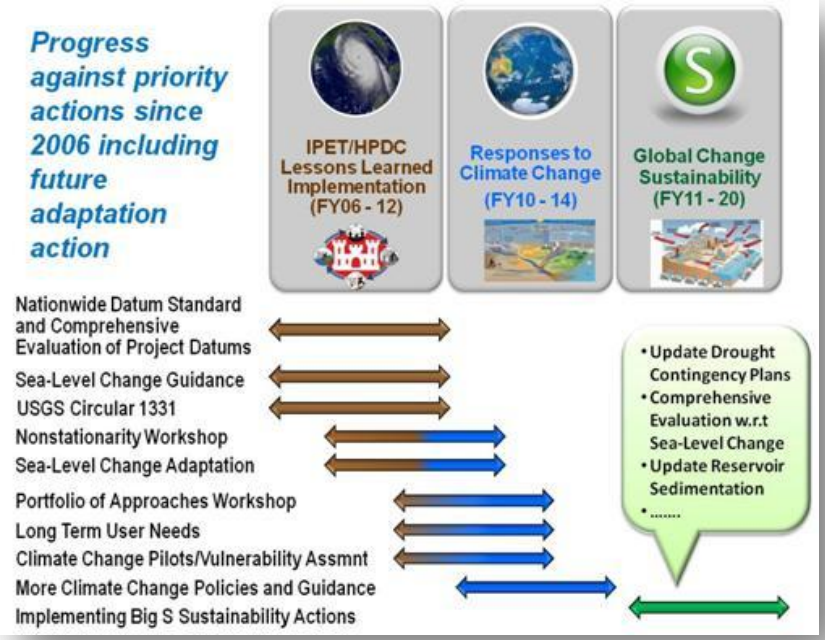

Figure 9. Interconnections between the three primary programmatic efforts supporting USACE climate change adaptation. Brown refers to the IPET/HPDC Lessons Learned Implementation Team activities, blue to Responses to Climate Change Program activities, and green to Global Change Sustainability Program activities.

[13] see https://ipet.wes.army.mil/
[14] see http://www.iwr.usace.army.mil/docs/hpdc/hpdc.cfm
[15] see http://www.asce.org/uploadedFiles/Publications/ASCE_News/2009/04_April/ERPreport.pdf

incorporate foreseen and surprise changes into our projects and programs. The IPET-HPDC Lessons Learned Implementation Team began working in 2006 to develop guidelines and recommend policy and program changes along with supporting technologies, to address dynamic processes, temporal and spatial changes, and their impacts to USACE projects on watershed, regional or system scale (e.g., subsidence, climate change and variability, sea level change).

Since 2006, the IPET/HPDC Lessons Learned Implementation Team has been active in responding to the lessons learned from Hurricane Katrina. The Team's goals related to climate change were to develop guidelines and recommend policy and program changes along with supporting technologies, to address dynamic processes, temporal and spatial changes, and their impacts to USACE projects on watershed, regional or system scale. Progress to date related to climate change adaptation includes three major areas: datums, sea-level change, and water resources management. Teams are working on adaptive management, how to incorporate social vulnerability, how to account for the effects of incremental changes over time to project performance, and integrating adaptation and mitigation.

RESPONSES TO CLIMATE CHANGE

The Responses to Climate Change Program (RCC) began in FY10, with the objective to develop and implement practical, nationally consistent, and cost-effective policies, methods, and approaches for effective adaptation of our projects, systems, and programs to climate change. In FY10, the RCC helped to support the CCAWWG workshop on nonstationarity and was the major source of support for the portfolio of approaches workshop. It is helping to fund the sea-level change guidance supporting adaptation.

The RCC is also the primary support in FY 11-12 of several climate change adaptation pilot studies conducted to test the CEQ flexible framework for adaptation at the project scale and to increase our understanding of how to prepare for climate change adaptation planning and implementation. These are described in more detail later. Climate change adaptation pilot projects that span the project life cycle and business lines continued in river basins, coastal regions, and ecosystem projects. The lessons learned from the adaptation pilots and vulnerability assessments are helping USACE to mainstream climate change adaptation, improve our planned detailed vulnerability assessment methods, and develop an adaptive management strategy for climate change and variability. This ultimately will improve water resources management and planning methodologies.

In FY 10-11, the RCC is developing and conducting preliminary, nationwide, screening-level vulnerability assessment of the CW portfolio of constructed and natural projects, both planned and existing. In FY11-12 more detailed vulnerability or stress-tests within the CW portfolio, with a focus on highest priorities and the existing portfolio. The results of the vulnerability assessments will assist in prioritizing further actions. RCC projected costs are $2.4M in FY10, $8.5M in FY11, and $5M in FY12 - FY14.

GLOBAL CHANGE SUSTAINABILITY

USACE has a requirement to successfully perform its missions, operations, programs, and projects in spite of an increasingly dynamic environment. Dynamic global changes such as changes in demographics, land use and land cover, socioeconomic and political conditions, and subsidence can

adversely impact USACE missions, programs, projects and operations. It is safer and more cost-effective to assess, plan, and prioritize now for adaptation to global change effects within an integrated water resources management context, rather than simply reacting on an ad hoc basis to future impacts as they emerge. The Global Change Sustainability (GCS) program builds on the foundational work of the RCC and the IPET/HPDC Lessons Learned Implementation Team to enhance the sustainability and resilience of our built infrastructure and the natural environment by providing a proactive, nationally consistent, and regionally sensitive framework and program of actions that will reduce the impacts and costs of global change effects.

The GCS will initially address the following areas of highest need: updating drought contingency plans, performing a comprehensive evaluation of USACE projects with respect to sea-level change, developing consistent strategies for dealing with global changes in coastal zones, updating reservoir sedimentation studies according to strategic and priority needs, and integrating adaptation and mitigation. Projected costs for this initiative are $10M in FY11 through FY20.

USACE ACCOMPLISHMENTS SUPPORTING EFFECTIVE CLIMATE CHANGE ADAPTATION PLANNING AND IMPLEMENTATION

The programmatic resources and collaborative actions described above that we have already undertaken to address climate change have resulted in very real accomplishments that support effective climate change adaptation planning and implementation. Accomplishments in several areas are described in more detail below.

NATIONWIDE DATUM AND SUBSIDENCE STANDARD

Findings from the IPET following Hurricane Katrina identified errors in vertical control, datum conversions, and accounting for subsidence, combined with increases in global sea level, as contributing factors in the disaster. USACE, with the assistance of USGS and NOAA experts, developed a standardized nationwide vertical datum and subsidence standard. This is the foundation for our collaborative and consistent approach to dynamic and changing coastal conditions. Since 2006, we have developed a series of new guidance regulations, policies, and manuals to support the nationwide datum and subsidence standard. We instituted the nationwide datum, trained and certified district datum coordinators, conducted a comprehensive evaluation of USACE projects with respect to datums, developed a database to track datums and datum compliance, provided workshops and training for the field, and assisted in technical support for districts. This effort will continue to completion in FY12. Tools and methods developed by this team will support the FY11-14 comprehensive evaluation of USACE projects with respect to sea-level change.

The USACE has a large coastal program that supports inland and maritime transportation, hurricane and coastal risk reduction, and ecosystem restoration. Our existing coastal infrastructure includes both natural and constructed components. So, we're very interested in what the future holds for coastal areas. The IPET findings were a call to USACE to update and expand policies and guidance to incorporate new and changing conditions in project planning and engineering. We began with an update to the existing USACE planning guidance on sea-level change and expanded it to the whole project life cycle (except regulatory).

The scenario-based sea-level change guidance (Figure 10) was developed with the aid of other agency experts from NOAA and USGS was released in 2009 in the form of Engineering Circular 1165-2-211, "Incorporating Sea-Level Change Considerations in Civil Works Programs," which has a two-year life span. This guidance is on schedule to be updated in July 2011 to account for new information, though the changes are not significant. However, we do expect additional information in the next several years to result in larger changes in the next update, and the regulatory program will be added following appropriate consultation.

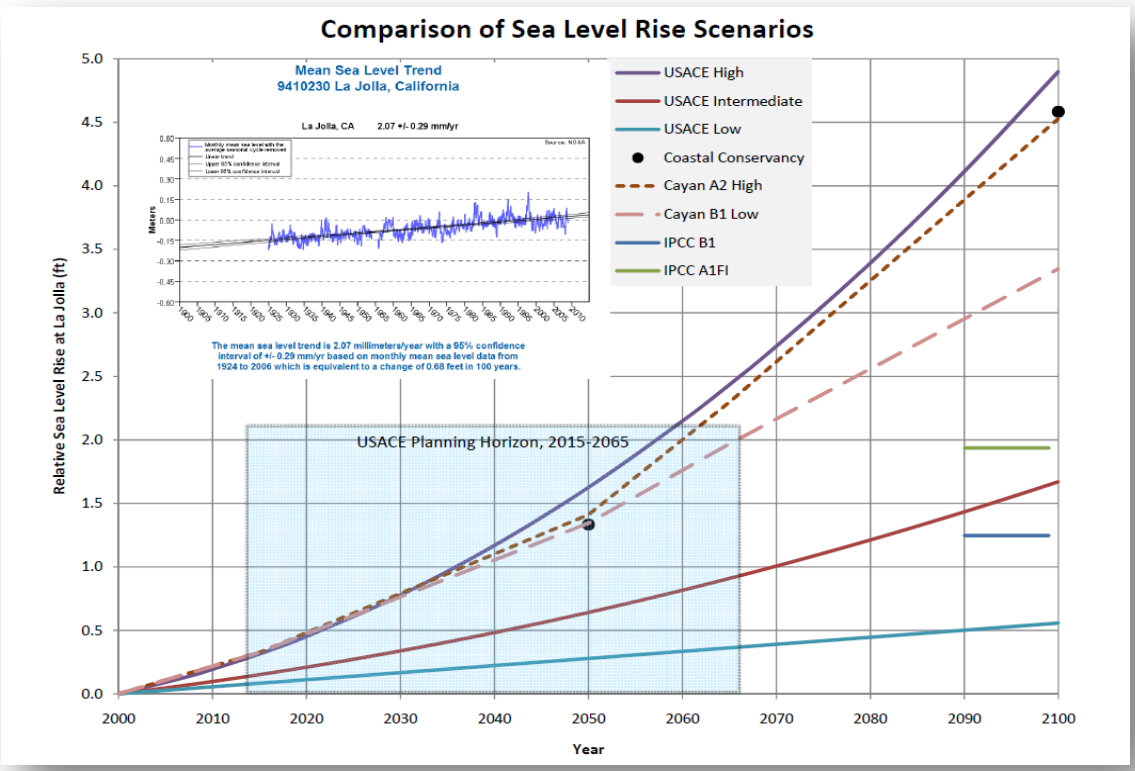

Figure 10. Sample of USACE EC 1165-2-211 sea-level change guidance applied to actual project site.

Perhaps the most important concept in this guidance is the clear understanding of the complex inter-related system around coastal climate change, including the very uncertain interaction between the socio-economic and natural system components. These are difficult enough to project into the future without the added potential effects of climate change, but it is exactly the range of

potential future conditions that we must understand in order to prepare and adapt our coastal communities to climate change.

As shown in Figure 10, our guidance incorporates three scenarios. The lowest blue curve is the extrapolated historical trend, which is an extrapolation of the NOAA tide gauge data shown in the inset box. This curve is primarily controlled by regional sea level change projection and land uplift or subsidence. The red intermediate curve is the updated 1987 National Research Council (NRC) curve 1. The blue and green markers that bound this line indicate the IPCC Special Report on Emissions Scenarios (SRES, IPCC 2000) B1 and A1FI scenarios at 2100. Note that the IPCC to date does not provide an analytical expression of sea-level change that allows us to develop a curve, but rather a single point in time in the future. The purple line provides the updated NRC curve 3. We can also represent stakeholder scenarios or projections. For this location, the dotted lines on the graph show locally-generated estimates (marked Cayan and Coastal Conservancy). The blue shaded box indicates the Corps' typical planning horizon.

To follow on this guidance, we are currently (FY09-11) developing updated coastal guidance addressing climate change impacts, responses, and adaptation, titled "Procedures to Evaluate Sea Level Change Impacts, Responses, and Adaptation." In FY11, the Responses to Climate Change Program (see next section) provided some additional funding to support this largely IPET/HPDC Lessons Learned Implementation Team effort, which is expected to be complete in late 2011 or early 2012. Additional work beyond this will address the effects of changing tides, waves, surges, and coastal storms.

WATER RESOURCES MANAGEMENT

At the urging of the Director of Civil Works in May 2007, USACE engineers and scientists began to evaluate the current state of knowledge of climate change impacts to water resources and how we could adapt our operations, programs, and projects to these impacts. This effort eventually culminated in the formation of the Climate Change and Water Working Group (CCAWWG) and the publication of USGS Circular 1331, "Climate Change and Water Resources Management: A Federal Perspective" published jointly (a first!) in 2009 (Brekke et al. 2009). In this collaborative effort, USACE and Reclamation represented the water resources operating agencies, and USGS and NOAA represented the water resources science agencies. CCAWWG has now expanded to include FEMA, EPA, and NASA. Representatives of Federal Highway Administration and Navy have participated in many activities.

USGS Circular 1331 included a list of user needs, which became the focus of several follow-on efforts. First, methods to address nonstationary hydrology was identified as a critical need, and second, it was clear that water resources users need best practice guidelines to assist them as they select form among the portfolio of approaches to develop climate information for use in planning, design, and operations that provide adaptive capacity. The IPET-HPDC Lessons Learned Implementation Team supported the interagency January 2010 "*Workshop on Nonstationarity, Hydrologic Frequency Analysis, and Water Management*." The Team supported the Responses to Climate Change Program in leading the interagency workshop on "Assessing a Portfolio of Approaches for Producing Climate Change Information to Support Adaptation Decisions" in November 2010. USACE and Reclamation also studied the user needs in more detail, and in early 2011, they jointly published a report, "Addressing Climate Change in Long-Term Water Resources

Planning and Management: User Needs for Improving Tools and Information" (Brekke et al. 2010). This report also included perspectives from a wide variety of other water managers. The science agencies (primarily USGS and NOAA) are currently developing a response that lays out a strategy for research in response to the identified user needs. Follow-on activities to all of these are funded under the Responses to Climate Change Program.

ADAPTATION PILOTS

Beginning in late 2009, the RCC supported climate change adaptation pilot studies. The goal of these initial pilots was to understand how climate is changing, apply this understanding to missions and operations, and develop and prioritize alternative adaptation actions. These pilots had three desired outcomes: 1) to test the Council on Environmental Quality (CEQ) proposed flexible framework for climate adaptation at the project scale, 2) to develop and demonstrate innovative methods, strategies, policy, and technologies supporting climate change adaptation, and 3) to build USACE district capacity in the professional and technical competencies important in climate change adaptation. The pilots range from coastal ecosystem projects to inland multi-purpose projects to evaluations of how climate change could affect future reservoir sedimentation. These pilots are led by district staff and can include interagency, academic, and other expert participation.

EachFY10 pilot concentrated on a central question to focus the participants on a key knowledge gap applicable to other projects. Example central questions are:

- How do we allow for shoreline retreat to preserve critical tidal and near-shore ecosystems in a long-term regional planning context?
- How will changing climate affect reservoir sedimentation?
- How do we incorporate climate change considerations into reservoir operating policies that will be robust and adaptable to potential climate changes?
- What information is needed for monitoring and assessing drought for water management decision making? How should this information be communicated to stakeholders?
- At what point will back bay flooding in certain portions of the beach decrease benefits to the point that beach renourishment is unjustified in those locations?

Only one pilot is complete (the C-111 Spreader Canal ecosystem restoration project); the remaining pilots are in various stages of progress. The most important lessons-learned to date are:

1. *Establishing a policy, no matter how broad, reduces the time and cost of adaptation*. For example, the C-111 Spreader Canal pilot was relatively quick and easy to accomplish because this coastal project could address projected future changes using the existing USACE sea-level change policy. On the other hand, for the paired basins sediment study being conducted with Reclamation, there is no policy, process, or guidance for selecting appropriate climate information for use in hydrology and sediment models . A policy helps to narrow the sometimes overwhelming ranges of alternatives, provides legal justification for decisions, and decreases planning and study time.

2. *Adaptation requires best available actionable science*, not simply best available science. There is a huge body of scientific literature about climate science. However, users require

some translation and a reasonable process to move from science outputs to adaptation planning and implementation.

3. *Costs and benefits are dynamic* and will change over time and space just as climate and other global changes do. Cost-benefit analyses that underlie adaptation planning and implement decisions may need to look at regional benefits or quantify changing benefits. A long-term planning horizon may be required to capture these dynamic changes in costs and benefits. Consideration of dynamic changes over time can guide adaptive management decisions.

An unexpected finding was that the pilot leads appreciated the framework's questions-based approach, because it encouraged them to take a more holistic view of all of the issues facing the project, rather than moving quickly into implementation using the same tools and methods (essentially a status quo approach). The development of a central question helped to focus pilot teams on the most important impact from climate change. Other lessons learned to date from the pilots include the following:

- Local or project-level application of the framework often concentrates on one or two aspects of the framework
- The development and use of consistent national and regional climate scenarios is critical to support local or project level implementation of the framework.
- Time and cost to study climate impacts and apply them to mission and operations are orders of magnitude higher than for agency-level planning
- Actual implementation takes additional time for adaptation options that involve stakeholder collaboration, engineering and design, construction, permitting, environmental impact assessments
- The CEQ adaptation framework is adaptable and general enough to be applied to existing projects at any step

The pilot projects will be continued in FY11-12 through a competitive process resulting in 9 additional funded pilots beginning in FY12. Priorities for FY11-12 include the following type of studies:

- Pilot studies to evaluate a proposed USACE framework for Risk-Informed Decision-Making (RIDM) for Climate Change.
- Pilot studies to support the sea-level change adaptation guidance being completed in FY11.
- Pilot studies that test the lesions learned from the FY10 workshops on nonstationarity and the portfolio of approaches to developing climate information.
- Policies that include collaborative work with other federal agencies, states, tribes and local governments on climate change topics of common interest.
- Pilot studies to support regional collaboration and solve regional climate change problems.

Figure 11. Coralville Reservoir, flood of 2008 – see inset box (next page) summarizing climate change adaptation pilot at this location.

- Pilot studies that support and use Integrated Water Resources Management (IWRM) as a framework for climate change adaptation within a watershed or river basin.
- Pilot projects that address bottom-up vulnerability assessments of USACE projects and/or systems of projects.

Example Pilot Project: Potential Impacts of Climate Change to Reservoir Operations

Reservoirs are designed to provide storage of water for many reasons: to help reduce flood risk, augment river flow support navigation and ecosystem requirements, increase water supply capacity, enhance hydropower, and support recreation benefits. Historically, reservoir design depended heavily on knowledge of the past observed rainfall and runoff data in a watershed. In most cases, reservoir regulation rules were congressionally authorized based on knowledge at the time of the design. With over 600 dams, the US Army Corps of Engineers is very concerned that increases in precipitation, especially very heavy precipitation could reduce the performance of its dams.

The pilot project team – including Iowa State University – conducted a dual-purpose pilot study of Coralville Reservoir, a multipurpose dam on the Iowa River that a) evaluated the proposed flexible framework for adaptation at a project level, and b) evaluated how to incorporate climate change considerations into reservoir operating policies to increase resilience. First, the team assessed vulnerabilities associated with climate change to identify where adaptation could help meet mission requirements at Coralville Reservoir. Next, the team evaluated projected climate changes. They found that the dominant future trend is for increased temperature and precipitation, with earlier spring snowmelt. These factors lead to greater risk of summer flooding (as observed in 1993 and 2008). On the other hand, there is less risk of spring snowmelt flooding (which dominated the original project design), and lower risk of prolonged drought periods. Using a risk-based approach, they identified the most likely and highest consequence impacts to project performance and associated key performance questions and metrics. The team then evaluated a range of adaptation measures and found that, even with adaptation, risk will remain. The most effective adaptive measures are likely to be those that take a broader, systemic view of flood risk management rather than considering just the authorized project. This would likely require new authorities and require broader participation by state and local government.

NATIONWIDE SCREENING-LEVEL VULNERABILITY ASSESSMENT

During fall 2010, USACE initiated a nationwide screening-level assessment of the vulnerability of its mission, operations, programs, and projects to climate change. The objectives of the nationwide screening-level assessment are to drive prioritization of adaptation measures as well as develop overarching policy. Similar national or global vulnerability assessments and even global assessments have performed using readily available geospatial tools, datasets, and indicators. Recent examples include Vorosmarty et al. (2000), Metzger et al. (2008), Larsen et al. (2008), Brody et al. (2008), Loarie et al. (2009), and Helbron et al. (2009).

For USACE, a combination of context and caution guided the design of the national-scale, high-level vulnerability assessment process. Since we are dealing with a complex, interrelated and

interdependent system in which isolation of cause and effect is inadvisable. We know that we should integrate multiple indicators rather than use single indicators. In using multiple indicators, we must also consider how they are correlated, because too much correlation could inadvertently bias further analyses or their interpretations.

Our the national-scale, high-level vulnerability assessment is more focused on changes over time (or process) rather than conditions at any state, becasue changes over time can help to highlight expects and unexpected results, and when there might be changes of state that could result from crossing thresholds or tipping points. The vulnerability assessment, to the extent possible, is also focusing on questions about "why" – or causal relationships – rather than about "how." The why questions support a reflective, forensic process that help to identify cascading impacts and unintended consequences.

Finally, the vulnerability assessment encourages a high capacity for uncertainty to dampen our reflexive desire to reduce uncertainty or over-simplify the system in a way that or decisions result in unintended and/or long-term consequences for which we have not developed monitoring or evaluation systems. This high capacity for uncertainty includes the requirement to engage in critical review and adjust our actions as necessary, a key tenet of the IPET, HPDC, and other analyses following Hurricane Katrina. A high capacity for uncertainty could result in, for example, scenarios to address a broad range of potential future outcomes, such as in the USACE sea-level change guidance. Or, it could allow us to develop a broad policy around nonstationary hydrology that can be refined over time as new knowledge becomes available.

A multidisciplinary project team of USACE scientists and engineers working together with academic and private sector experts developed an approach that supports assessment of business areas as well as an integrated assessment. We selected a reasonable large-scale approach that is indicator or index based, can utilize existing databases, is reproducible, can be updated as needed, and can be applied consistently by USACE personnel in different locations, to provide valuable screening level information on vulnerability to climate change. The preliminary results are expected in late 2011 or early 2012. These results will eb reported in the June 2012 submittal to CEQ.

INTEGRATING ADAPTATION AND MITIGATION

The global change threats facing USACE infrastructure and programs are by their nature integrated and often reinforcing. The projected increases in mean global and continental temperatures resulting from past and continued greenhouse gas (GHG) emissions, for example, may well accelerate the recent trends in population distribution whereby increasing numbers of people are living on vulnerable coasts and flood plains. The successful, efficient implementation of our work to characterize and understand specific global change threats to USACE projects and programs depends on a response plan of action that correctly takes account of these integrated effects. So, for example, climate change adaptation measures can be taken to decrease USACE vulnerability to changes stemming from demographic shifts to coasts and flood plains, or to increase project resilience against changes in the timing and form of precipitation in specific regions. But these adaptation efforts have to be planned, executed, and evaluated in concert with both the more general resource conservation measures and the more specific GHG emissions reductions and other climate change mitigation measures required of USACE and its public and private partners.

The complexity of the hydrologic system and the long time scale of most USACE operations have meant that unforeseen consequences have resulted from changes we implement in practice, because the interconnections are not fully known or understood. The potential for unintended consequences cannot be allowed to become a hindrance to action with respect to climate change adaptation and mitigation, however. The immensity and immediacy of global changes mean that the need for quick decision making and execution on one side must be continually re-balanced against the slower accumulation of fine-grained science and engineering knowledge on the other (e.g., Dessai et al. 2009). To strike and then monitor this balance for the various global change threats, USACE will make use of the close, cooperative relationships developed during emissions inventory pilot testing with District and Division personnel who are directly facing global change threats, and hence must integrated adaptation and mitigation.

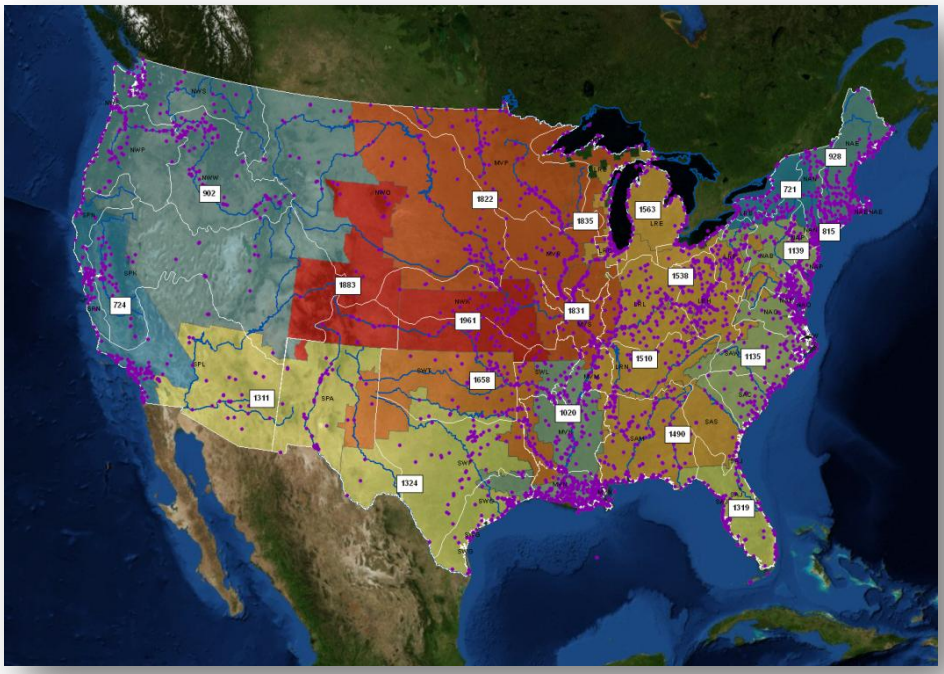

Figure 12. Visualization of eGrid (colored regions) and USACE projects (purple dots) in the continental US (after EPA, from data accessed December 2010). Emissions intensities relate to the CO2 equivalent in the fuel used to generate electricity.

Our first steps are to be able to visualize important factors for integrated decision-making around adaptation and mitigation. For example, using the data from the Emissions and Generation Resource Integrated Database (eGRID[16]) and locations of Corps projects (Fig. 12), we can begin to make decisions about which locations are best suited to which mitigation strategies. The different colors represent areas with different emissions intensity in terms of pounds of CO_2 equivalents – CO2e – (CO2, methane, and nitrous oxide) per MWH produced, as shown by the numbers in Figure 12. Cool colors (like New York) indicate lower values of emission intensity in terms of CO2e, whereas warmer colors like red (in the center of the country) indicate higher values of emission intensity in terms of CO2e.

[16] See http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html

This is not the whole story when it comes to making decisions, but it does provide information to support decision-making. For example, we don't want to increase electric vehicle usage in areas with high carbon intensity (because that would increase emissions). It will be a higher priority to increase renewable energy sources at appropriate locations where the carbon intensity is high (to reduce emissions) than where carbon intensity is low. Finally, all other things being equal, investments in energy efficiency produce a greater return where emissions intensity are highest Combining this information with the results of the vulnerability assessment helps us to begin to integrate investment decisions. Integrated assessments support a portfolio management approach with mix of near-term and long-term actions.

FY12 PRIORITIES: TOP SIX

NATIONAL ACTION PLAN TO MANAGE FRESHWATER RESOURCES IN A CHANGING CLIMATE

In the October 2010 Report to the President (CEQ 2010), the Federal Interagency Climate Change Adaptation Task Force described Federal agency actions needed to better prepare the Nation to respond to the impacts of a changing climate. The Task Force recommended in the Progress Report that the Water Resources and Climate Change Adaptation Workgroup of the Task Force develop a national action plan to identify steps that Federal agencies can take to improve management of freshwater resources in a changing climate. To accomplish this goal, the Workgroup wrote the National Action Plan to Manage Freshwater Resources in a Changing Climate (NAP). The NAP was released for public review in June 2011. The NAP makes six major recommendations:

1. Establish a planning process to adapt water resources management to a changing climate
2. Improve water resources and climate change information for decision-making
3. Strengthen assessment of vulnerability of water resources to climate change
4. Expand water use efficiency
5. Support Integrated Water Resources Management (IWRM)
6. Support training and outreach to build response capability

USACE has been the lead agency on developing supporting actions for Recommendation 5 on Integrated Water Resources Management. USACE has agreed to lead the implementation of supporting actions that are intended to improve river basin governance, better coordinate drought and flood risk management for a changing climate, and support adaptive management, beginning in late FY11. Certainly, the new PR&G and the associated agency-specific guidelines would be an important consideration.

RISK-INFORMED DECISION-MAKING FOR CLIMATE CHANGE

USACE is developing a risk management framework to incorporate climate change uncertainties into decision making. A single risk management framework enables the USACE to develop broadly applicable and transparent process that considers climate change. The framework is systematic, scalable, simple and flexible and can be applied at the project level or for a system of projects, such as watershed plans for integrated water resources management. The framework is intended to be

applied across the entire project life-cycle, since climate change uncertainty may require making sequential decisions over time and updating design and plans to incorporate new and changing information.

The risk assessment approach includes consequence and likelihood assessment. The framework can employ qualitative and/or quantitative techniques for risk analysis and outlines how to choose an approach. It also describes formulation of risk management alternatives under changing conditions, an important consideration for climate change adaptation. The framework emphasizes the need for stakeholder involvement throughout the decision process. The risk management framework will be a foundation for developing strategies to incorporate climate change into the decision making processes of USACE, with FY12 priorities being ecosystem restoration, flood risk management, and water management.

NONSTATIONARITY

One of the objectives of the January 2010 *Workshop on Nonstationarity, Hydrologic Frequency Analysis, and Water Management* was to facilitate Federal interagency efforts to account for nonstationarity in hydrologic frequency analysis. The Hydrologic Frequency Analysis Work Group[17] (HFAWG) is currently revising Bulletin 17B, *Guidelines for Determining Flood Flow Frequency (*U.S. Interagency Advisory Committee on Water Data 1982). The new revision will likely update the current section on "Climate Trends" and may say that major changes in climate may be occurring over decades or centuries. Although the Bulletin 17B revision under way may permit time-varying parameters or other techniques where changes in climate and flood risk over time can be quantified, it is likely there will be a number of unanswered questions remaining.

In parallel with the revision of Bulletin 17B, USACE, FEMA, Reclamation, and the Federal Highways Administration (FHWA) have agreed to work together to write a "terms of reference" (TOR) to discuss approaches to and issues regarding nonstationarity, climate change, and flood risk. The TOR could also describe future opportunities for Federal collaboration. USGS and NOAA may also participate in this effort. Nonstationarity should also be considered in the new PR&G and agency-specific guidelines. Developing methods and procedures to address nonstationarity throughout the project life cycle is an FY12 priority action for the USACE.

PORTFOLIO OF APPROACHES

The wide portfolio of possible approaches for producing and using climate change information for water resource adaptation questions can bewilder planners and engineers because each method or analytical technique in this portfolio brings uncertainties and particular deficiencies, some of which are large or only partly characterized and poorly quantified. Also, operating and resource management agencies looking to use these techniques to inform their climate adaptation planning currently lack good practice guidelines for helping them assess the approaches and choose appropriate ones for particular adaptation decisions. To answer this need for support, CCAWWG

[17] HFAWG is a work group of the Subcommittee on Hydrology (SOH) of the Advisory Committee on Water Information (ACWI), see http://acwi.gov/hydrology/Frequency/B17bFAQ.html.

conducted a workshop on "*Assessing a Portfolio of Approaches for Producing Climate Change Information to Support Adaptation Decisions*" 9-10 November 2010 in Boulder, CO.

One objective of the workshop was to gauge support for the idea of good practice guidelines to support climate change adaptation decision-making. The workshop provided a platform for agency representatives to discuss their approaches for producing and using climate change information and to hear from climate science agencies on the possibility and desirability of establishing a multi-agency, common framework of good practices for assessing the strengths and limits of the approaches.

To be useful and adaptable in the face of changing conditions, good practice guidelines for water-resource adaptation decisions will not dictate individual approaches to be taken for specific applications. Rather, they will help agencies develop robust, defensible, and reproducible practices for assessing the strengths and limits of different approaches to using climate information at the various choice-points in their decision processes. The guidelines ideally will be flexible enough to apply to current state-of-the-science information as well as to future climate science developments.

During FY12, the CCAWWG workshop organizers will draft and publish a larger report, which will contain extended abstracts for the presentations from workshop speakers. The report will also provide more details on the portfolio of approaches to climate information for water-related adaptation decisions and the first steps identified in the workshop for building guidelines for using those approaches. These approaches will also be tested in selected UASCE climate change adaptation pilot studies.

MORE REFINED VULNERABILITY ASSESSMENTS

This report contains the preliminary high-level vulnerability assessment required by CEQin September 2011 in the form of answers to the guiding questions. The USACE is conducting a more detailed, yet still high level, nationwide screening-level vulnerability assessment underway is conducted at a scale that can help prioritize adaptation measures and guide overarching policy development. Both of these assessments can be considered top-down assessments, which are typically hazard- or scenario-based (e.g., Füssel 2008). The top-down, or large-scale vulnerability assessment approach for future climate impacts is a scaled approach that arrives at vulnerability assessments from global (e.g., socio-economic and climate projections) to local scale (physical vulnerabilities).

However, these assessments are not sufficient, in and of themselves, to guide project or watershed-level decision-making. Instead, as USGS Circular 1331 noted, some combination of top-down and bottom-up approaches is necessary to plan and design detailed adaptation implementation at a local scale. The bottom-up approach is generally vulnerability-based and examines past and current issues, beginning from sectoral analyses of impacts, followed by assessments of adaptive capacity and vulnerability to future projected conditions. The difference in perspectives between top-down and bottom-up assessments can serve as a tool for increasing understanding around impacts and adaptation (e.g., Dessai and Hulme 2004), and hence climate policy is perceived as the unifying factor for these approaches.

In FY12, USACE will refine the top-down assessment already underway, and also begin more detailed, bottom-up assessments to identify project-scale vulnerabilities and adaptation alternatives. In combination, these vulnerability assessments will support detailed climate change adaptation planning, investment decisions, and implementation details.

METRICS AND ENDPOINTS

Appropriate metrics and endpoints for the assessment of the productivity and efficiency of climate change adaptation activities are critical to achieve our desired results: to develop practical, nationally consistent, legally justifiable, and cost effective measures, both structural and nonstructural, to reduce vulnerabilities and improve the resilience of our water resources infrastructure impacted by climate change. The wrong choice of measures and endpoints will hinder our ability to develop truly sustainable adaptation measures. The right choice of metrics and endpoints will ease the transition to a new organizational culture that

As a result developing and implementing metrics and endpoints for climate change adaptation is a high priority activity for FY12. Federal metrics are still under discussion at this time, so our approach is based on the National Research Council (2005) discussion of metrics for the Climate Change Science Program (now US Global Change Research Program). They describe process, input, and outcome measures that could provide the basis for our own.

Following their approach, USACE could consider process metrics that those that measure the actions required to achieve the goal of mainstreaming adaptation. These could include establishing leadership with authority to allocate resources, direct efforts, and facilitate progress; implementing a strategy for setting priorities and allocating resources; encouraging collaborative efforts and the use of common tools where appropriate; and putting procedures in place to enable or facilitate the use or understanding of adaptation measures by others, internal and external to USACE. Given current progress described in this report, USACE is well on the way to achieving these types of process metrics.

Input measures are more describable and (qualitatively) countable than outcome metrics, but should be approached with care so that the quantification is not the focus. If we consider input metrics to be those that measure the tangible inputs required to achieve the goal mainstreaming climate change adaptation, we could devise a phased approach to be sure that new knowledge is incorporated in USACE missions, operations, programs, and projects. For example, one measure could be the sufficient commitment of resources to allow USACE adaptation measures to be implemented according to an initial strategy. But a related measure could also be to support the opportunities to incorporate new learning into the overall strategy and into implementation plans. The new information could arise from unanticipated discovery, competing ideas and interpretations, and innovative and comprehensive approaches. Input metrics designed to incentivize organizational behavior changes might promote human capital, transition from planning to operational activities, and transmitting data and knowledge. Input metrics could also help ensure that adaptation support programs take advantage of existing resources, knowledge, collaborative relationships, and common tools in an appropriate manner.

Outcome metrics can be used to measure the use of climate change adaptation planning and implementation outputs. For example, USACE has identified one outcome as increased

understanding of, or reduced uncertainties supporting decision-making related to climate change adaptation planning in a comprehensive systems approach that incorporates anticipatory management to remain adaptable and sustainable over time. Another example could be that climate change adaptation planning has been translated into operational use by USACE programs and projects. Another might be that climate change adaptation planning has improved processes, methods, tools, technologies, and capabilities to address the range of climate change impacts facing USACE, and that these are adaptable to remain relevant as needs change.

Finally, impact metrics may be used to measure the long-term consequences of the mainstreaming climate change adaptation. For USACE, important impacts to measure might be how climate change adaptation planning has informed policy and improve decision-making, or how adaptation planning and implementation have benefitted the Nation by reducing risk to life and property, enhancing economic vitality, promoting environmental and infrastructure sustainability, and reducing vulnerability to dynamic processes.

SUMMARY

This report presents the climate change adaptation policy statement, progress on climate change challenges, programmatic efforts, and adaptation planning priorities of the US Army Corps of Engineers as of 3 June 2011. The guiding questions posed by the White House Council on Environmental Quality in its *Implementing Instructions* about how climate change impacts USACE mission and strategic goals, and how we are coordinating and collaboration to better manage climate change adaptation, form the basis of a high-level vulnerability assessment to climate change.

Our progress to date is significant, and includes interagency collaboration around climate change impacts to water resources and performing pilot projects to test and evaluate climate change adaptation measures. Products include a foundational report, *Climate change and water resources management: A federal perspective*, workshops directed at priority issues of climate change adaptation for water resources managers, guidance development, and a report on user needs for long-term water resources planning.

USACE has coordinated and collaborated extensively to address the climate challenges facing us, and we continue to do so even as we conduct our nationwide screening-level assessment of vulnerability to climate changes and begin additional adaptation pilot projects. We are working to integrate adaptation and mitigation activities, and providing resources to achieve our highest priorities for FY12. These priorities include: supporting the National Action Plan to Manage Freshwater Resources in a Changing Climate, developing and implementing a framework for risk-informed decision-making for climate change, addressing the critical needs of nonstationary hydrology and how to select from the portfolio of approaches, refining our vulnerability assessments to include bottom-up approaches at the project level, and developing metrics and endpoints to measure adaptation effectiveness.

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APPENDIX A: GUIDING QUESTIONS

How is climate change likely to affect the ability of your agency to achieve its mission and strategic goals?
Think about how climate change impacts your agency's strategic plan (or related long-term planning document/guidance). This question is meant to trigger a high-level evaluation, not a comprehensive examination of all agency programs and operations. To answer this question, please respond to the three subparts below.

a) To focus your response, identify at least three of your agency's strategic goals or objectives to evaluate. (You can elect to work on more than three goals at this time if you wish, although it is not required. At a later date, you will be required to evaluate all relevant goals.) You may find your strategic goals are too broad to evaluate effectively in which case you should select three strategic objectives instead.
The agency strategic goals or objectives selected for this exercise are:

Goal/Objective 1:

Goal/Objective 2:

Goal/Objective 3:

b) For each goal or objective listed above, identify major climate change impacts that may significantly impact your agency's ability to meet the goal or objective. Briefly describe how these impacts affect your selected goals or objectives. *Some examples of climate change impacts are provided in Appendix F. Note that this is not an exhaustive list. After reviewing the recommended literature, you may wish to identify a climate change impact that is not listed in Appendix F. Consider how each goal or objective is impacted by climate change. Also consider if the impacts of climate change could undermine your agency's ability to successfully achieve the selected goals or objectives.*

c) What steps has your agency taken to manage the effects of climate change on the selected goals or objectives?

2. **How can Federal agencies coordinate and collaborate to better manage the effects of climate change?** *In some cases, climate change impacts cut across Federal agencies' missions and operations, for example, those related to water resource management, public health, and communities. Agencies can improve their effectiveness in developing climate change adaptation measures and leveraging resources by coordinating and collaborating on cross-cutting issues. The tables below may help guide your response.*

a) Identify Federal agencies that are likely to face similar climate change impacts and management challenges to your agency. Describe how their management challenges are similar to yours.

Agency	How Climate Change Management Challenges are Similar

b) Is your agency already collaborating with other agencies to develop strategies to adapt to climate change impacts that cut across agency mission and operations? If so, identify the agencies and briefly describe the collaboration or project? If your agency is engaged in many collaboration activities, select a few of the most significant.

Agency	Existing Collaboration/Project

c) Identify and describe opportunities for new or additional collaboration activities with other agencies to leverage resources and develop consistent adaptation strategies.

Agency	Potential Collaboration/Project