U.S. ARMY CORPS OF ENGINEERS

CLIMATE CHANGE ADAPTATION PILOTS

SEPTEMBER 2012
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The hydrologic and coastal processes underlying water resources management are very sensitive to changes in climate and weather. The U.S. Army Corps of Engineers (USACE) has a compelling need to understand and adapt to climate change and variability because our Civil Works Program and associated water resources infrastructure represent a tremendous Federal investment that supports public safety and local and national economies. USACE is mainstreaming climate change adaptation across activities to enhance the resilience of our nation’s water resources infrastructure, and to reduce our vulnerabilities to the effects of climate change. We have developed a governance structure to support mainstreaming adaptation by establishing an overarching USACE Climate Change Adaptation Policy Statement and a Climate Change Adaptation Steering Council.

Our overarching policy requires USACE to mainstream climate change adaptation in all activities to help enhance the resilience of our built and natural water resources infrastructure and reduce its potential vulnerabilities to the effects of climate change and variability. Based on the best available and actionable science, we identified six adaptation priority areas. Our progress on these priorities benefits from extensive interagency collaboration and an active program to improve our knowledge about climate change and adaptation.

One way that USACE is improving our knowledge about climate change impacts and adaptation is by conducting targeted pilot studies to test new ideas and to develop and utilize information at the project-level scale, and to glean information needed to develop policy and guidance. Through these pilots, USACE is developing and testing alternative adaptation strategies to achieve specific business management decisions; identify new policies, methods, and tools to support adaptation for similar cases; learn how to incorporate new and changing climate information throughout the project lifecycle; develop, test, and improve an agency level adaptation implementation framework; and to implement lessons learned. Each of these pilot studies addresses a central question that will help guide us as we develop policy and guidance to mainstream adaptation including the following:

- **How do we allow for shoreline retreat to preserve critical tidal and nearshore ecosystems in a long-term regional planning context?**
- **What is the relationship between changing climate conditions and reservoir sedimentation, and could this relationship shorten the lifetime of the infrastructure project or impact its flood control pool?**
- **How do we incorporate climate change considerations into reservoir operating policies that will be robust and adaptive to potential climate changes?**
• How will dredging cost requirements at Great Lakes harbors vary in the future as the climate potentially changes precipitation regimes and runoff characteristics?
• Can we develop a conceptual framework for how climate change information might be incorporated into ecosystem restoration projects?
• Is mountain snowpack and subsequent runoff changing due to changes in climate, and is the Missouri River Basin, therefore, more susceptible to droughts and floods?
• How do we facilitate well-designed and inclusive multi-stakeholder collaboration with the local decision makers for the purpose of identifying vulnerability to sea-level change impacts, acceptable levels of risk, and the most acceptable alternatives over the project lifecycle?

Taken together, however, the pilot projects are providing a body of knowledge and tested methods that will be the foundation of how USACE successfully adapts to climate change, thereby increasing our resilience to, and decreasing our vulnerability from, the effects of changing climate.

One of the most important lessons learned to date is that establishing a policy, no matter how broad, reduces the time and cost of adaptation. This is because policy not only provides legal and technical justification, it also narrows the range of potential alternatives and guides planning and study approaches to support the desired decisions. Based on this lesson learned, USACE is working to develop both enabling (e.g., how do we frame the approach) and implementing (e.g., how we adapt) policies and guidance for adaptation.

We also found that adaptation requires not simply the best available science, but actionable science. This is important because science alone is not determinative for policy. There is a gap between science and application that must be addressed in policy. Fortunately, engineers are ideally positioned to translate science into practice. We found that we have enough science now to develop initial adaptation policy and guidance, and that close coupling of engineering to science speeds development of policy and guidance.

Lastly, a third important factor identified in our pilots is that costs and benefits are dynamic and will change over time, just as climate does. We may need to look at regional benefits or quantify changing benefits. Consideration of dynamic changes over time can guide adaptive management decisions. These are just a few of the lessons learned; the following pages provide highlights from each pilot project with their specific lessons learned and key results that will form the basis for future policy, guidance, and methods.
KEY

[1] Application of Sea-Level Change Guidance to **C-111 Spreader Canal**, Florida
[2] Climate Change Associated Sediment Yield Impacts on the Rio Grande, **Cochiti Dam and Lake**
[3] Climate Change Impacts on the Operation of **Coralville Lake**, Iowa
[6] Upland Sediment Production and Delivery in the **Great Lakes Region** under Climate Change
[8] Climate Modeling and Stakeholder Engagement to Support Adaptation in the **Iowa-Cedar Watershed**
[10] Utilization of Regional Climate Science Programs in Reservoir and Watershed Risk-Based Assessments, **Oologah Lake and Watershed**
[12] Formulating Mitigation/Adaptation Strategies through Regional Collaboration with the **Ohio River Basin Alliance**
[13] Climate Change Impacts on Water Supply in **Marion Reservoir Watershed**, Kansas
[14] **Red River of the North** Flooding at Fargo, North Dakota
In January 2011, the U.S. Army Corps of Engineers (USACE) and the Bureau of Reclamation, under the auspices of the Climate Change and Water Working Group (CCAWWG), co-published *Addressing Climate Change in Long-Term Water Resources Planning and Management* (LT Doc). The document describes the water management community’s needs for climate change information and tools to support long-term planning. Within that context, 39 gap statements were made across eight primary categories:

1) Summarize Relevant Literature  
2) Obtain Climate Change Information  
3) Make Decisions About How To Use the Climate Change Information  
4) Assess Natural System Response  
5) Assess Socioeconomic and Institutional Response  
6) Assess System Risks and Evaluate Alternatives  
7) Assess and Characterize Uncertainties  
8) Communicate Results and Uncertainties to Decision-makers

The USACE Responses to Climate Change (RCC) Pilots are helping to address many of the gaps identified and presented through the CCAWWG LT Doc Process. The RCC links to CCAWWG are illustrated in Table 1

(Image: Missouri River Mountain Snowpack Accumulation and Runoff Pilot Study)
<table>
<thead>
<tr>
<th>USACE RCC Pilot</th>
<th>CCAWWG Primary Gap Relationships</th>
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</table>
| 1 Application of Sea-Level Change Guidance to C-111 Spreader Canal, Florida (SAJ) | 4) Assess Natural System Responses  
6) Assess System Risks and Evaluate Alternatives  
7) Assess and Characterize Uncertainties |
| 2 Climate Change Associated Sediment Yield Impacts on the Rio Grande, Cochiti Dam and Lake (SPA) | 4) Assess Natural System Responses  
6) Assess System Risks and Evaluate Alternatives |
| 3 Climate Change Impact on the Operation of Coralville Lake, Iowa (MVR) | 4) Assess Natural System Responses |
| 4 Climate Change Associated Sediment Yield Impacts and Operation Evaluations at Garrison Dam North Dakota (NWO) | 4) Assess Natural System Responses |
| 5 East Rockaway Inlet to Rockaway Inlet, NY Collaboration Framework Development (NAN) | 6) Assess System Risks and Evaluate Alternatives  
7) Assess and Characterize Uncertainties  
8) Communicating Results and Uncertainties to Decision-makers |
| 6 Upland Sediment Production and Delivery in the Great Lakes Region under Climate Change (LRE) | 2) Obtain Climate change Information  
4) Assess Natural System Response |
7) Assess and Characterize Uncertainties |
| 8 Climate Modeling and Stakeholder Engagement to Support Adaptation in the Iowa-Cedar Watershed (MVR) | 7) Assess and Characterize Uncertainties  
8) Communicating Results and Uncertainties to Decision-makers |
| 9 Framework for Building Resiliency into Restoration Planning – Lower Columbia River Estuary (NWP) | 7) Assess and Characterize Uncertainties  
8) Communicating Results and Uncertainties to Decision-makers |
| 10 Climate Change Impacts on Water Supply in Marion Reservoir Watershed, Kansas (SWT) | 3) Make Decisions About How to Use the Climate Change Information  
6) Assess System Risks and Evaluate Alternatives  
7) Assess and Characterize Uncertainties |
| 11 Missouri River Basin Mountain Snowpack – Accumulation and Runoff (NWD) | 2) Obtain Climate Change Information  
3) Make Decisions About How to Use the Climate Change Information  
4) Assess Natural System Response |
| 12 Formulating Mitigation/Adaptation Strategies through Regional Collaboration with the Ohio River Basin Alliance (LRH) | 6) Assess System Risks and Evaluate Alternatives  
8) Communicating Results and Uncertainties to Decision-makers |
| 13 Utilization of Regional Climate Science Programs in Reservoir and Watershed Risk-Based Assessments, Oologah Lake and Watershed (SWT) | 6) Assess System Risks and Evaluate Alternatives |
| 14 Red River of the North Flooding at Fargo, North Dakota (MVP) | 2) Obtain Climate Change Information  
3) Make Decisions About How to Use the Climate Change Information  
7) Assess and Characterize Uncertainties |
8) Communicating Results and Uncertainties to Decision-makers |
BACKGROUN D

Man-made drainage features have disrupted the hydrologic regime of the Everglades, causing a transition from a wetland system characterized by overland sheet flow, to one where water moves swiftly through conveyance features to point source discharge areas along Florida Bay. The altered hydroperiods have led to declines in prey bases for numerous macrofauna, including migratory birds. The changes in freshwater hydrology have also led to secondary effects on the estuarine and marine environments of Florida Bay. Damaging freshwater pulses from the Spreader Canal Western Project, located in Southern Miami-Dade County, Florida, southeast of Everglades National Park, disrupt flow patterns and create an unnatural salinity envelope along the shorelines and farther into the bay. These salinity changes adversely impact nursery areas for fish and invertebrate species. The C-111 Spreader Canal Western Project Recommended Plan includes the following major features: Frog Pond Detention Area (FPDA) with 225 cubic feet per second (cfs) pump station; Aerojet Canal with 225 cfs pump station; and ten plugs in the C-110 Canal. These features are shown below along with a depiction of the estimated zone of freshwater wetland rehydration. The FPDA and Aerojet Canal are intended to work in unison to create a nine-mile long hydraulic ridge adjacent to Everglades National Park. The ridge will serve to block groundwater flows from moving into the C-111 Canal from Everglades National Park, therefore, retaining water in Taylor Slough to enhance freshwater wetland function and to improve the quantity, timing and distribution of flows into Florida Bay. Improved habitat conditions are expected to result in increased numbers of birds and nearshore marine organisms.

VULNERABLE BUSINESS LINES
Flood Risk Reduction, Ecosystem Restoration, Water Supply

CENTRAL QUESTION ADDRESSED BY PILOT

How do we allow for shoreline retreat to preserve critical tidal and nearshore ecosystems in a long-term regional planning context?

APPROACH

This pilot tests the application of recent U.S. Army Corps of Engineers (USACE) sea-level change and datum guidance and policy. The Engineering Circular (EC) 1165-2-211 (and 212) evaluation was conducted during the later stages of the plan formulation process to estimate the impact of sea-level change on project benefits. Maps were created to show projections of the benefited freshwater wetland area and the shoreline. Impacts to freshwater wetland rehydration benefits were estimated by determining the fraction of benefit area inundated under increased mean sea level. Impacts to salinity benefits were estimated based on the availability and potential suitability of freshwater habitat for conversion to saltwater habitat.
LESSONS LEARNED

- Enabling policy requiring the consideration of three scenarios of sea-level change guidance supported a fairly rapid analysis of sea level rise (depth) and salinity changes during the planning process.
- Mean Higher High Water (MHHW) is a better indicator than mean sea level (MSL) for the transition from freshwater to saltwater ecosystems.
- Allowing for shoreline retreat in environmental restoration areas can preserve critical tidal and nearshore ecosystems.
- Simple and quick GIS-created inundation maps with one-foot increments are adequate for planning phase studies given the uncertainties of topographic information, water supply, and habitat response. When possible, more sophisticated evaluation tools could be used to take into account substrate stability, erosion/sedimentation, and vegetation salinity tolerance.
- Sustaining ecosystem restoration benefits requires planning for long-term adaptation capacity, including coordination with other regional flood protection planning efforts.

KEY RESULTS

- Establishing a policy that describes climate impacts to consider, no matter how broad, reduces the time and cost of adaptation planning.
- Both costs and benefits are dynamic over space and time.
- Long-term maintenance of nearshore salinity project benefits is feasible for this project under projected sea-level change, given few natural or man-made topographic obstructions to shoreline retreat.
- The ecological functions of transitioning habitat are likely to be limited for some period as the quality of the replacing habitat will be constrained initially.
- Long-term restoration and protection of freshwater wetland habitat upland of the MSL line is dependent upon sufficient delivery of freshwater supplies to protect salinity intolerant vegetation and peat soil substrate from infrequent higher tide events.
- Sufficient delivery of freshwater will require enhanced water supplies as provided by regional restoration efforts in addition to the water provided by this project.
- The study is complete.

FOR MORE INFORMATION

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BACKGROUND
Climate models for the Southwestern United States project average temperature increases that have the potential to lead to increasing aridity, decreasing soil moisture, and declines in headwaters mountain snowpacks. How such hydrologic changes might affect stream flow and sedimentation at the U.S. Army Corps of Engineers (USACE) Cochiti Dam and Lake Project is the topic of this pilot study. Cochiti Dam is located at the confluence of the Rio Grande and the Santa Fe River on Pueblo de Cochiti Land, approximately 50 river miles north of Albuquerque, NM. The dam, which was completed and operational in 1975, has a drainage area of approximately 11,685 square miles and serves as the primary flood control structure for snowmelt runoff control on the mainstem of the Rio Grande. Cochiti Lake storage includes approximately 500,000 acre-feet for flood control and another 105,000 acre-feet for sediment accumulation. As of 2009, approximately 73,517 acre-feet remained in the sediment reserve space.

VULNERABLE BUSINESS LINES
Flood Risk Reduction, Navigation, Hydropower, Recreation

CENTRAL QUESTION ADDRESSED BY PILOT
What is the relationship between changing climate conditions and reservoir sedimentation, and could this relationship shorten the lifetime of the infrastructure project or impact its flood control pool?

APPROACH
This pilot is part of a joint U.S. Bureau of Reclamation (Reclamation) - U.S. Army Corps of Engineers (USACE) study that examined climate change impacts at paired reservoirs, including Bighorn Lake in Montana and Wyoming, Elephant Butte Reservoir in New Mexico, Garrison Reservoir in North Dakota, and Cochiti Reservoir in New Mexico. Reclamation provided USACE with dynamically downscaled climate model ensembles with projections for monthly changes to temperature and precipitation under five different climate scenarios for two different time periods: 2010 through 2039, and 2040 through 2069. Reclamation input these data into a Variable Infiltration Capacity (VIC) model to derive values for runoff, infiltration, and contributions to groundwater from precipitation falling on a particular subset of the region. These data were then input by USACE into its Upper Rio Grande Water Operations Model (URGWOM) in order to model changes of stream discharge into Cochiti Lake. Future sedimentation at Cochiti Lake was determined using monthly discharge as input to existing sediment transport equations.
LESSONS LEARNED

- Because climate change is only one of many factors that can affect sediment influx to reservoirs, an integrated watershed model would more effectively account for watershed changes that affect stream flow, sediment transport, and other hydrologic variables.
- Knowledge of local climate, climate trends, hydrology and fluvial geomorphology are essential to make sense of model results.
- Expertise needs to be available within the district to evaluate information produced by others.

KEY RESULTS

- The projected changes in temperature and precipitation produced a decrease in stream flow volume along the Rio Grande mainstem, characterized by lower-volume, shorter-duration, earlier spring runoff pulses and decreases throughout the rest of the year.
- Overall reductions in inflow to Cochiti Lake were found, particularly in the period from 2040 to 2069 relative to the late 20th century baseline. These were driven by overall declines in runoff volume, particularly in winter and spring, and a shift in the hydrograph to an earlier, lower spring peak flow.
- Reservoir sedimentation rates are likely to decline, but sediment yield from tributary arroyos is expected to continue and possibly increase as climate warms. This may contribute to increasing rates of aggradations in the Rio Grande that, in turn, may increase the potential for overbank flows.
- The rate of sediment accumulation behind Cochiti Dam is expected to decline as a direct result of projected temperature and precipitation changes with no adverse effect on the lifetime of the project, and possibly extending the project life.
- Under climate scenarios for which peak and average inflows to Cochiti both decline, average and flood flows downstream are also expected to decrease. This is expected to have follow-on impacts to water allocations throughout the Rio Grande Basin, as well as conservation flows, ground water recharge, ground water contributions to surface flows, and other hydrologic relationships.
- The study is complete.

FOR MORE INFORMATION

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BACKGROUND
The U.S. Army Corps of Engineers (USACE) owns or operates almost 700 U.S. dams and reservoirs. Climate change could potentially impact all of these projects, which must operate continuously to meet authorized purposes while balancing competing demands. Coralville Reservoir is a multipurpose USACE reservoir on the Iowa River with authorized purposes of flood risk reduction, fish and wildlife, water quality, low flow augmentation, and recreation. This pilot study is developing methods and plans to assess and improve the robustness of reservoir water control operations in the context of climate change. The pilot study is leveraging work from the USACE Watershed Study of the Iowa Cedar Rivers Basin, which is a participating United Nations Educational, Scientific and Cultural Organization (UNESCO) Hydrology for the Environment, Life and Policy (HELP) basin.

VULNERABLE BUSINESS LINES
Flood Risk Management, Recreation

CENTRAL QUESTION ADDRESSED BY PILOT
How do we incorporate climate change considerations into reservoir operating policies that will be robust and adaptive to potential climate changes?

APPROACH
The approach used in this study first evaluated original project purposes and project design, the basis for storage allocation, the assumptions of sediment yield, frequency of uncontrolled releases, as well as the spillway design flood. At this phase, we also considered whether vulnerabilities exist because hydrologic conditions are different than originally assumed, and analyzed whether there have been observed changes to the original design parameters. Next, we used a risk-based approach to identify the most likely, highest consequence impacts that may result from climate change. We identified key performance questions and
LESSONS LEARNED

- We should attempt to avoid assumptions about what future climate data will indicate, and be open to revisiting questions/metrics.
- Vulnerability assessments need to consider all relevant factors – downstream development, land use change in watershed, etc.
- Managing expectations is important – and inability to definitively describe hydrologic response to climate change requires non-traditional decision making.
- Climate models may do a better job of modeling changes in the mean, but not necessarily the extreme, which may be of most interest.
- Climate data and downscaled models have limitations.
- It is better to define questions regarding climate vulnerabilities in a less specific way than was done in this pilot.
- The approach to analyzing the climate data would be determined best by first understanding the project’s sensitivity and vulnerability to climatic variation, and then formulating alternatives to reduce the climate sensitivity (increase robustness) of the project.
- Downscaled climate data was unable to provide a basis for developing regulation procedures to reduce risk in future major flood events, and emphasizing the importance of short-term climate forecasts and the need to develop tools capable of informing water managers.

KEY RESULTS

- Operation of the Coralville Lake project provides flood control benefits for communities downstream, as well as along the Mississippi River below the confluence with the Iowa River.
- Low-flow release agreements have been reached between Iowa City Water Works and the State of Iowa to provide a minimum flow of 150 cubic feet per second (cfs) at Iowa City, Iowa. Also, a drought contingency plan constructively rations water during extreme drought periods.
- Upward trends in average annual temperature and total annual precipitation have been observed in Iowa between the early 20th and early 21st century, and at the tested gauges within the Iowa River Basin. These trends are statistically significant at 95 percent confidence.
- There is a larger increase in temperature over this time period than in precipitation. There is a strong cyclical component in both temperature and precipitation, and the endpoint of the trend is still within the historical, cyclical variability.
- There also has been an observed increase in the occurrence of the heaviest precipitation events (i.e., more days of heavy precipitation per year). Observations of the Iowa River indicated increased mean and variance of annual 15-day peak discharge between the design period (pre-reservoir), which was used to formulate assumptions, and actual operations (reservoir in operation-present).
- The study is scheduled to be completed in December 2012.
BACKGROUND
Climate change is predicted to affect temperature and precipitation within the Missouri River Basin. Changes in temperature, the timing of snowpack runoff and the amount of precipitation could significantly alter basin runoff. Runoff, vegetative cover and altering the timing of precipitation are all major factors for sediment yield. These combined changes could affect the Missouri River Reservoir System and dam operations. Garrison Dam, located on the Missouri River in central North Dakota, has a drainage area of over 180,000 square miles and a storage capacity of 23.8 million acre-feet. It is also the largest of the mainstem reservoirs located in the upper Missouri River Basin. Altered runoff and sedimentation due to climate change could affect the Missouri River reservoir system and dam operations.

VULNERABLE BUSINESS LINES
Flood Risk Management

CENTRAL QUESTION ADDRESSED BY PILOT
How will climate change affect basin runoff, sedimentation rates, and operations of the Garrison Dam?

APPROACH
This pilot is part of a joint U.S. Bureau of Reclamation (Reclamation) - U.S. Army Corps of Engineers (USACE) study that looked at paired reservoirs, including Bighorn Lake in Montana and Wyoming, Elephant Butte Reservoir in New Mexico, Garrison Reservoir in North Dakota, and Cochiti Reservoir in New Mexico. Under climate change conditions, hydrologic and land cover variation can be used to develop revised sediment load conditions. This study considers the potential impact of climate-induced hydrologic changes to the Garrison Dam Reservoir. The specific impact examined in this study is the relationship between changing climate and basin runoff that could affect reservoir sedimentation, or influence the flood control capabilities of the dam. A watershed sedimentation evaluation was performed with a range of parameters to examine climate change impacts. The study used statistically downscaled regional climate projections for five different climate scenarios: drier and cooler, drier and warmer, wetter and cooler, wetter and warmer, and a median future precipitation and temperature condition. The Variable Infiltration Capacity (VIC) model used the projected climate data to develop future inflows into the Garrison Reservoir. In-depth analysis of a potential method using climate forces to drive hydrologic models was performed. VIC outputs were applied to reservoir routing programs and streamflow-sediment relationships to evaluate future operations and inform management decisions. Measured stream gage data and historic reservoir survey data were used to develop sediment rating curves to define the streamflow-sediment relationship. The VIC flows...
APPRAOCH continued

were applied to this relationship to estimate the change in reservoir capacity. The six mainstem Missouri River dams were simulated as a system using the Daily Routing Model; as the pool elevations and releases increase at the Garrison Dam, the operations of the other five reservoirs can be adjusted to compensate. This helped reduce the overall effect of the increased flows into the system.

LESSONS LEARNED

- Because there were no policies supporting adaptation planning involving inland hydrology at the time of the study, it was not clear how to proceed. Fortunately, there are now several efforts (e.g., nonstationarity, portfolio of approaches) supporting development of enabling guidance (how to frame an approach) and implementation guidance.
- Even climate scenarios with less precipitation can result in increased reservoir inflows due to changes in timing.
- Sediment impact evaluations based on storage change and stream gage data as in this pilot do not reflect runoff timing and vegetation change, which can affect basin sediment yield.

KEY RESULTS

- Establishing a policy describing climate impacts to consider, no matter how broad, reduces the time and cost of adaptation planning.
- All climate change scenarios evaluated result in an increase in sediment loading and inflows.
- Impacts from changing sedimentation rates on flood regulation would be minor for this large mainstem reservoir, but hydrologic changes could potentially be significant.
- Changes in projected flow due to bias corrections are greater than changes due to future climate scenarios examined.
- The projected climate-adjusted sediment rates have no immediate impact on dam safety as long as the spillway design flood does not increase.
- Sedimentation rates can increase the frequency of non-normal reservoir releases.
- Climate-adjusted flows can have a large impact on pool elevations and releases for all climate scenarios evaluated.
- The Missouri River mainstem dams should be modeled as a system.
- Climate-adjusted runoff and sediment yield could increase the rate of storage depletion in Garrison Reservoir.
- Timing of precipitation plays an important role in reservoir inflows, which is important because the runoff to Garrison Dam is affected by snow volume and snowmelt.
- The study is complete.

FOR MORE INFORMATION

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**Gain River Dam, North Dakota RRC Pilot**

**Approach continued**

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**Lessons Learned**

- Because there were no policies supporting adaptation planning involving inland hydrology at the time of the study, it was not clear how to proceed. Fortunately, there are now several efforts (e.g., nonstationarity, portfolio of approaches) supporting development of enabling guidance (how to frame an approach) and implementation guidance.
- Even climate scenarios with less precipitation can result in increased reservoir inflows due to changes in timing.
- Sediment impact evaluations based on storage change and stream gage data as in this pilot do not reflect runoff timing and vegetation change, which can affect basin sediment yield.

**Key Results**

- Establishing a policy describing climate impacts to consider, no matter how broad, reduces the time and cost of adaptation planning.
- All climate change scenarios evaluated result in an increase in sediment loading and inflows.
- Impacts from changing sedimentation rates on flood regulation would be minor for this large mainstem reservoir, but hydrologic changes could potentially be significant.
- Changes in projected flow due to bias corrections are greater than changes due to future climate scenarios examined.
- The projected climate-adjusted sediment rates have no immediate impact on dam safety as long as the spillway design flood does not increase.
- Sedimentation rates can increase the frequency of non-normal reservoir releases.
- Climate-adjusted flows can have a large impact on pool elevations and releases for all climate scenarios evaluated.
- The Missouri River mainstem dams should be modeled as a system.
- Climate-adjusted runoff and sediment yield could increase the rate of storage depletion in Garrison Reservoir.
- Timing of precipitation plays an important role in reservoir inflows, which is important because the runoff to Garrison Dam is affected by snow volume and snowmelt.
- The study is complete.

**For More Information**

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BACKGROUND
Considering sea-level change impacts to highly populated and developed urban areas may require different approaches than for less developed areas. The East Rockaway Inlet to Rockaway Inlet, New York Collaboration Framework Development RCC pilot study area is an urban, highly developed economically-diverse community, with over 10,000 structures, including critical infrastructure such as a sewage treatment plant, a hospital, and numerous primary and secondary education facilities. The pilot focuses on developing a collaborative framework to assess vulnerability to sea-level change impacts. The study also includes the development of lifecycle alternatives to reduce risk, with the recognition that solutions to address these problems can be implemented over time. The project study area is located on the Atlantic coast of New York City between East Rockaway Inlet and Rockaway Inlet. Rockaway Beach is located on a peninsula that separates the Atlantic Ocean to the south from Jamaica Bay to the north. The peninsula is entirely within the Borough of Queens, New York (Figure 1). The Atlantic coast shoreline of the Rockaway Peninsula is subject to storm-induced recession and long-term erosion. Erosion has significantly reduced the height and width of many beachfronts within the area. Low-lying areas are currently subject to frequent and severe damages from tidal inundation and wave run-up. The project area is exposed to increased risk due to sea-level change and storm surge inundation. Long-term Federal involvement in storm damage reduction for the project area remains an issue of concern and is undergoing investigation in the East Rockaway Inlet to Rockaway Inlet and Jamaica Bay, New York Reformulation Study.

VULNERABLE BUSINESS LINES
Flood Risk Reduction

CENTRAL QUESTION ADDRESSED BY PILOT
How do we facilitate well-designed and inclusive multi-stakeholder collaboration with the local decision makers for the purpose of identifying vulnerability to sea-level change impacts, acceptable levels of risk, and the most acceptable alternatives over the project lifecycle?

Figure 1: The study area for the RCC Pilot, East Rockaway Inlet to Rockaway Inlet, New York Collaboration Framework Development, is illustrated in the white box to the left and consists of the Rockaway Peninsula, between Beach 19th Street in the east, and Beach 149th Street to the west, from the Atlantic Ocean shoreline to the south, to the Jamaica Bay shoreline to the north in Queens, New York.
APPRAOH
This pilot climate change adaptation study includes a multidisciplinary team of decision makers to collaboratively identify, inventory, and map areas/infrastructure and critical facilities with the greatest risk for repetitive sea-level change impacts. The team is also working to collaboratively develop acceptable alternative lifecycle plans and strategies to reduce risk in those areas, both along the Atlantic Ocean and Jamaica Bay shorelines. This pilot study complements the Draft New York State Sea Level Rise Task Force Recommendations presented in the November 2010 document, and efforts by the New York City Panel on Climate Change. The lessons learned during this RCC pilot will be used to develop policy and guidance supporting collaborative coastal climate change adaptation planning. The successes and challenges of building a Sea-Level Change Risk Reduction Team (SLCRRRT) for this project are being documented so that other similar projects will have an easier time in establishing collaboration among stakeholders for sea-level change risk reduction alternative development across plan formulation, socio-economic, engineering, and environmental considerations.

LESSONS LEARNED
- The size, density and variation of structures in an urban coastal environment pose challenges to developing storm damage reduction alternatives. We need to improve our range of possible adaptable alternatives.
- The U.S. Army Corps of Engineers (USACE) is ahead of the curve in developing specific alternatives at Rockaway that address sea-level change projections, risks and consequences. We need to train local entities on USACE sea-level change requirements at study initiation.

KEY RESULTS
- Our visualization of sea-level change projections based on Engineer Circular (EC) 1165-2-212 Sea-Level Change Considerations for Civil Works Programs are similar to local science agency estimates.
- The projections provide a good tool for communicating with city and state agencies, as well as the private organizations (power, telecommunications) involved.
- The study is scheduled to be completed in spring 2013.

FOR MORE INFORMATION
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INNUNDATION MAPPING WITH SLC AND STORM SURGE EVENTS
- Year 2020, Intermediate SLC, 50-year Event
- Year 2030, Low SLC, 50-year Event
- Year 2050, High SLC, 10-year Event
BACKGROUND
The U.S. Army Corps of Engineers (USACE) has 139 harbors in the Great Lakes. Many of these harbors sit at the outlets of rivers that convey large amounts of sediment and create periodic dredging requirements. It is currently unknown how dredging costs vary with climate variability and future climate change. This study will examine the St. Joseph River and Maumee River watersheds to estimate the potential effects of climate change on dredging requirements. The project study area is focused on two characteristic areas within the Great Lakes region: St. Joseph River located in Michigan and Indiana, which enters Lake Michigan through St. Joseph Harbor in the Detroit District, and the Maumee River located in Ohio, which enters Lake Erie through Toledo Harbor in the Buffalo District. These harbors were selected because of their sizable dredging requirements, and the existence of sediment production and transport models that can be updated with new climate scenarios.

VULNERABLE BUSINESS LINES
Navigation

CENTRAL QUESTION ADDRESSED BY PILOT
How will dredging cost requirements at Great Lakes harbors vary in the future as the climate potentially changes precipitation regimes and runoff characteristics?

APPROACH
Within each of the two study areas, the approach will entail two stages. The first stage will analyze historic data to determine the variability of dredging costs and the primary drivers, and then compare this information to the observed hydroclimate variability. Dredging costs will be evaluated both for the frequency and the magnitude of each dredging operation. The observed hydroclimate data will be evaluated to determine what characteristic storm events (e.g., 1, 3, 5, 7, and 15-day rainfall runoff events) produce significant sedimentation and the meteorological context (e.g., gulf moisture, great lakes convection) that ultimately drives those events. This information will be used to identify the primary drivers of dredging, and highlight climate conditions that should be evaluated in the second stage. The second stage will explore projections of future climate variability to evaluate how the primary drivers of dredging costs may change. This will be accomplished by working with two sets of Coupled Modeled Intercomparison Project (CMIP) Global Climate Model (GCM) data. The first data set is the Bias...
APPRAOCH continued
Corrected Statistically Downscaled (BCSD) data. The second data set is dynamically downscaled data developed with climate experts from the National Oceanic and Atmospheric Administration (NOAA) Great Lakes Environmental Research Lab (GLERL). The statistical and dynamically downscaled climate data will be informative for different types of hydroclimate drivers, as well as to determine if downscaling methodology provides a different system response. As necessary, the climate information will be used within the Soil and Water Assessment Tool (SWAT) lumped parameter model and the Integrated Landscape Hydrology Model (ILHM) grid-based distributed parameters to produce numeric response metrics. The primary response metrics to be evaluated and used to make statements about potential future dredging costs will be those metrics determined as drivers from stage one.

LESSONS LEARNED
- Evaluating potential impacts from climate change on dredging needs to use available observational data and to be tied to observed hydroclimatic variability.
- Hydrologic and hydraulic models need to be kept current.
- Data for use in climate assessments can require significant processing before use in models. The Regional Circulation Model (RCM) from NOAA has output at six-hour intervals for a single climate change scenario. Use of this data will require programming to get the data into a useable format.
- Availability of experienced personnel is limited.

KEY RESULTS
- Communication and attribution of current climate events is a critical question with operations and maintenance personnel, and stakeholders.
- Anticipated results include the potential need for additional dredge disposal facilities and insights into the particular climatological changes that will most significantly impact dredging needs.
- The study is scheduled to be completed in September 2013.

FOR MORE INFORMATION
Travis Dahl, P.E, LRE, CELRE-HH-W, U.S. Army Corps of Engineers, Travis.A.Dahl@usace.army.mil
Sea-level change may negatively impact wetland resilience in the San Francisco Bay, thus affecting ecosystem outputs for wetland restoration projects. This pilot study will test the proposed risk informed decision-making (RIDM) framework and evaluate its application to understand the risks posed by sea-level change in the U.S. Army Corps of Engineers (USACE) planning-feasibility phase. The Hamilton Wetland Restoration Project (HWRP) was authorized by Section 101 (b) (3) of the Water Resources Development Act (WRDA) 1999 and provides for wetland ecosystem restoration through beneficial reuse of dredged material. The project provides Federal and non-federal navigation projects in the San Francisco Bay an opportunity for beneficial reuse of suitable dredge material to facilitate ecosystem restoration. The HWRP consists of constructing perimeter levees bordering the site along with internal berms and phase containment levees, which excavate one breach into San Pablo Bay. The HWRP also utilizes approximately 10,600,000 cubic yards of dredged material to restore approximately 990 acres of habitat.

**VULNERABLE BUSINESS LINES**

Ecosystem Restoration

**CENTRAL QUESTION ADDRESS BY PILOT**

Given the potential effects of sea-level change, how can we reduce the risk that the acres of seasonal wetlands planned for construction at the HWRP will not decrease over the study period?

**APPROACH**

The current project accepts the potential wetland habitat conversion from seasonal to tidal, as sea level rises. The study will introduce a hypothetical constraint to the HWRP, currently under construction, that requires the perpetuation of the wetland mosaic as designed (20 percent seasonal and 80 percent tidal wetlands), and particularly the perpetuation of seasonal wetlands, which may be the most vulnerable at the study site if sea level rises and upland migration is constrained. The pilot study is using the draft RIDM framework to explore risk and uncertainty associated with multiple scenarios of sea-level change and different restoration measures. The RIDM matrix will facilitate communication about the feasibility of restoring
seasonal wetlands that are resilient to sea-level change for a project that touches three mission areas: navigation, ecosystem restoration, and flood risk management. The lessons learned during this RCC pilot will be used to develop policy and guidance supporting coastal climate change adaptation planning, and in particular, will inform national team efforts developing the RIDM framework and the sea-level change adaptation guidance. Modeling will be done to show the evolution of inundation frequency curves to evaluate current and future sea level rise scenarios on the future without project, and future with project condition. This will enable a more robust risk assessment. Graphs will also be developed that display estimated critical thresholds where inundation and habitat conversion will occur.

**LESSONS LEARNED**

- Clear communication is facilitated by developing a group understanding of the terms used in discussions and any assumptions held by team members.
- Including a glossary of terms in the final RIDM framework is useful.
- More detailed sea-level change information is necessary to thoroughly evaluate application of the RIDM framework to assessing the effects of climate change on a project in the feasibility study phase.

**KEY RESULTS**

- Through its use of the proposed RIDM framework, the team is discovering the importance of testing each step of the RIDM process before finalizing RIDM guidance.
- The study team held a workshop to establish the decision context for the study and defined problems, opportunities, constraints, objectives, impacts of climate change on objectives, decision making criteria, evident uncertainties, and climate change data.
- A second workshop was held to begin identifying and assessing risks to the project.
- The team will continue to work on this critical step of the proposed RIDM framework.
- The study is scheduled to be completed in March 2013.

**FOR MORE INFORMATION**

Tom Kendall, CESPEN-ET-P, U.S. Army Corps of Engineers, Thomas.R.Kendall@usace.army.mil
BACKGROUND
The Iowa-Cedar Rivers Basin includes some of the most fertile agricultural land in the country, as well as three large urban areas. However, in recent years, the region has declined in ecological integrity, and experienced several monumental floods that well surpassed all previous records as well as the capacity of existing flood risk management systems. Questions have been raised about the role of climate change and how it might impact future floods. Current land uses may have also exacerbated the extent of flood damages. Stakeholders are motivated now to make changes to reduce impacts during future events. Additionally, an interagency team is advancing understanding, supporting local initiatives, and developing a comprehensive watershed plan.

VULNERABILITY
Flood Risk Management, Ecosystem Restoration

CENTRAL QUESTION ADDRESSED BY PILOT
How will climate and land use changes affect the state of the watershed; can land use changes and best management practices reduce flood risk significantly; and how can the community adapt to new climatic patterns, as recently experienced, as well as future variability and uncertainty?
APPROACH

The pilot study is focusing on the Indian Creek watershed with three related efforts. The first effort includes a series of five stakeholder dialogue workshops to increase understanding of, and to give definition to the problems, objectives, adaptation strategies, and their associated trade-offs and uncertainties. The second effort is an assessment of how land use and climate changes affect hydrology, including a comparison of multiple hydrology models in order to better frame historical and existing conditions. The last effort includes the development and comparison of climate data. This comparison will include different downscaling methods, including the development of North American Regional Climate Change Assessment Program (NARCCAP) data for use in the Soil and Water Assessment Tool (SWAT); and the generation of statistically-scaled historical rainfall observations at an existing rain gauge for use within a Hydrologic Unit Code (HUC)-scale watershed.

LESSONS LEARNED

- Stakeholders were able to understand the climate change information when it focused on impacts, including the likelihood that extreme events will continue, and that climate change presents an additional factor of uncertainty related to the floodplain.
- Collaboration is critical for leveraging resources and making a significant impact. In this study, numerous products and resources were leveraged to support this project, including partner team members and specialists, and information from past and adjacent studies.
- It is important to adequately prepare for public engagement. With a widely diverse group of stakeholders, it is challenging to address the needs and concerns of everyone; clarifying the goals of each session and letting the stakeholders contribute to the content is most appropriate.

KEY RESULTS

- Land use and climate change both have significant impacts on stream flow regimes across a range of precipitation events. Thus, when planning in an urban watershed, both future development and precipitation trends may compound the impacts of storm intensity and frequency, and therefore, the impacts of flood events.
- The Indian Creek stakeholders now understand that they may continue to experience intense storms, that there are actions they can take to reduce their risk, and they are able to access resources to enable them to do so.
- There is interest in making changes to land uses in the floodplain, but there is also a lack of consensus among policy makers and residents. Thus, a primary concern among stakeholders is in public education and rallying support for change.
- Additional results related to modeling and stakeholder dialogue are pending.
- The study is scheduled to be completed in January 2013.

FOR MORE INFORMATION

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BACKGROUND
The physical characteristics of the Columbia River estuary differ from most North American estuaries: river discharge is much greater; salinities are much lower, tidal forcing is greater; and bottom sediment is less stable. The Columbia River entrance is characterized by exceptionally strong wave-current interactions. As a consequence, the river entrance has been recognized as one of the most dangerous coastal inlets in the world for navigation. These factors also make it a difficult location for ecosystem restoration. Since the estuary provides rearing grounds for 12 Evolutionarily Significant Units (ESU) of salmon and steelhead, it provides a unique opportunity to test the emerging risk management and adaptive management planning tools for their ability to incorporate climate change into future restoration planning. The project study area is located in the Pacific Northwest, Lower Columbia River Estuary. The estuary extends from the mouth upstream to Bonneville Dam, a distance of about 145 miles, and is the largest human population center on the Columbia River. This well-informed population holds multiple perspectives on how water resources management could enhance ecosystem restoration, providing an ideal location to test ways to balance competing needs through collaboration and education.

VULNERABLE BUSINESS LINES
Ecosystem Restoration

CENTRAL QUESTION ADDRESSED BY PILOT
Can we develop a conceptual framework for how climate change information might be incorporated into ecosystem restoration projects?
APPROACH

This pilot is working to establish a common understanding among stakeholders in regard to participants’ ecosystem restoration project experiences, and how information on climate change impact can be utilized to develop a common ecosystem restoration project planning and feasibility framework. The project will use three case studies, including Post Office Lake, Sandy River Delta, and Crims Island restoration projects, as starting points to investigate how climate change methodologies might be worked into the U.S. Army Corps of Engineers (USACE) six-step planning process. The lessons learned during this RCC pilot will be used to aid in the development of policy and guidance supporting collaborative and risk-informed coastal climate change adaptation planning. The pilot addresses mainstreaming climate change adaptation so that it is treated as one of the numerous challenges facing the project area and receives similar attention as a risk element, with special consideration in defining the future conditions. This pilot project will test vulnerability-based risk analysis decision making by identifying project vulnerabilities in the context of climate change. Potential adaption management options are triggered by predefined tipping points and thresholds. The lessons learned during this RCC pilot will be used to aid in the development of policy and guidance supporting risk-informed decision making (RIDM), collaborative processes, and coastal climate change adaptation planning. So far, the team has conducted two webinars. The first summarized climate change modeling and information available in the Pacific Northwest area, as well as descriptions of anthropogenic versus natural variability, hydrologic downscaling, and USACE-developed relative sea-level change estimates at the mouth of the Columbia River. The second webinar focused on RIDM, setting a context for dealing with climate change as another risk element to be considered in the ecosystem restoration study process.

LESSONS LEARNED

- In the first workshop, the list of vulnerabilities differed by location, that is, being close to the mouth (characterized by strong tidal influence, complex sediment transport, and saline effected), mid-reach (transitional tidal, shallow floodplain lakes) or upstream (delta and terrestrial flow dominant).
- A comprehensive and consistent decision-making process (e.g. risk register or matrix) is necessary to consider unique features.
- Conceptual modeling is a key tool to develop a better picture of the pertinent processes, stressors, and vulnerabilities, and is vital to risk assessment. It also informs the model drivers (variables and metrics) used for quantifying risk impacts.
- Different teams develop quite different approaches to resolving the basic task of vulnerability determination. This has implications for adaptive management, since the adaptive management process is an intensively social endeavor.
- Spending time to design a decision making framework may be as important as the scientific and engineering understanding of the physical process in producing an optimal result, since the human dimensions can be more complex and unpredictable and, thus, harder to manage.

KEY RESULTS

- Tidal changes have implications for the future habitat in narrow elevation bands, especially near the estuary mouth.
- The study is scheduled to be completed in October 2012.

FOR MORE INFORMATION

Keith Duffy, NWP-EC-HY, U.S. Army Corps of Engineers, Keith.B.Duffy@usace.army.mil
Water resources management is complicated by extremes of low and high precipitation and runoff, particularly when competing needs must be balanced. Marion Reservoir, located on the Cottonwood River in Marion County, Kansas, is a multipurpose reservoir with authorizations for flood control, water quality control, recreation, and water supply. The water supply in this reservoir (44,730 acre-feet) is owned by the State of Kansas. The Kansas Water Office, acting with legislative authority on behalf of the State of Kansas, currently has annual water marketing contracts totaling 1,834 acre-feet with the communities of Hillsboro, Marion, and Peabody, Kansas. These contracts have expiration dates ranging from 2021 to 2039. No allocation presently exists for future water supply storage. There have been three prolonged periods of drought recorded in the Cottonwood River Basin. The most prolonged and most severe occurred between 1952 and 1957. The average monthly inflow during this time period was 12 percent of the period average (1922-1988), and it included six months of zero inflow. The lowest Palmer Drought Severity Index (PDSI) value during this period was -6.06, which is considered to be an extreme drought. A firm yield of 8.1 million gallons per day (MGD) has been calculated based on this drought, which satisfies the demand for existing water supply contracts. It is unclear, however, if current contracts can be met in the context of future changes in climate.

VULNERABLE BUSINESS LINES
Water Supply, Flood Risk Management

CENTRAL QUESTION ADDRESSED BY PILOT
How can climate modeling be incorporated as a decision-making tool with respect to existing and future water supply contracts?

APPROACH
Our approach was to investigate if and how climate change projections could be used to develop a range of future conditions impacting firm yield. Firm yield can be quantitatively determined by simulating reservoir operations with hydrographs developed from climate projections. Uncertainties exist in both the climate projections and in the hydrologic modeling, which must be addressed in order to produce meaningful results. Therefore, a gridded dataset of bias-corrected, spatially-disaggregated (BCSD,) statistically downscaled climate data, customized for the Marion Reservoir watershed, was converted from a native greatest common measure (GCM) grid cell size and redistributed into 1/8° spacing. The resulting grid cells were superimposed across the Marion Reservoir watershed. Hydrographs were then
developed from the BCSD dataset by running simulations in the Variable Infiltration Capacity (VIC) model. Numerical Routing was then used to project each of the hydrographs into a long-term simulation of pool elevations so that droughts could be identified. A mass balance approach was used and iteration proceeded automatically, firm yield thresholds were identified at specific time intervals that can be used as indicators to reevaluate the viability of existing water supply contracts.

LESSONS LEARNED

- Unlike coastal or mountainous areas where changes in sea level or snowpack elevation may be more easily observed, climate impacts on water supply reservoirs in the Great Plains region are less obvious.
- The uncertainties associated with climate projections can be evaluated for decision making by identifying timelines and trigger points in which decisions can be made to avoid unintended consequences. This is best done by evaluating the spread of potential future outcomes.
- The process developed for this study can be applied to other water supply reservoirs as a predictive tool.

KEY RESULTS

- Changes in precipitation in conjunction with changes in evapotranspiration and hydrologic runoff produce ensembles that indicate no major changes in firm yield, although some extremes exist.
- Projected water supply yields will be evaluated as individual members of the model ensemble to determine which trajectories may lead to outcomes that may need to be managed differently than current contracts account for.
- Using this information, conclusions can be drawn about whether or not the project can meet existing water supply contracts, and also if additional water supply will be available in the future.
- Climate projection ensembles do not show pronounced uniformity in precipitation changes in this region, although the ensemble mean does trend toward more net precipitation.
- The study is scheduled to be completed in December 2012.

FOR MORE INFORMATION

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BACKGROUND
Mountain snowpack has a significant impact on runoff in the Missouri River Basin, and can determine whether the basin is experiencing a normal, dry (2000) or wet (2011) year. This pilot focuses on the Missouri Mainstem Reservoir System, the largest reservoir storage system in the United States. Runoff from mountain snowpack generally occurs during the May through July period in the system. Mountain snowpack only affects two of the six main stem projects: Fort Peck in Montana, and Garrison in North Dakota. However, runoff into these two reservoirs during the three-month mountain snowmelt runoff season, between May and July, normally comprises nearly 40 percent of the total runoff in the upper Missouri River Basin (Missouri River above Sioux City, Iowa – 248,000 square miles). During this three-month period, almost half of the total annual runoff occurs in the Missouri River. The study is investigating the relationship between mountain snowpack accumulation and runoff, versus overall basin conditions as it relates to drought and flood conditions. The U.S. Army Corps of Engineers (USACE), the National Oceanic and Atmospheric Administration (NOAA), the National Resources Conservation Service (NRCS), State of South Dakota (SD), and the U.S. Geological Survey (USGS) partnered for this study.

VULNERABLE BUSINESS LINES
Flood Risk Reduction, Navigation, Hydropower, Recreation

CENTRAL QUESTION ADDRESSED BY PILOT
Is mountain snowpack and subsequent runoff changing due to changes in climate, and is the Missouri River Basin, therefore, more susceptible to droughts and floods?

APPROACH
The team is following a six-step process to answer the central question above: acquire relevant driver data, conduct data analysis, boil down data analysis results, apply results to simulated real-time regulation, consider future effects due to climate change, and report results. Data is being acquired from various sources and assembled into the three datasets covering 20-year epochs for this pilot. The data is then analyzed to determine if climate change has affected factors such as precipitation and temperature, which determine the natural inflow to the reservoirs. Since the data analysis step is producing a voluminous amount of results, it is necessary to conduct a critical review of the data analysis to sort out comparable and reasonable results before applying these results to any sort of real-time regulation scenarios. The end-result will be a
MISSOURI RIVER BASIN MOUNTAIN SNOWPACK RCC PILOT

APPROACH continued

representative set of data adjusted for climate change that will be used in existing real-time reservoir regulation models. The boiled-down results, which would be 20-year continuous datasets, would then be applied to legacy inflow forecasting models and reservoir regulation models to determine impacts of climate change to existing real-time regulation practices. The current system master manual allows for some adjustment in short-term and long-term planning, as it pertains to forecasted runoff. The results from this study could lead to some adjustment in how monthly and annual regulation plans are developed. In order to continue meeting the authorized purposes of the Missouri River Mainstem Reservoir System, additional studies should be performed using the climate change datasets to determine changes needed to regulation and decision-making procedures. Additionally, long-term studies may include individual water control manual revisions, master manual revisions and re-allocation studies. Once results are reported, USACE will consider how they can be incorporated into regulation of system.

LESSONS LEARNED

- Though partnering with agencies, academia and other experts is necessary to perform climate-related projects, it has been very difficult and time consuming to develop the necessary agreements and financial mechanisms to complete related research with partners.
- The Missouri Basin has moved from an extreme flood year (2011) directly to an extreme drought year (2012). We are constantly asked whether we can attribute the extreme conditions to climate change, necessitating the need to develop processes supporting attribution and talking points.
- This work requires station-by-station analysis with snowpack (SNOTEL) and streamflow data, as well as careful evaluation of voluminous historical air temperature and precipitation records to ensure that all driver data sets are complete and accurate.

KEY RESULTS

- Developing over-arching interagency agreements specifically addressing climate change issues will allow teams to quickly access expertise available in other agencies.
- Identification of trends and associated locations (e.g. stationarity) may prove useful.
- The study is scheduled to be completed in September 2013.

FOR MORE INFORMATION

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Missouri River Basin – Mountain Snowpack Water Content
2011-2012 with comparison plots from 1997*, 2001* and 2011
July 19, 2012

Total above Fort Peck

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Total Fort Peck to Garrison

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BACKGROUND

The Ohio River Basin contains a multitude of operating Federal reservoirs, navigation locks and dams, power generation plants and other critical infrastructure that depends on informed management of sustainable water resources. Ecological resources in the Ohio River and its major tributaries include numerous federally-protected species that may be at risk from climate change. Climate change may impact all types of water resources management in the basin. The Great Lakes and Ohio River Division (LRD) Division Commander approved the Ohio River Basin Comprehensive Reconnaissance Report in December 2009. The report evaluated water resources problems across 204,000 square miles using a watershed approach for data collection and analysis, and engaged numerous Federal and state agencies, local interests, and academia during the problem identification process. The four-district U.S. Army Corps of Engineers (USACE) team considered the potential effects of climate change on future management of water resources. As a result of study outreach efforts with stakeholders, a consortium of basin interests was assembled into what is now known as the Ohio River Basin (ORB) Alliance. This group of Federal, state, conservation, academic, non-profit, and consultant professionals has evolved into a coalition addressing common interests in water resources and basin-wide climate change issues. The team is very diverse in its composition because of the size of the region being studied (which encompasses four USACE districts) and as a result of the diversity within the ORB Alliance, which is comprised of many non-USACE members. Two additional members from the U.S. Geological Survey (USGS) and National Oceanic and Atmospheric Administration (NOAA) were added to the pilot team in July because of their expertise in climatology and downscaling climatic changes.

VULNERABLE BUSINESS LINES

Navigation, Recreation, Flood Risk Management, Hydropower, Ecosystem Restoration

CENTRAL QUESTION ADDRESSED BY PILOT

Can regional climate change mitigation/adaptation strategies, collaboratively developed with the ORB Alliance and formulated using Integrated Water Resources Management (IWRM) principles, be made operational within the Ohio River Basin to counter the anticipated water resources, ecological, and infrastructure impacts of climate change?
APPROACH

The study approach consists of nine tasks. The first was to establish a climate change working group within the alliance. The second was to define study objectives by refining study objectives included in the proposal. The third was to identify and agree on downscaled basin climate changes. The group then identified ecosystem resources and infrastructure that are at-risk from the effects of climate change in a GIS framework, and characterized levels of risk that could be expected. The next step was to identify primary water managers and their operating regulations for storing and discharging water under extreme weather conditions and determine the current state of infrastructure, institutional capability and readiness to address climate change impacts (capability and readiness gaps were identified in the study). The sixth step was to formulate structural and nonstructural mitigation/adaptation strategies, using an IWRM approach that addresses gaps in current operations for climate change and future rehabilitation needs. Following these steps, the group prepared a draft report on the study process, findings, and recommended actions for USACE and ORB Alliance review. Subsequent steps include preparing a final report and brochure for public use, and compiling and sharing lessons learned through the USACE SharePoint site and ORB Alliance website.

LESSONS LEARNED

- Collaborative synergy inspires innovative approaches and ideas that should all be considered.
- The volume of climate change information on regional downscaling alone will challenge the pilot team to select appropriate information on climate change effects to serve as the foundation for formulation of adaptation and mitigation strategies.
- Need to provide advice on how to select from among the portfolio of climate information.

KEY RESULTS

- Including climate expertise from USACE and other agencies is a key element, both in laying a foundation for a successful pilot and to educate team members.
- The study is scheduled to be completed in September 2013.

FOR MORE INFORMATION

BACKGROUND
Of the more than 600 multi-purpose U.S. Army Corps of Engineers (USACE) reservoir projects, 117 include storage for water supply. Collectively, they provide enough water to supply the average household needs of about 85 million Americans for a year. Our changing climate will increase the criticality of effectively managing these national water assets for future generations. The goal of this pilot study is to demonstrate a sustainable local, tribal, state and Federal government risk management process associated with climate change impacts to evaluate future reservoir yield, water quality, and soil and water conditions in the watershed. Information generated during this process will help decision makers determine subsequent planning steps. This pilot study could serve as a template for other reservoirs and watersheds. The study area is the Oologah Lake and watershed located in northeast Oklahoma and southeast Kansas. An advantage of selecting this area is the existing reservoir/watershed models and baseline information developed from a recently completed general investigation study. Oologah Lake supplies approximately 50 percent of the potable water for the Tulsa, Oklahoma metropolitan area, as well as to rural water supplies throughout northeast Oklahoma. The City of Tulsa and others are concerned about potential habitat, water quality, and additional impairments related to sedimentation of the reservoir, turbidity, and nutrient loading.

VULNERABLE BUSINESS LINES
Water Supply

CENTRAL QUESTION ADDRESSED BY PILOT
How can information from regional Federal climate science programs be used in water resource model assessments and associated risk management decision making by local, tribal, state and Federal interests; and what is the value of information from a detailed assessment compared to a reconnaissance-level assessment?

APPROACH
The objective of the pilot study is to demonstrate a Western States Federal Agency Support Team (WestFAST)
 field-level approach to applying climate science by leveraging regional Federal programs. Programs include the National Oceanic and Atmospheric Administration (NOAA) Southern Climate Impacts Planning Program (SCIPP) and the Department of Interior (DOI) South-Central Climate Science Center at the University of Oklahoma. The pilot study will also include collaboration with additional local, tribal, state, Federal, and non-government stakeholders. This interactive study approach will encourage stakeholder input and information exchange. The first phase assessment of the pilot will demonstrate a reconnaissance, or state water plan level of detail, for this pilot project, building on existing streamflow projections developed by the U.S. Bureau of Reclamation for western states. The second phase of the pilot will provide an example of a more detailed, or feasibility level, approach to evaluate climate change impacts to reservoir yield and water quality,
APPROACH continued

and soil and water conditions in the watershed. Climate projection datasets will be collected, using a variety of global and regiona l climate models and statistical downscaling. Data for each climate model and statistically downscaled dataset will be compared to observed conditions to develop ensembles of future projections. The Variable Infiltration Capacity (VIC)\(^2\) model will be benchmarked with a historical dataset, and then the ensembles will be run through VIC to provide output for incorporation into existing Lake Oologah and watershed models. Output will include time-series hydrographs for a 50-year planning horizon that can be used for watershed and reservoir simulation and yield studies. The initial concept application of the USACE five-step risk informed decision-making (RIDM) process will be integrated with these activities. Phase one and two results will be compared to determine the value of the information added by investing additional time and money required for the feasibility level approach. This comparison will be useful for determining the level of effort necessary for incorporating climate change considerations into the USACE Specific, Measurable, Attainable, Risk-Informed, and Timely (SMART) planning guidelines.

LESSONS LEARNED

- Working with agencies such as the DOI, Department of Energy (DOE), Environmental Protection Agency (EPA), National Aeronautics and Space Administration (NASA), Natural Resources Conservation Service (NRCS), and others on water resources and climate change projects facilitates consistent Federal approaches.
- It can be difficult to transfer funds between agencies. Simplified processes are needed to more efficiently leverage the climate science and related resources associated with multiple Federal agencies.

KEY RESULTS

- A policy that provides for the efficient transfer of funds between agencies for climate change technical support would enable groups to leverage Federal technical resources and promote a national collaborative approach to the development and field application of climate science.
- The study is scheduled to be completed in March 2013.

FOR MORE INFORMATION

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\(^1\) WestFAST is a collaborative initiative between 11 Federal agencies with water management responsibilities in the West. WestFAST was established to support the Western States Water Council, and the Western Governors Association in coordinating Federal efforts regarding water resources. Refer to: http://www.westgov.org/wswc/WestFAST.htm

\(^2\) Refer to: http://www.hydro.washington.edu/Lettenmaier/Models/VIC/index.shtml
Northern snowmelt-dominated watersheds are particularly sensitive to changes in temperature. Basin topography (mountains, plains, or a combination of both), can play a role in mediating or enhancing changes in snow. The Red River of the North watershed is a large snow-dominated watershed whose topography is a factor in causing floods of relatively long durations. The basin is generally very flat, and slopes gradually down from south to north. Snowmelt usually occurs first in the southern part of the basin, while the northern part of the river is still frozen. Flooding on the Red River of the North has increased in magnitude and frequency since 1942. The flood of record occurred in 2009. Currently, the U.S. Army Corps of Engineers (USACE) is designing a project worth approximately $2 billion to reduce flood risk for 200,000 residents of Fargo, North Dakota, and Moorhead, Minnesota. The future reliability of this project will depend on how climate change impacts future flooding.

**VULNERABLE BUSINESS LINES**

Flood Risk Management

**CENTRAL QUESTION ADDRESSED BY PILOT**

Are tools and data available for USACE to provide reliable estimates of future flooding using climate projections, including magnitude, frequency and, seasonality of precipitation? In the warming climate, how will changes in precipitation patterns for a historically snowmelt-dominated basin affect flood events?

**APPROACH**

The study used climate projections to develop and run a hydrologic model in order to evaluate future flood potential of the RRN upstream from the city of Fargo. The simulations created by the model used, the Coupled Model Intercomparison Project (CMIP) Global Climate Model (GCM), were supported by the Intergovernmental Panel on Climate Change. The simulations were used as coarse scale representations of future climate possibilities. Downscaled results of those simulations are being considered from various leveraged sources, including the North American Regional Climate Change Assessment Program (NARCCAP), and the Statistically Downscaled WCRP CMIP3 Climate Projections archive. These climate projections are being evaluated to see how well they represent the critical aspects of historical flood events, including snowfall and rainfall timing.
and quantities, on a temporal basis consistent with flood events. The results of this evaluation will help to characterize climate information for later use in the pilot. The climate information will be applied to the Hydrologic Engineering Center’s Hydrologic Modeling System (HEC-HMS) framework to simulate flood events within the watershed for historic and future time periods. The ability of the hydrologic modeling effort to simulate historically accurate distributions of floods will be assessed and will inform characterization of potential future flood events.

LESSONS LEARNED

- Using climate projections from NARCCAP and the CMIP3 statistical archive requires expertise in data acquisition, manipulation, and management beyond that typically required for hydraulic and hydrologic applications.
- NARCCAP climate simulations should be evaluated with respect to determining whether meteorological and climatological event types of interest are simulated reasonably prior to incorporation in hydrologic models.
- Developing trained experts within USACE through pilots such as this one will facilitate studies of this type in the future.

KEY RESULTS

- Building capacity to address climate change in hydraulic and hydrologic studies will speed the process of these studies.
- The study is scheduled to be completed in September 2013.

FOR MORE INFORMATION

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STAGE 1 DIVERSION CHANNEL – INLET NEAR CITY OF BRECKENRIDGE, 11TH STREET BRIDGE OVER THE OTTERTAIL RIVER LOOKING NORTH
BACKGROUND
Climate change impacts to Hawaii threaten native forests, streams and wetlands, and could increase land-based pollution in nearshore waters. Hawaii’s coral reefs are at risk of climate change impacts associated with rising ocean temperatures that in turn increase coral bleaching and ocean acidification, threatening coral reefs’ stability. Healthy reefs provide the best defense against future natural threats. In the last 13 years, nearly one-fourth of the corals in West Maui have been lost. Today, land-based pollution poses a significant threat to coral reef health as well. A watershed approach of addressing sediment, erosion and pollutant inputs throughout the watershed is necessary. The West Maui watershed supports a diverse set of land uses, including conservation, tourism, agriculture and urban areas. Each prospective area has a significantly different understanding of climate change risks and vulnerabilities, and differing ideas about the types and importance of climate change adaptation measures. The West Maui Watershed Plan, authorized under §729 of the Water Resources Development Act (WRDA) 1986, is an interagency planning process supporting the West Maui Ridge to Reef Initiative, which is one of the first efforts in the State of Hawaii to implement a comprehensive management strategy to address impacts to coral reefs across multiple watersheds. The initiative aims to engage various Federal and state agencies, and non-governmental organizations in order to implement a strategy to reduce the threats of land-based pollution to coral reefs in West Maui. The West Maui Ridge to Reef Initiative takes an action-oriented approach to integrated water resource management (IWRM). As an initial step, a number of Federal agencies and organizations are funding technical studies and public education efforts to support the state and U.S. Army Corps of Engineers (USACE) funded watershed plan. The State of Hawaii and other agencies will implement priority, on-the-ground actions as they are identified, while the state and USACE funded watershed plan is developing the associated comprehensive strategy.

VULNERABLE BUSINESS LINES
Ecosystem Restoration

CENTRAL QUESTION ADDRESSED BY PILOT
How can a risk-informed decision-making (RIDM) framework be incorporated at the beginning of a collaborative planning process for a place-based climate change adaptation strategy, and what are the challenges in implementing an IWRM framework?

APPROACH
Using a shared vision planning (SVP) process, the interagency team is establishing a RIDM context and decision framework to guide development of the watershed plan. The lessons learned during this RCC pilot will be used to develop policy and guidance supporting collaborative coastal climate change adaptation planning. The West Maui Watershed Ridge to Reef Initiative is a prototype for integrated and collaborative planning, and provides a process to coordinate Federal, non-federal, and
APPRA ISO CONTINUED

non-governmental activities. The National Oceanic and Atmospheric Administration (NOAA) initiated the first phase of the initiative with the development of the Kahekili Watershed Assessment. Watershed assessment in the Wahikuli and Honokōwai watersheds follow the Environmental Protection Agency (EPA) nine elements of watershed planning. The National Resources Conservation Service (NRCS) is assisting in the implementation of erosion and sediment control best management practices on agricultural lands. The National Fish and Wildlife Foundation (NFWF) is funding an on-site watershed coordinator. Multiple state agencies and local non-governmental organizations are leading technical studies, monitoring programs, public outreach, and on-the-ground projects addressing fresh and marine water resources, native forest conservation, water quality and water supply management. USACE is providing strategic planning, climate adaptation strategy, multi-purpose water management expertise, and facilitation to integrate all activities into an efficient and effective program that will help build long-term capacity and promote community stewardship of the watershed.

LESSONS LEARNED

• A common logo, vision, process and timeline promote local and community engagement and stewardship under IWRM.

• The RIDM concept and the USACE process are not easily understood, especially among natural resource managers. An increased shared understanding of decision frameworks and definitions facilitates increased integration of organizations and actions.

• By considering climate change and risk early in the process, interagency teams more easily see the key long-range issues and identify innovative solutions to these issues.

• Many non-federal and Federal agency planning processes end at formulation of alternative strategies and have minimal specific requirements to long-term feasibility, sustainability, operations, maintenance, and climate change. USACE processes provide this additional analysis and technical assistance.

• There are a variety of tools across agencies and organizations that address risk and uncertainty, including climate change. The USACE SVP provides a collaborative process for selecting and adjusting the technical analysis tools to fit the unique needs of each IWRM initiative.

KEY RESULTS

• Through a series of three workshops, the interagency team has identified threats/risks to the study, identified a shared identity as the West Maui Ridge to Reef Initiative, incorporated climate change into key goals and objectives, developed a decision framework, and prioritized data gaps in a risk informed context for immediate future actions.

• The study is scheduled to be completed in October 2012.

FOR MORE INFORMATION

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