

COMMISSION BRIEFING SLIDES/EXHIBITS

**BRIEFING ON FLOODING AND
OTHER EXTREME WEATHER EVENTS**

JANUARY 6, 2014

In the Eye of the Hurricane:
Super Storm Sandy
PSEG Nuclear
Preparations, Impacts and Lessons
Learned

Robert DeNight
Operations Director
Salem Generating Station

Salem and Hope Creek Generating Stations



Forecast vs. Actual

• **Forecasts** on October 29th at 6 pm called for:

- Additional rainfall of another $\frac{1}{4}$ - $\frac{3}{4}$ "
- Winds through midnight will be sustained at 30-45 mph with gusts of 45-65 mph
- Overnight winds will be sustained at 15-30 mph with gusts of 30-50 mph
- Storm surge will be 3-6' and will peak around midnight. Storm surge should recede by mid morning

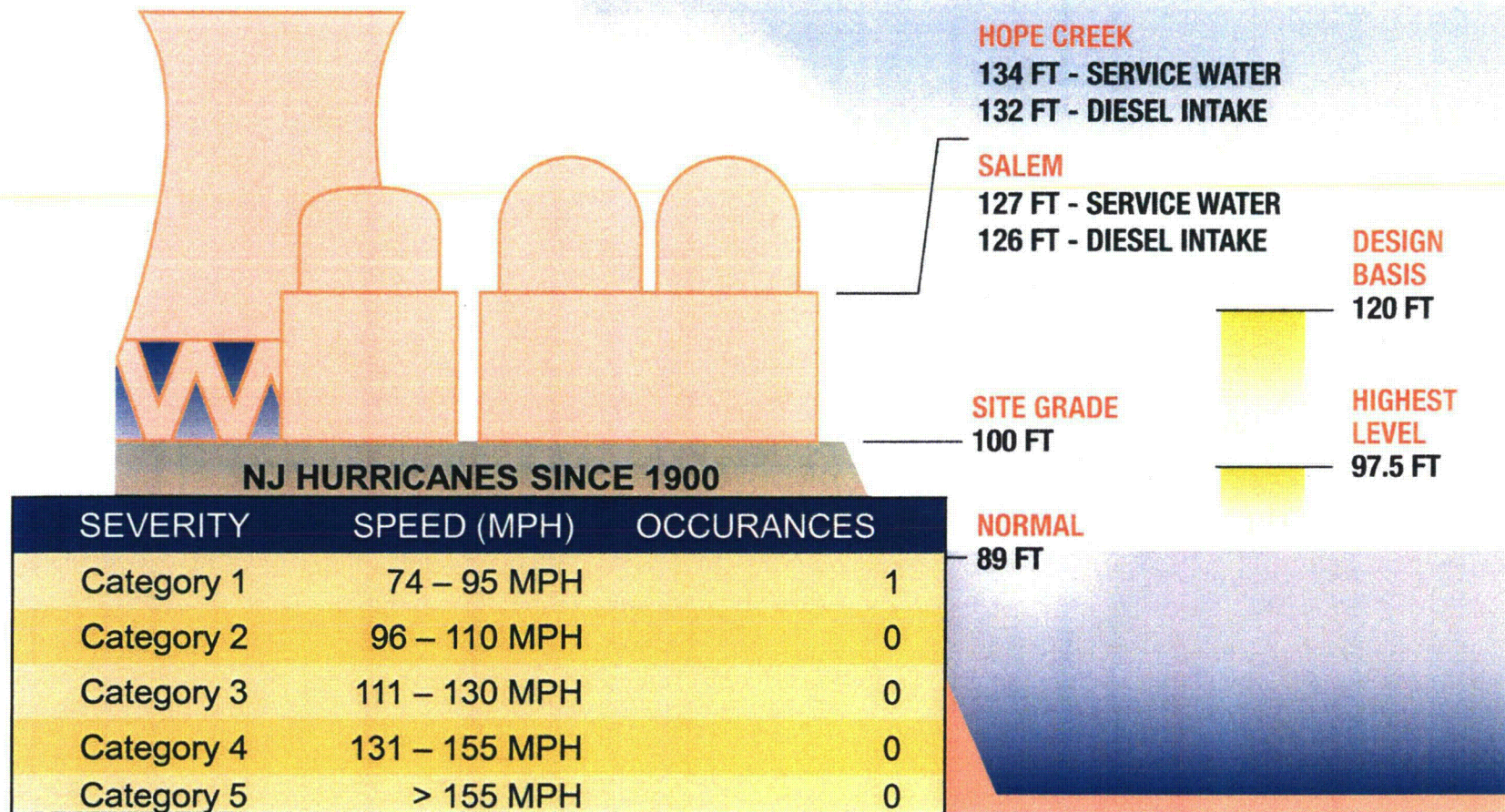
Forecast vs. Actual

- **Actual** weather from landfall at 8 pm through the early morning
 - Rainfall was consistent with forecast
 - Winds through the evening were 40-60 mph with gusts upon landfall of up to 90 mph
 - Winds were sustained through the night precluding storm restoration to begin until 7 am
 - Storm surge ranged from 11-13.6', causing widespread flooding and devastation to the region

PSEG Nuclear Unit Status

- Hope Creek - 100% Rated Thermal Power
- Salem Unit 1- 100% Rated Thermal Power
- Salem Unit 2 (two days prior to Sandy's arrival):
 - Defueled, Full Core offload, in Spent Fuel Pool
 - Defueled Mid Loop
 - Single Source of Off-site power
 - Major Equipment OOS
 - 2B Emergency Diesel Generator, 2B Vital Bus OOS
 - 2B 125V DC batteries
 - 21 SW Nuclear Header

Salem and Hope Creek Flood Design



Salem and Hope Creek Shutdown Criteria

- IF AT ANY TIME the river level is >98.5 ft, THEN INITIATE actions to place the Unit in Mode 3 within 6 hours and in Mode 5 within the next 30 hours.
- IF hurricane force winds are imminent, THEN **INITIATE** preparations such that the Unit is in Hot Standby (Mode 3) at least two hours prior to the projected arrival of hurricane force winds.

Salem and Hope Creek Emergency Action Levels (EALs)

- Unusual Event (UE)
 - Delaware River level reaches 99.5 feet at Salem units, 99.5 feet at Hope Creek
 - Average Wind Speed >95 mph for any elevation
- Alert – Escalation with UE conditions
 - Visible damage to Safety Related Structures

Implementation of Severe Weather Guidelines – Phase 1 (T-3)

- Operations
 - Inspect station blackout equipment
 - Verify remote shutdown panel communications
 - Indication and switch alignment
 - Hope Creek blockhouse sump pump staged

Implementation of Severe Weather Guidelines – Phase 1 (T-3)

- Maintenance
 - Protect spare equipment required for recovery
 - Inspect/remove/secure outside areas for potential missiles
 - Staging of sump pumps and sandbags
 - Availability of emergency supplies like flashlights, potable water, etc.

Implementation of Severe Weather Guidelines - Phase 2 (T-2)

- Site walkdowns
- Verifying water tight doors
- Emergency diesel generator availability
- Return Major Plant Equipment for Shutdown Safety
- Ensuring water intakes prepared for severe weather
- Address potential staffing requirement

Staffing requirements

Only essential personnel req'd to report

- Specific responders from two ERO teams
- Operations Support Center (OSCs)
- Technical Support Center (TSC)
- Emergency Operations Facility (EOF)

Implementation of Severe Weather Guidelines - Phase 3 (T-0)

- Close watertight doors
- Relocate personnel
- Implement preplanned sandbagging
- Relocate vehicles to shelter
- Establish Fire Protection command post
- Complete various Service Water Bay penetration repairs

Superstorm Sandy impacts

- Hope Creek - Remained at 100%, HC output greater than demand on PJM
- Salem Unit 1 manually taken offline at 1:09 am (5 day forced outage)
 - Four of the six circulating water pumps no longer available
 - Heavy debris, waves resulted in Travelling water screens stopping
- Non-vital Switching Station lost due to water intrusion
 - Loss of power to several buildings onsite
 - Lost onsite intranet, phones, met tower data to Salem control rooms

Staffing Requirements

- Suspended Salem Unit 2 refueling outage activities on Sunday evening, October 28
 - All equipment, except SW header, returned to Operations
 - Reactor Cavity flooded up to Refueling level for defense in depth
 - All contractors left site that weekend
 - First time in operating history to suspended refueling outage

Superstorm Sandy Lessons Learned

- Equipment Issues / Storm Preparations
 - Substation enclosures are susceptible to water intrusion
 - Lack of outage contingencies for loss of building capabilities
 - Lack of adequate sleeping arrangements for essential personnel.
 - Access road monitoring and shoring – extra fill / seawall

Lessons Learned – Root Cause

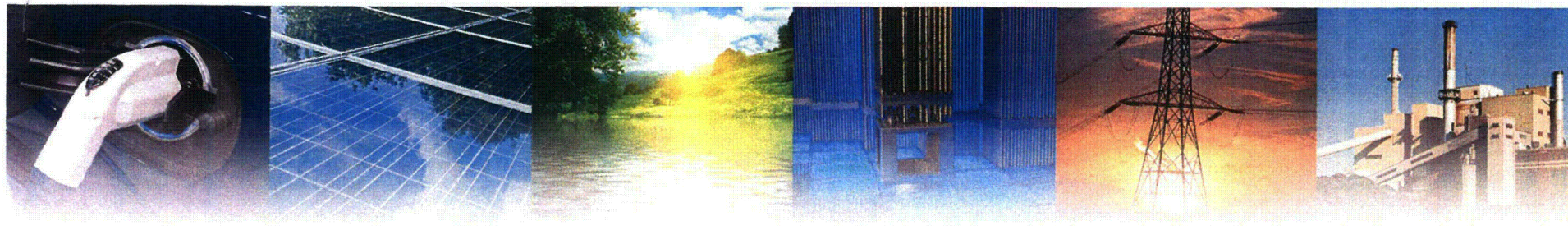
- Abnormal Procedure Guidance
 - Inadequate severe weather guidance in Abnormal procedure for wind speed, direction, grassing levels, tide, etc.
 - Decision Making on unit power did not account for wave action effects
 - Severe Weather Guide – No single designated information source for decision-making

Lessons Learned – Corrective actions

- Previous Shutdown Criteria
 - IF AT ANY TIME river level is >98.5 ft...
 - Maximum Tide was 97.2 feet
 - IF hurricane force winds are imminent...
 - Maximum average wind speed was 59 miles per hour
 - Wind direction shifted 180° in four hours directed at CWIS

Lessons Learned – Corrective actions

- New Shutdown Criteria
 - CW intake degradation index
 - Uses grassing, tide, wind speed and direction
 - Guidance to shutdown as a composite
 - If hurricane is to pass within 50 miles of site - shutdown



ELECTRIC POWER
RESEARCH INSTITUTE

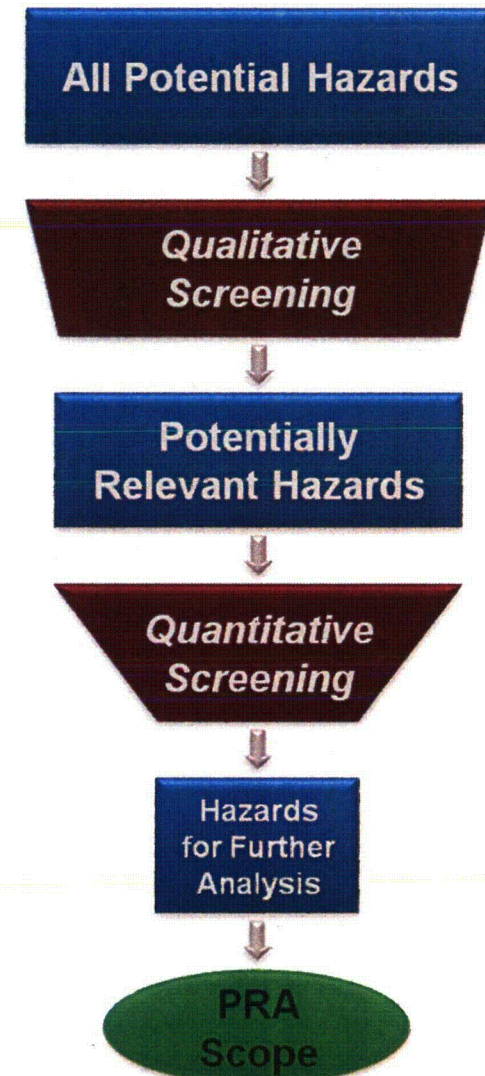
Perspectives on Risk Assessment for External Hazards

January 6, 2014

**Stuart Lewis, Program Manager
EPRI Risk & Safety Management Program**

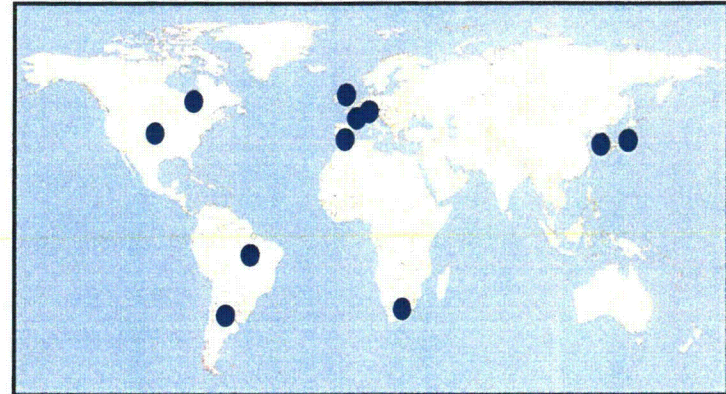
EPRI Guidance to Focus PRA Efforts

- EPRI 1022997, December 2011
Identification of External Hazards for Analysis in Probabilistic Risk Assessment
- Insights from development
 - Importance of plant-specific nature of hazards
 - Value of complementary qualitative and quantitative criteria



Use of EPRI Guidance

- Wide apparent interest among EPRI members
- Collecting of feedback from initial users underway
- Early insights for potential improvements
 - More detailed implementation process
 - Additional guidance on combined or correlated hazards



Methods for External Flooding

Activities

- Review of available methods
 - Unique treatments for different flood sources
 - Experience of US agencies and international organizations
- Selection of most promising approaches
- Testing in table-top and pilot applications

External Flooding Methods

Example resources explored and used:

| Hazard | Probabilistic Methods and Applications |
|-----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| River | <ul style="list-style-type: none">• Stochastic Event Flood Model (SEFM)• RunOff Routing Monte Carlo (RORB_MC)• Climatic-Hydrological Simulation of Extreme Floods (SCHADEX) |
| Hurricane | <ul style="list-style-type: none">• Joint Probability Method (JPM)• NUREG/CR-7134 Modeling Set |

From 2013 Regulatory Information Conference
Presentation – A. Miller and K. Huffman

Updating Methods for High Winds

Background

- Significant technology advancements in 1970's and 1980's
- EPRI's focus at that time: tornado missile evaluations

Current status

- Several new studies – most outside US
- EPRI updating methods and guidance (part of our *External Hazards Roadmap*)



Roadmap for High Winds Research

- Extracting useful information on high-wind phenomena from available sources
- Focus on missiles and wind loadings
 - Nature of vulnerabilities (actual and potential)
 - Exploring graded approach to fragility assessment
- Evaluating need to update risk analysis tools

Summary

- Challenges are site- and plant-specific
- Progressive screening can be effective
 - Focus use of resources
 - Assure important hazards are considered
- Current focus is to
 - Advance the state-of-practice for certain hazards
 - Improve ability to obtain insights and manage risks



Together...Shaping the Future of Electricity

National Efforts to Coordinate Studies and Databases to Review and Improve Methods to Assess Extreme Storm Events

Chandra S. Pathak, PhD, PE, D.WRE, F.ASCE

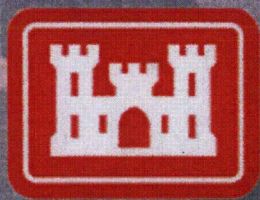
Engineering and Construction

US Army Corps of Engineers - HQ

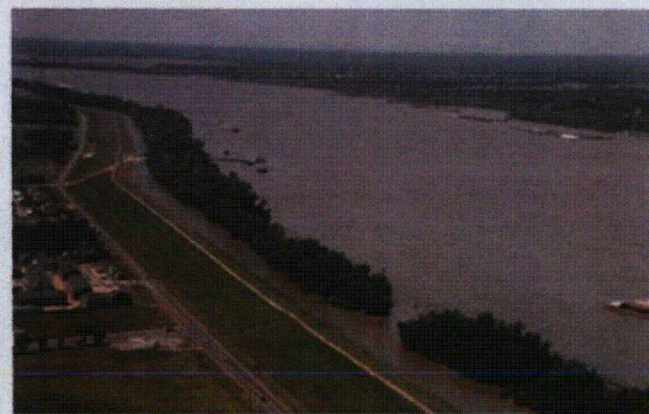
**Briefing On Flooding and Other
Extreme Weather Events**

Nuclear Regulatory Commission

6 January 2014



US Army Corps of Engineers
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Agenda

- Background
- Interagency collaboration on flood and extreme storm related activities
- Cataloging of extreme storm events
- R&D on flood flow and rain frequency analyses
- Summary



USACE Mission Areas

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Military Programs

- MILCON for Modular Force Global Positioning
- BRAC 05
- Field Force Engineering
- MILCON Transformation
- Environmental Restoration

Homeland Security



Civil Works

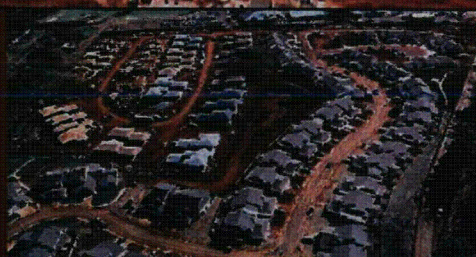


- Critical Infrastructure
- Anti Terrorism Plans
- Intelligence
- Facility Security Partnership

• Flood Risk Management

- Navigation, Hydropower
- Water Supply, Regulatory
- Recreation, Disaster Response
- Environmental Restoration

Real Estate



- DOD Recruiting Facilities
- Contingency Operations
- Acquire, Manage and Dispose

Interagency Support

- Federal
- State
- Local
- International

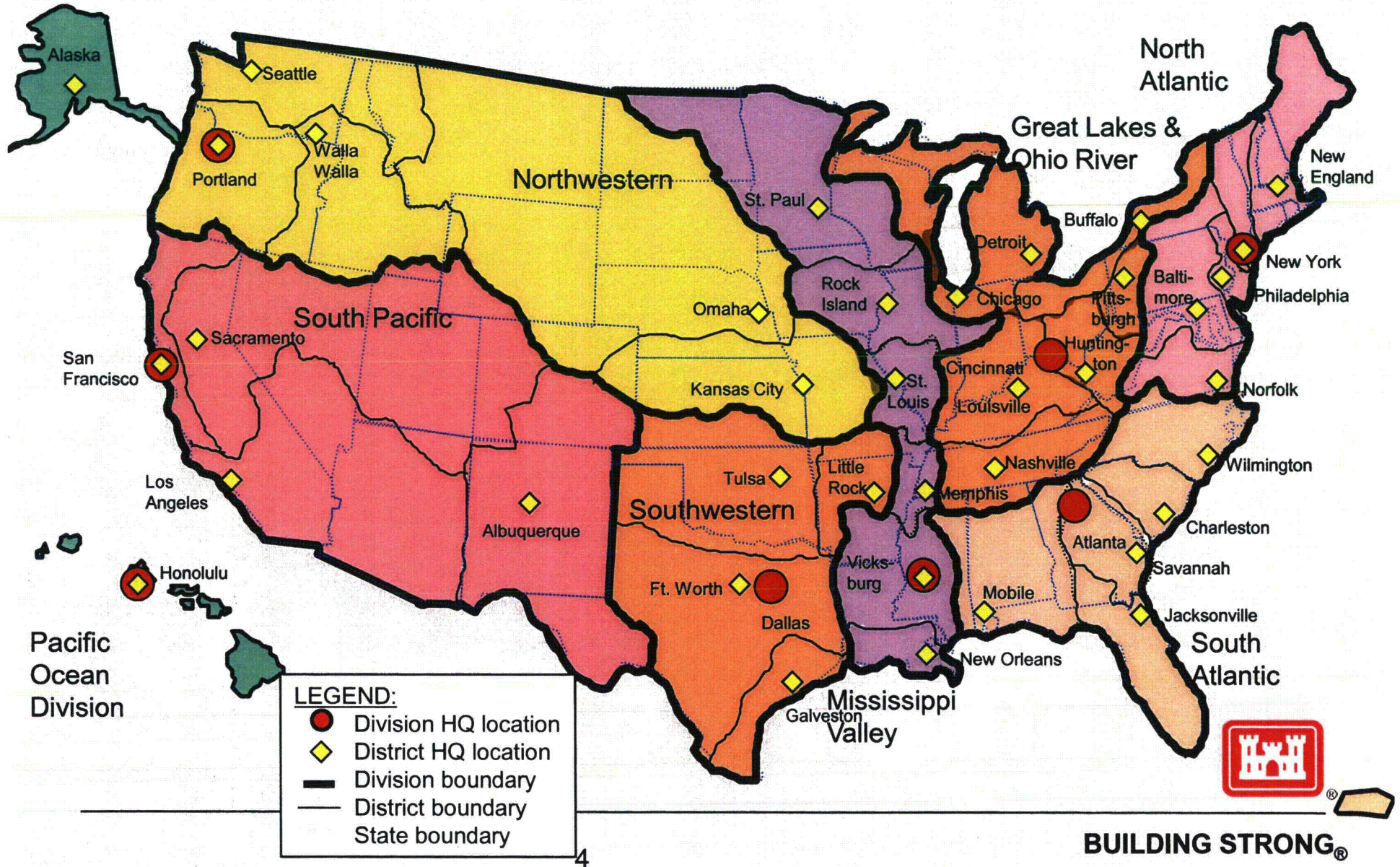
Research & Development

• Water Resources

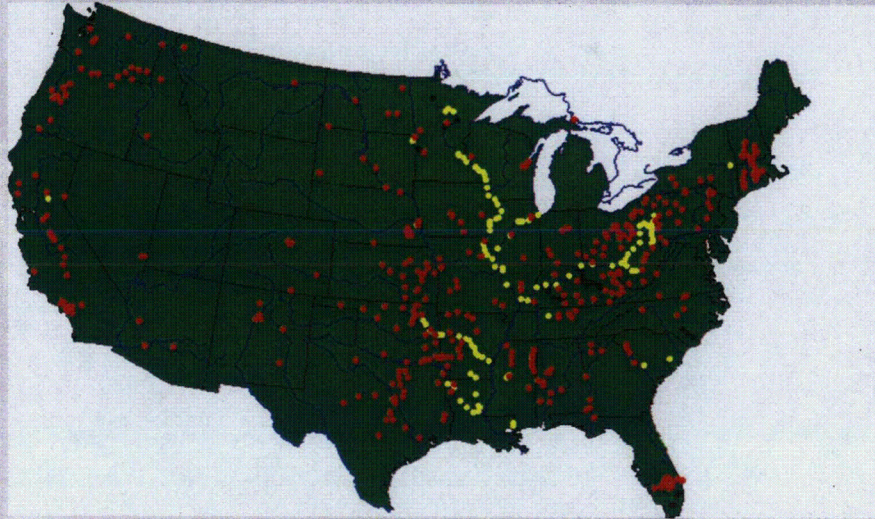
- Environment
- Installations
- Warfighter



Civil Works Divisions & Districts



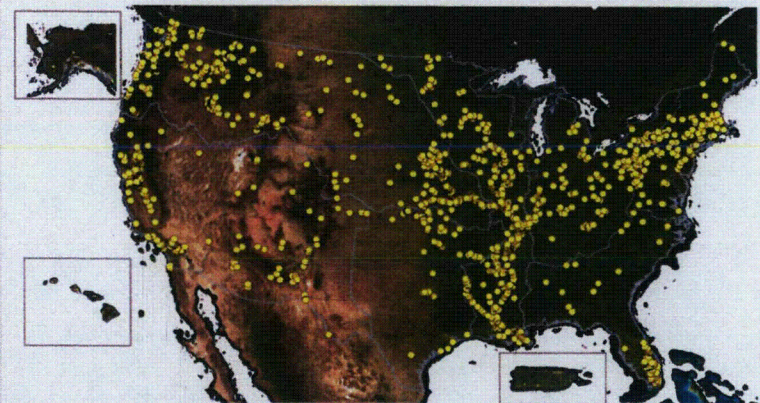
Infrastructure in USACE



702 Dams

***"Infrastructure follows Floods,
People Follow Infrastructure"***

- Portfolio Stats:
 - ▶ Very Large
 - ▶ Aging (+55 years)
 - ▶ Relatively untested
 - ▶ Geotechnical Challenges Dominate



+2,500 Levee Systems

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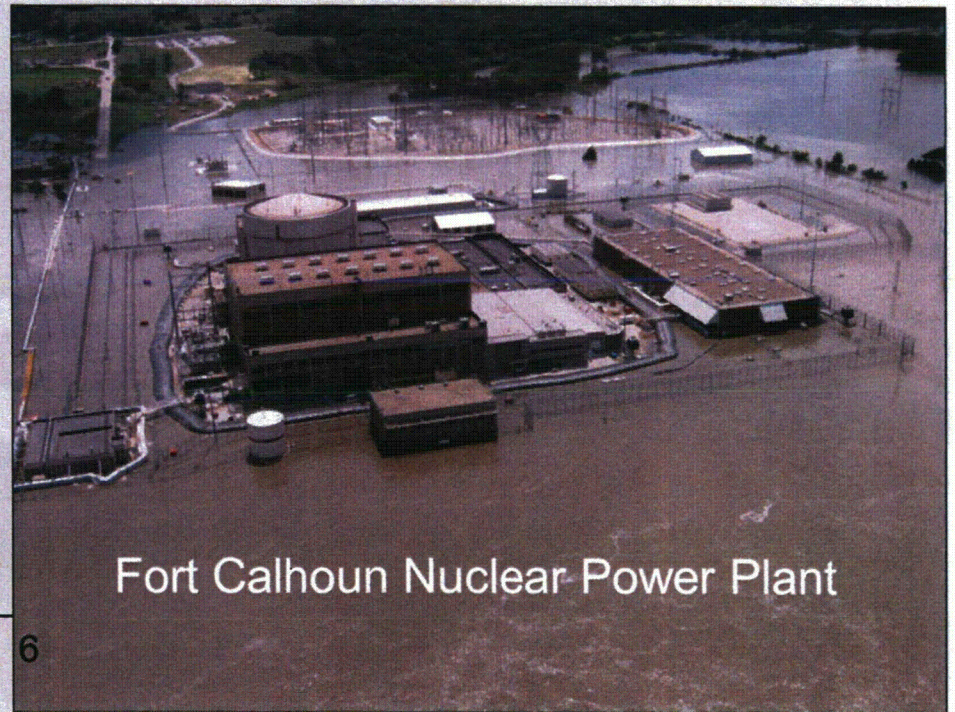
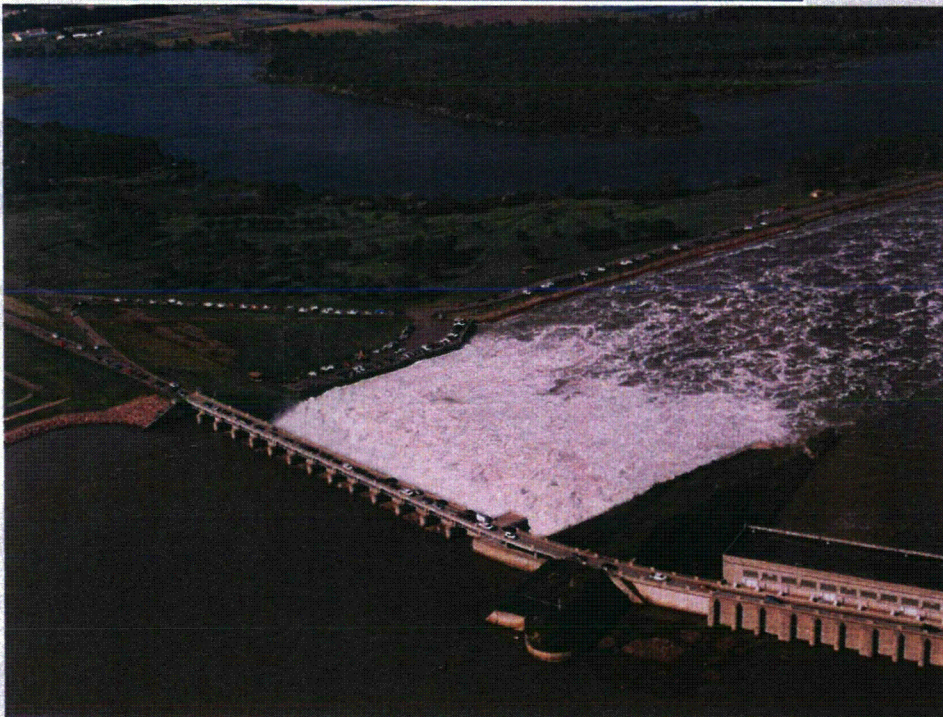
INTERAGENCY COLLABORATION



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of Engineers®**



GAVINS POINT DAM



Fort Calhoun Nuclear Power Plant



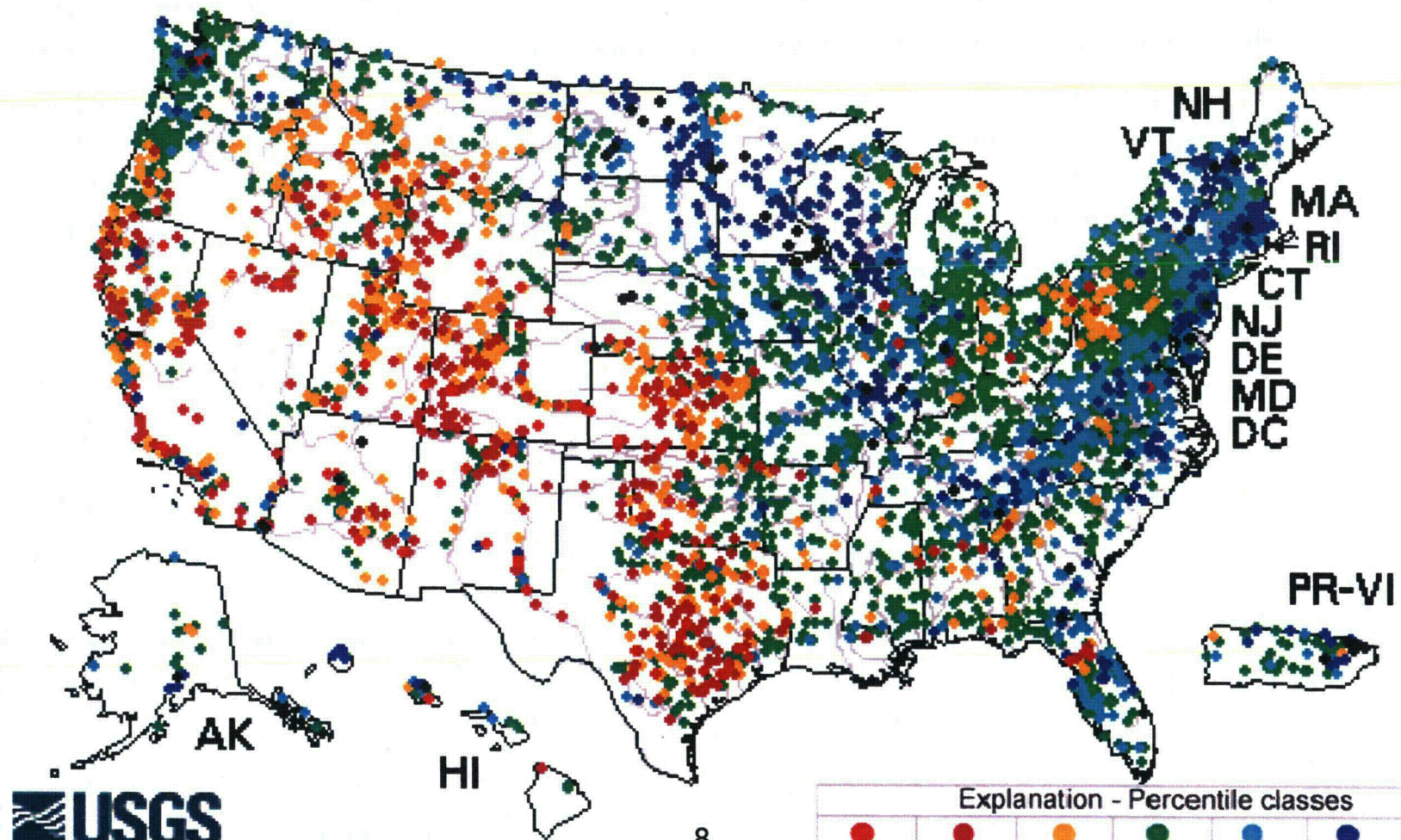
National Weather Service Support

- Provide Weather, Rain and Climate Forecasts:
 - Short-term (24-, 48- and 72-hour, 5-day)
 - Long-term (30-day and 90-day outlook)
- Provide River Flood Forecasting (a collaborative effort between agencies)
- *Rainfall Data Analysis - Publications*
 - 100-, 500-, 1000-year return period (Atlas 14, TP40)
 - Probable Maximum Precipitation - PMP (HMRs)



US Geological Survey (USGS) National Stream Gauging Program

Monday, June 24, 2013 11:30ET



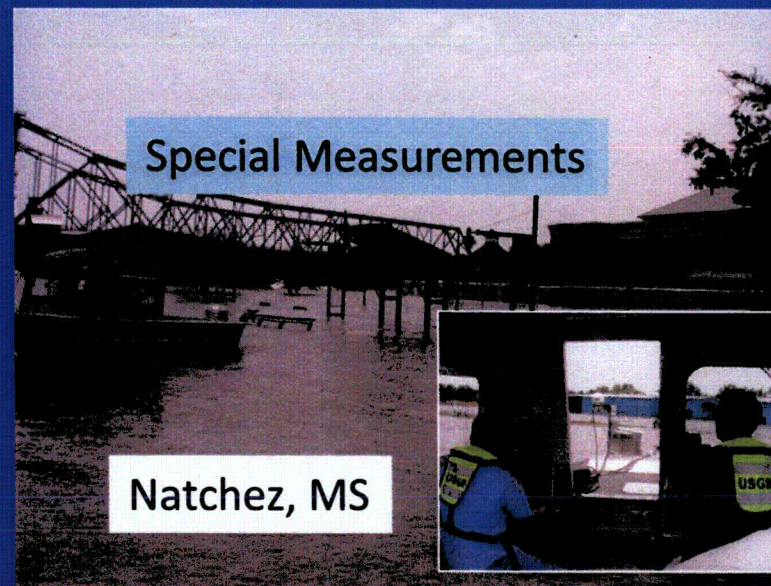
| Explanation - Percentile classes | | | | | | |
|----------------------------------|-----------------------------|--------------------------|-----------------|--------------------------|-----------------------------|------|
| | | | | | | |
| Low | <10 Much below normal | 10-24 Below normal | 25-75 Normal | 76-90 Above normal | >90 Much above normal | High |

RDG Deployment Prior to Flood



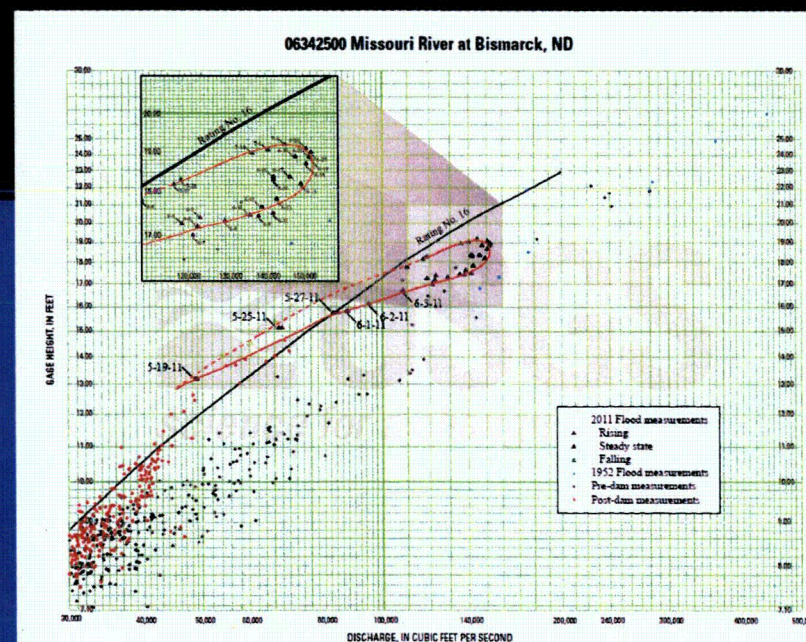
Minnesota River at Granite Falls, MN.

Special Measurements



Natchez, MS

- * Installation of Rapid Deployment Gages (RDG)
- * Special Streamflow Measurements (extreme events)
- * Flow Rating extensions

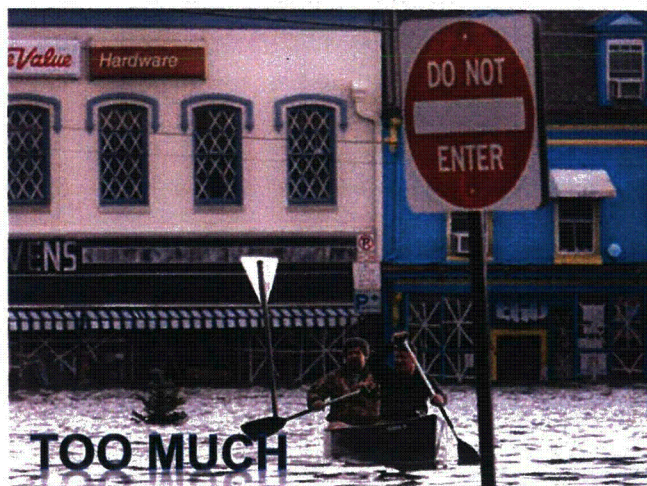


IWRSS

INTEGRATED WATER RESOURCES SCIENCE AND SERVICES

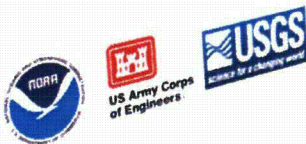


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**Integrated Water Resources
Science and Services
(IWRSS)**

*An Integrated and Adaptive Roadmap for
Operational Implementation*



February, 2009

IWRSS

Framework aligning the capabilities of multiple agencies with complementary water-related missions to address major water resource challenges and stakeholder needs

MOU – USACE, NOAA, USGS

“Collaborative Science, Services and
Tools to Support Integrated and
Adaptive Water Resources
Management”

May 11, 2011

Assistant Secretary of the Army for Civil Works
Deputy Undersecretary of Commerce for Oceans and Atmosphere
Director of the U.S. Geological Survey



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IWRSS: Two Charters

1. National Flood Inundation Mapping
2. System Interoperability and Data Synchronization



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National Flood Inundation Mapping

Purpose: to support the collaborative actions required to develop common flood inundation maps, products and services that will help the USACE, USGS, and NWS fulfill their missions.



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System Interoperability and Data Synchronization

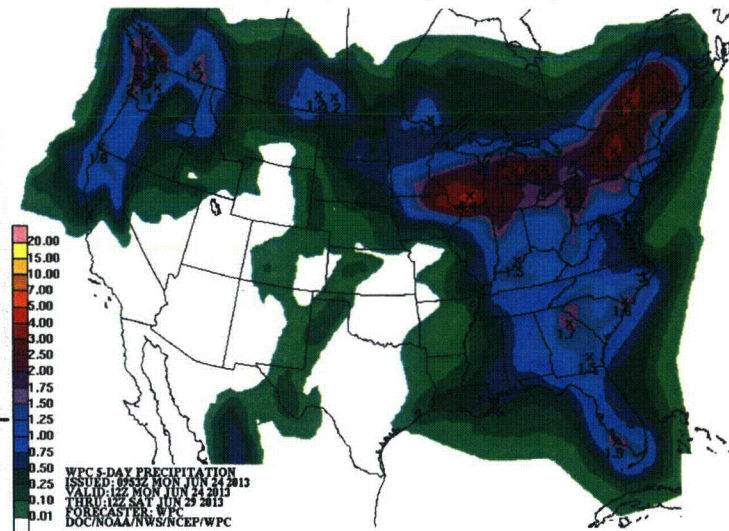
Major systems used across the 3 agencies will be made interoperable, i.e., data and information will be able to flow between them seamlessly.

Purpose: to define requirements and technical specifications for system interoperability and data synchronization.



USACE Extreme Storm Team

- 2008 – Sub-committee on Hydrology (of Advisory Committee on Water Information - USGS) establishes Interagency Federal Work Group on Extreme Storm Events
- 2010 – USACE establishes Extreme Storm Team
 - ▶ 12-member team
 - ▶ Collaboration with USBR



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Extreme Storm Data Needs

- Data Archiving & Analysis of Extreme Storm Events
- Regional and Site-Specific Probable Maximum Precipitation (PMP) Studies
- NWS/NOAA Hydro-meteorological Reports (HMR's) updates



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USACE Extreme Storm Projects

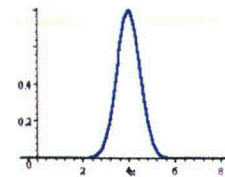
- **Update Extreme Storm Catalog**
 - Digitize Historic Storm Isohyetal Maps
 - Convert Radar Imagery for Rainfall
 - **Develop Extreme Storm Database**
- **Combine Database with USBR**
- Set up Web Site to Disseminate Data
- Chena Basin Site Specific PMP Study
- Review Wyoming Statewide PMP Study



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2013 R&D Project – ERDC, USACE

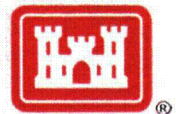
- Objective: Provide new, district-usable tools for improved estimation of **extreme precipitation and flow frequency**
- Methods:
 - ▶ Create software that implements existing and **new analytical methods –state-of-the-art for precipitation and flow frequency**
 - ▶ Develop new modeling techniques for extending precipitation and flow frequency curves
 - ▶ Use spiral delivery methods to successively roll out products
 - ▶ Use technical advisory committee to provide input on products, direction
- Products:
 - ▶ **Develop Precipitation Frequency Software**
 - ▶ **Develop Flow Frequency Software**



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Summary

- Interagency collaboration on flood and extreme storm related activities with USACE, NOAA, and USGS;
- Cataloging of historical extreme storm events – national significance; and
- R&D on flood flow and rain frequency analyses, specifically, from extreme storm events.

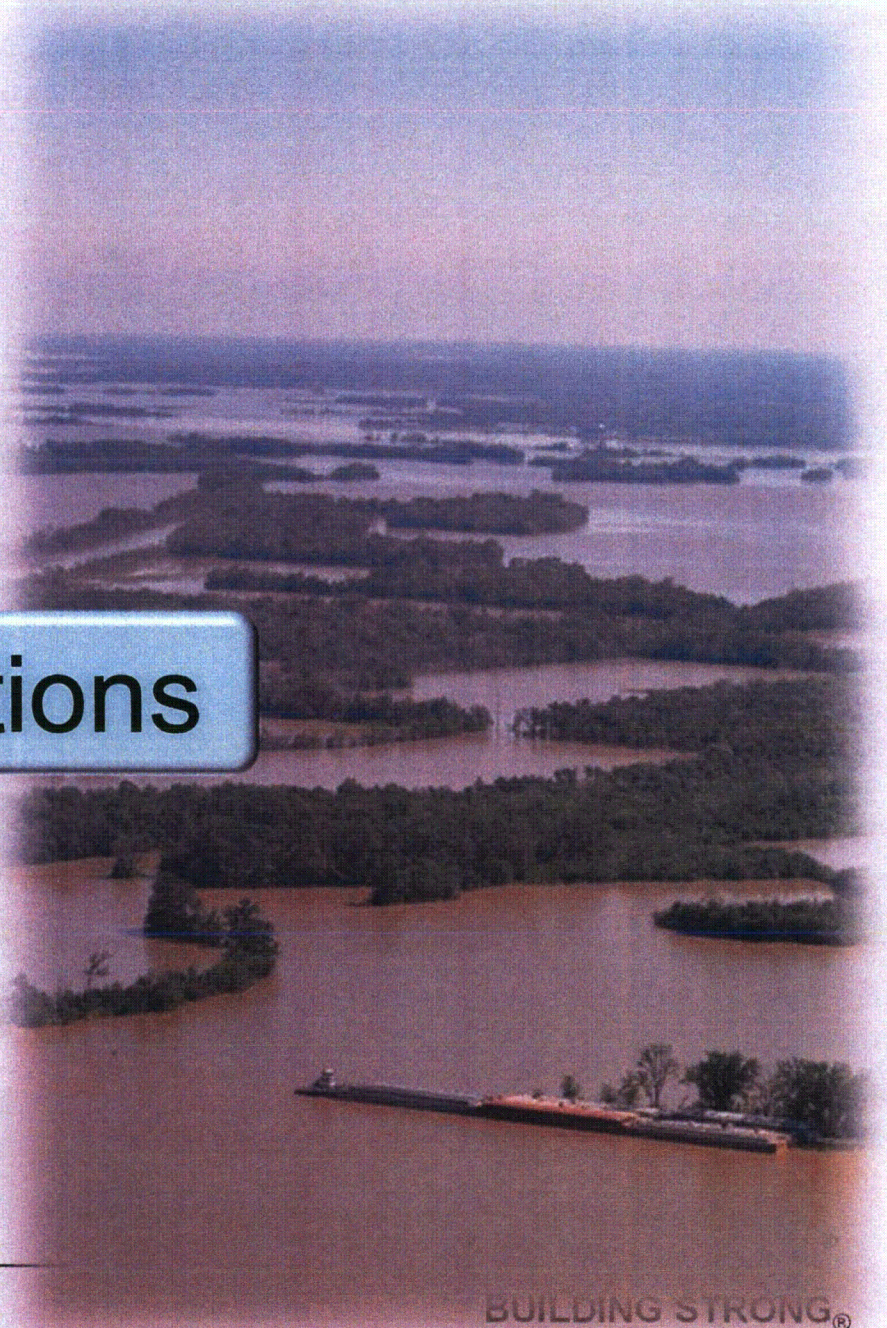


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Questions

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BACK UP SLIDES



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Civil Works Program

Preserving the Strength of the Nation

Delivering enduring, comprehensive, sustainable, and integrated solutions to the Nation's water resources and related challenges through collaboration with our stakeholders

(Regions, States, localities, Tribes, other Federal agencies)

(\$1.884 B) Navigation (39%)

**(\$1.370 B) Flood Risk (28%)
Management**

**(\$655 M) Ecosystem (14%)
Restoration & Stewardship**

(\$210 M) Hydropower (4%)

**(\$252 M) Recreation & Natural (5%)
Resource Management**

**(\$200 M) Regulatory Program: (4%)
Wetlands & Waterways**

(\$33 M) Water Supply (1%)

(\$35 M) Emergency Management (1%)

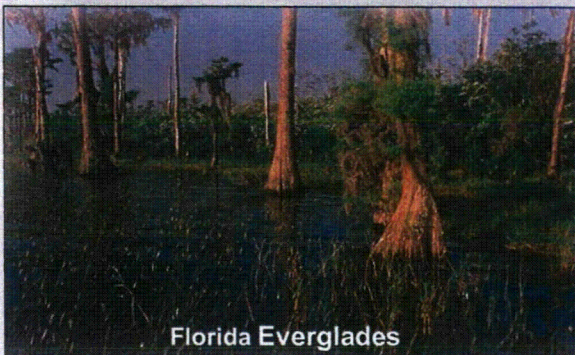
**(\$187 M) Expenses (4%)
(FY 2014 President's Budget)**



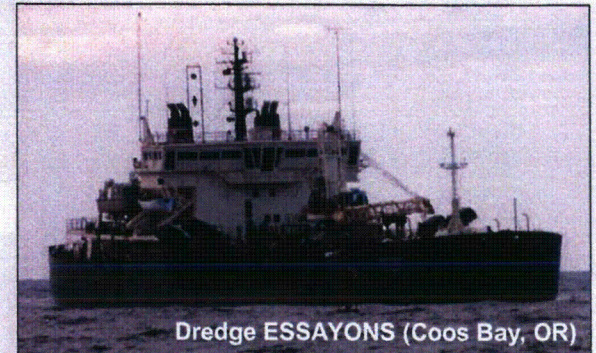
Lock and Dam 15 (Mississippi River, IL/IA)



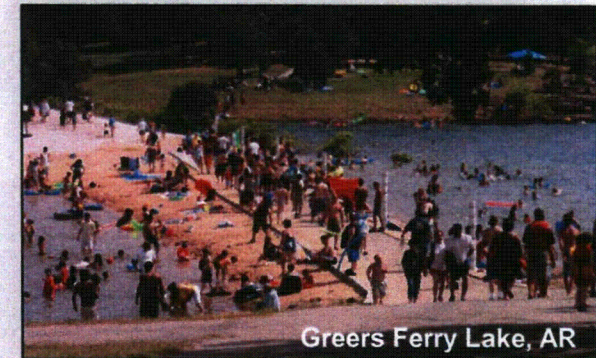
Flood Wall, Williamson, KY



Florida Everglades



Dredge ESSAYONS (Coos Bay, OR)



Greers Ferry Lake, AR

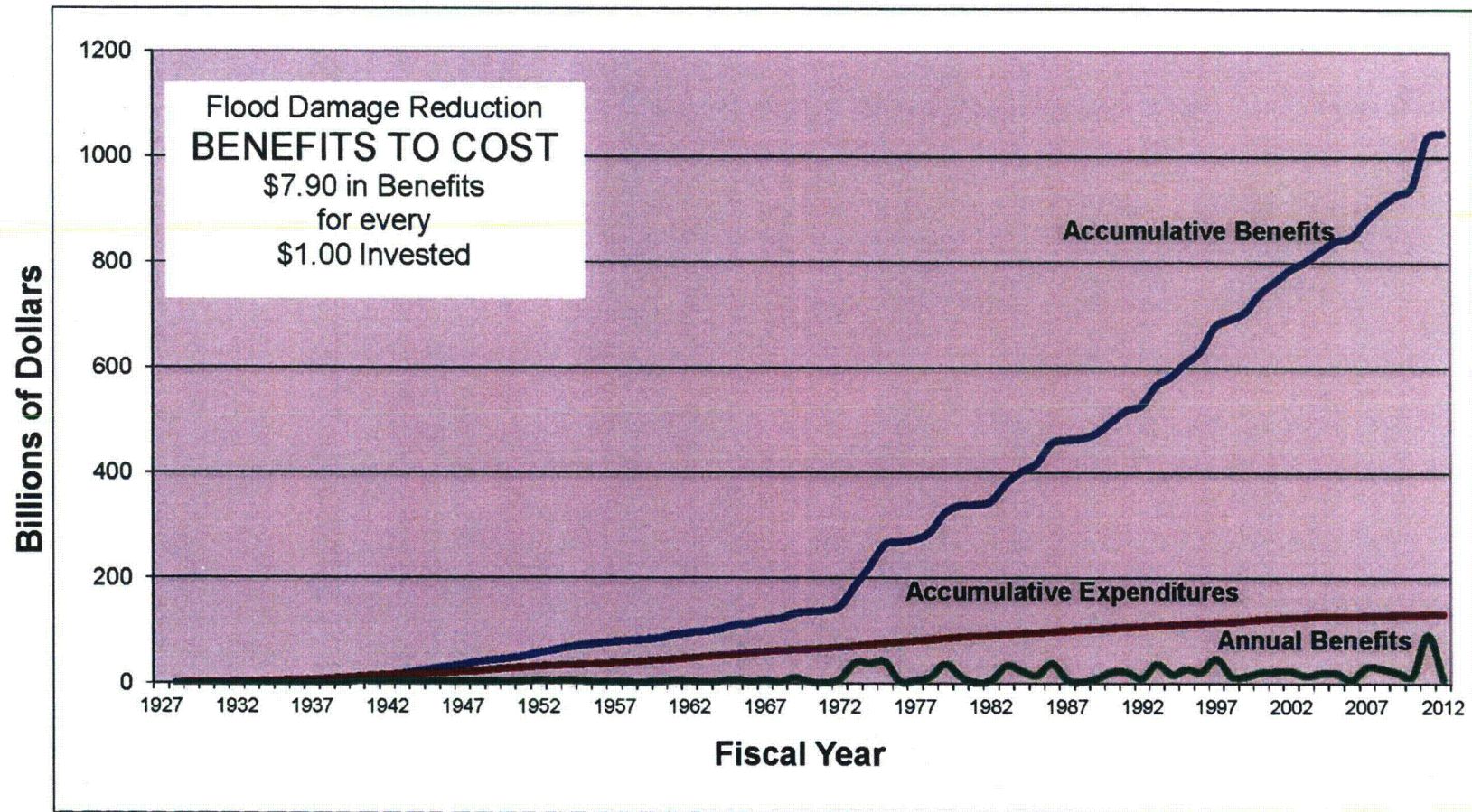


Bonneville II Powerhouse, WA

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Benefits of Federal Projects (Damages Prevented) Accumulative Corps Expenditures (Principle plus O&M)

Adjusted to 2000 Using Construction Cost Index EM 1110-2-1304 (Mar 2013 revision)

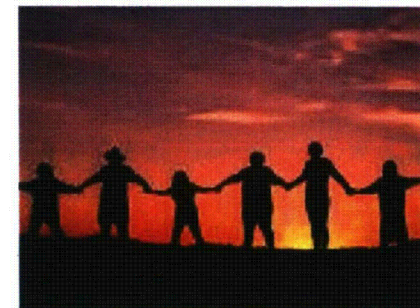


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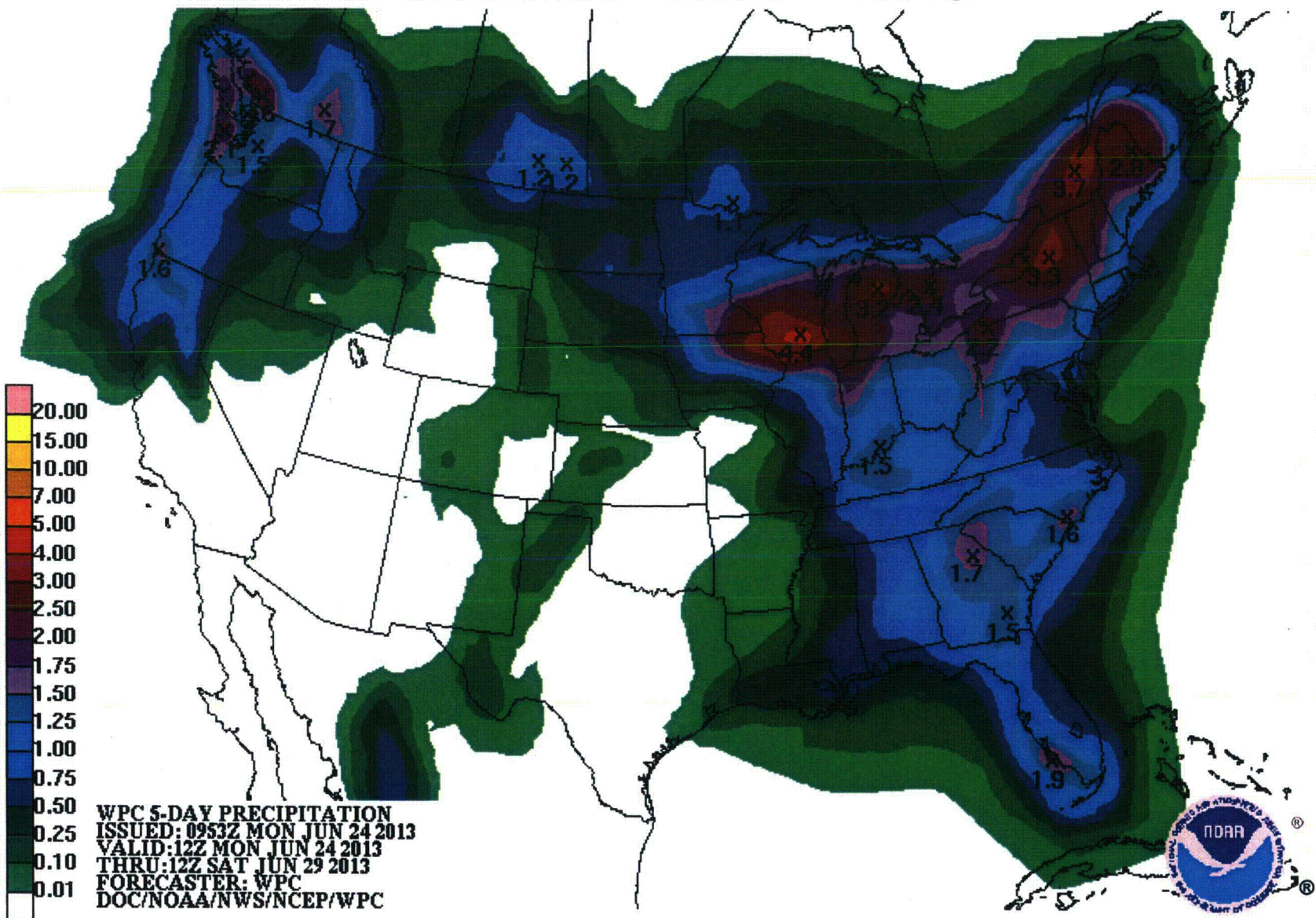


Communication/Collaboration

- Continuous forecast coordination between NWS forecasters and USACE decision makers including 100+ scenarios for spillway operations
- Daily coordination with USGS & USACE on real time discharge measurements to help validate and adjust hydraulic models and rating curves
- NWS personnel stationed at USACE Emergency Operations Center
- HEC-RAS collaboration with USACE, NWS, & HEC

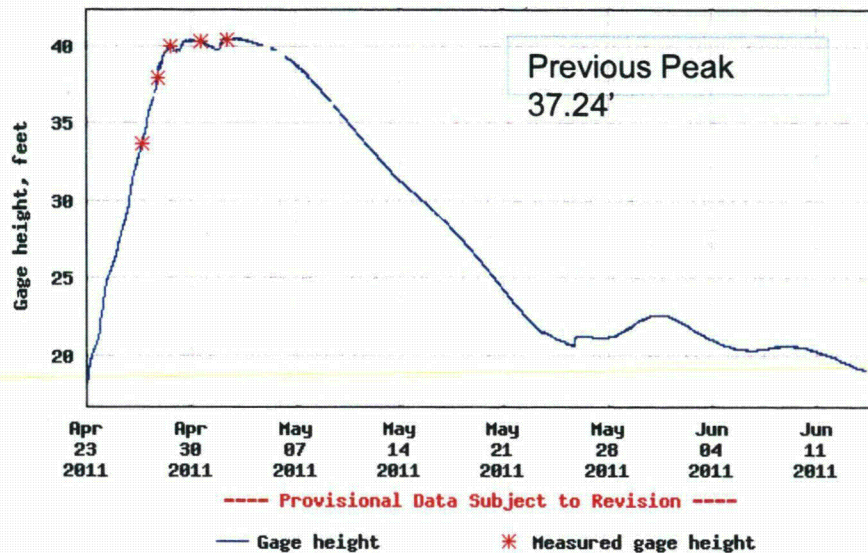


Quantitative Precipitation Forecasting (QPF)

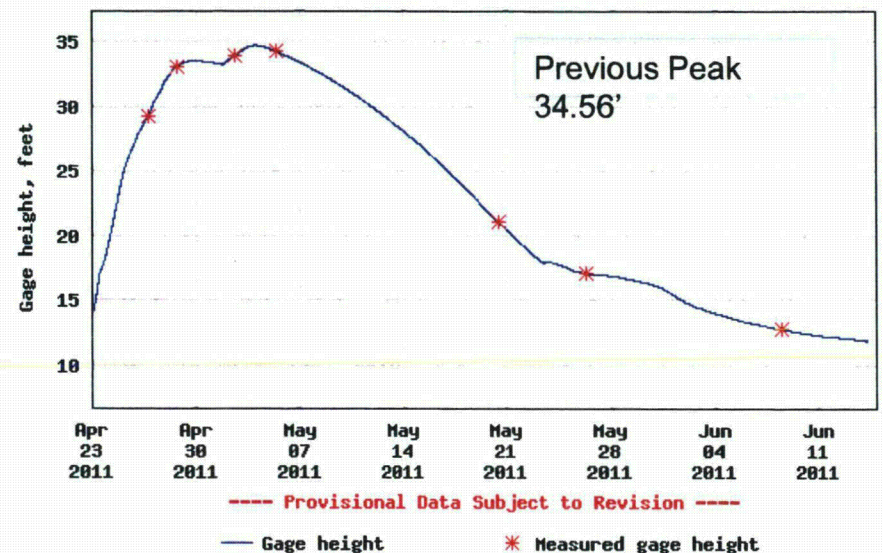




USGS 05599490 BIG MUDDY RIVER AT RTE 127 AT MURPHYSBORO, IL

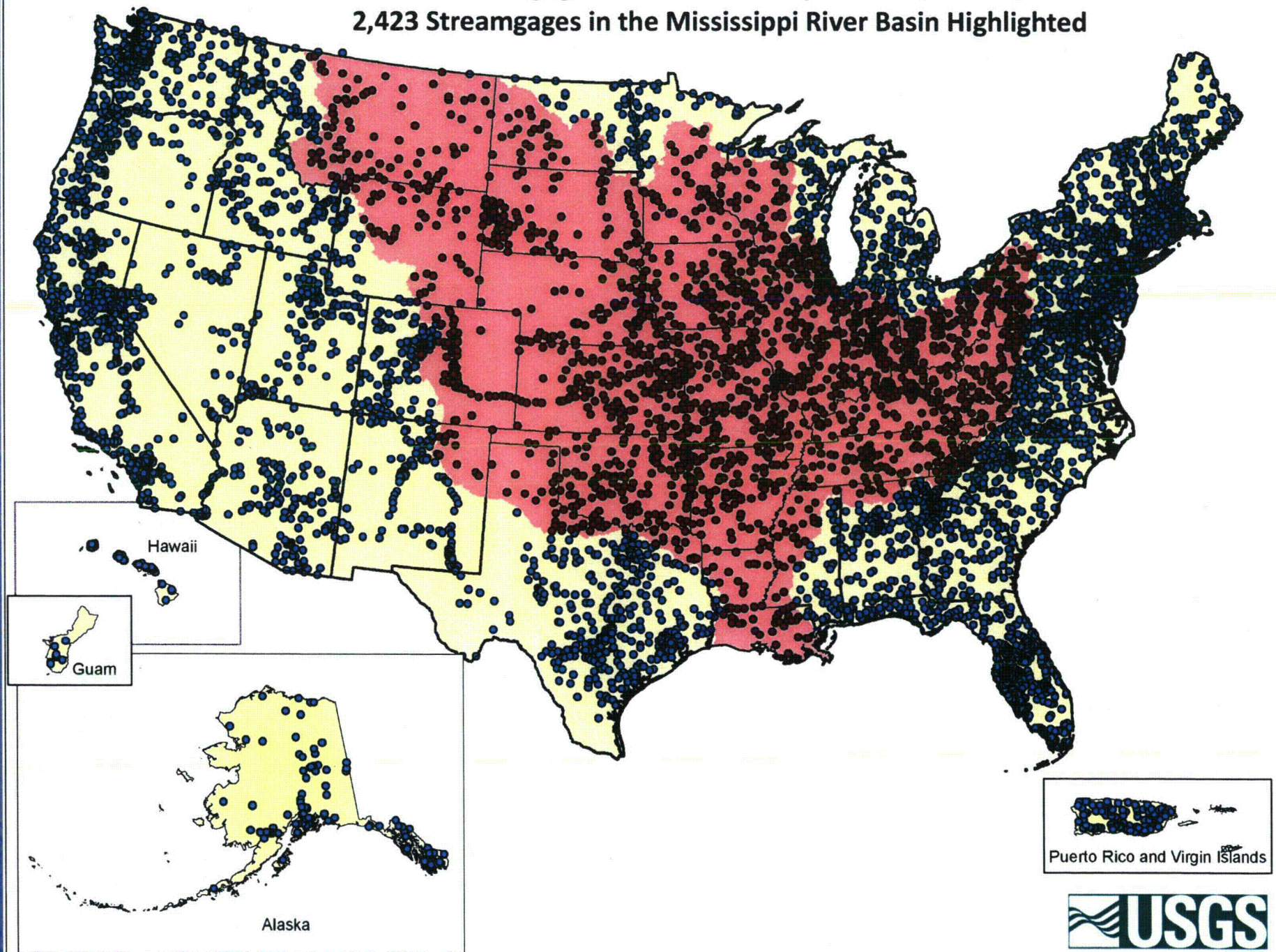


USGS 05597000 BIG MUDDY RIVER AT PLUMFIELD, IL



04/28/2011

USGS Streamgages Active in Water-year 2010, Total 7,845
2,423 Streamgages in the Mississippi River Basin Highlighted



Extreme Storm Data Sources

- US Storm Rainfall Events (1882-1973)
- Bucket Surveys (USACE, USBR, NWS)
- NOAA COOP Observations (1753-2012)
- NWS Radar Estimates (1993-2012)
- CoCoRaHS (1998-2012)
- Local & Regional Precipitation Networks
(NERain, SD-AWDN, NDAWN, DOT, ALERT, etc)



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Precipitation Frequency Products

- ▶ Investigation and reports of new techniques for extended precipitation frequency and AEP data, including updated statistical and stochastic precipitation modeling techniques. The primary focus will be on the research and development of stochastic techniques.
- ▶ Development of tools for the analysis and creation of precipitation frequency and AEP curves, including the relationship of recorded extreme storms to precipitation frequency / AEP
- ▶ Development of tools to create model input data from precipitation frequency and AEP curve data
- ▶ Development of tools to create model input data from the extreme storm database
- ▶ Research into the feasibility of using regional atmospheric models to understand how to scale extreme event data into even more extreme scales
- ▶ Research, development, and implementation (including user interfaces [UI]) of tools for improved determination of confidence limits of precipitation frequency / AEP curves



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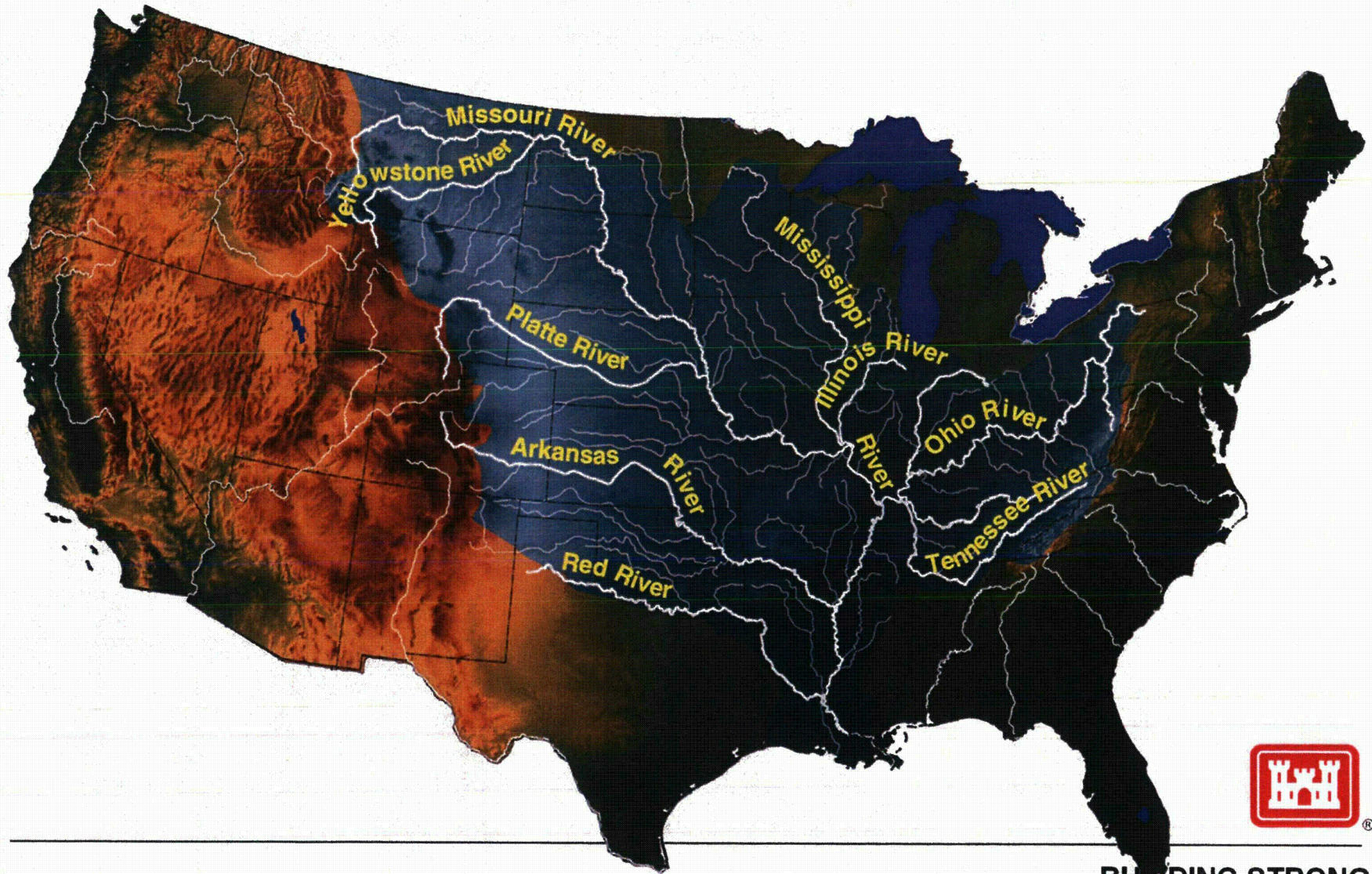
Flow Frequency Products

- ▶ Research into using the USACE hydrologic models (HEC-HMS and GSSHA) for transforming precipitation frequency / AEP data into flow frequency / AEP data
 - Testing of efficacy of approach
 - Proof-of-concept demo
 - Integration with precipitation frequency / AEP tools
 - UI development to create flow frequency / AEP
 - Guidance and tutorial documents
- ▶ Research, development, and implementation (including UI) of tools for improved determination of confidence limits of flow frequency / AEP curves
- ▶ Research and development of tools, interfaces, and capabilities to reduce local computational burden and increase usability of products



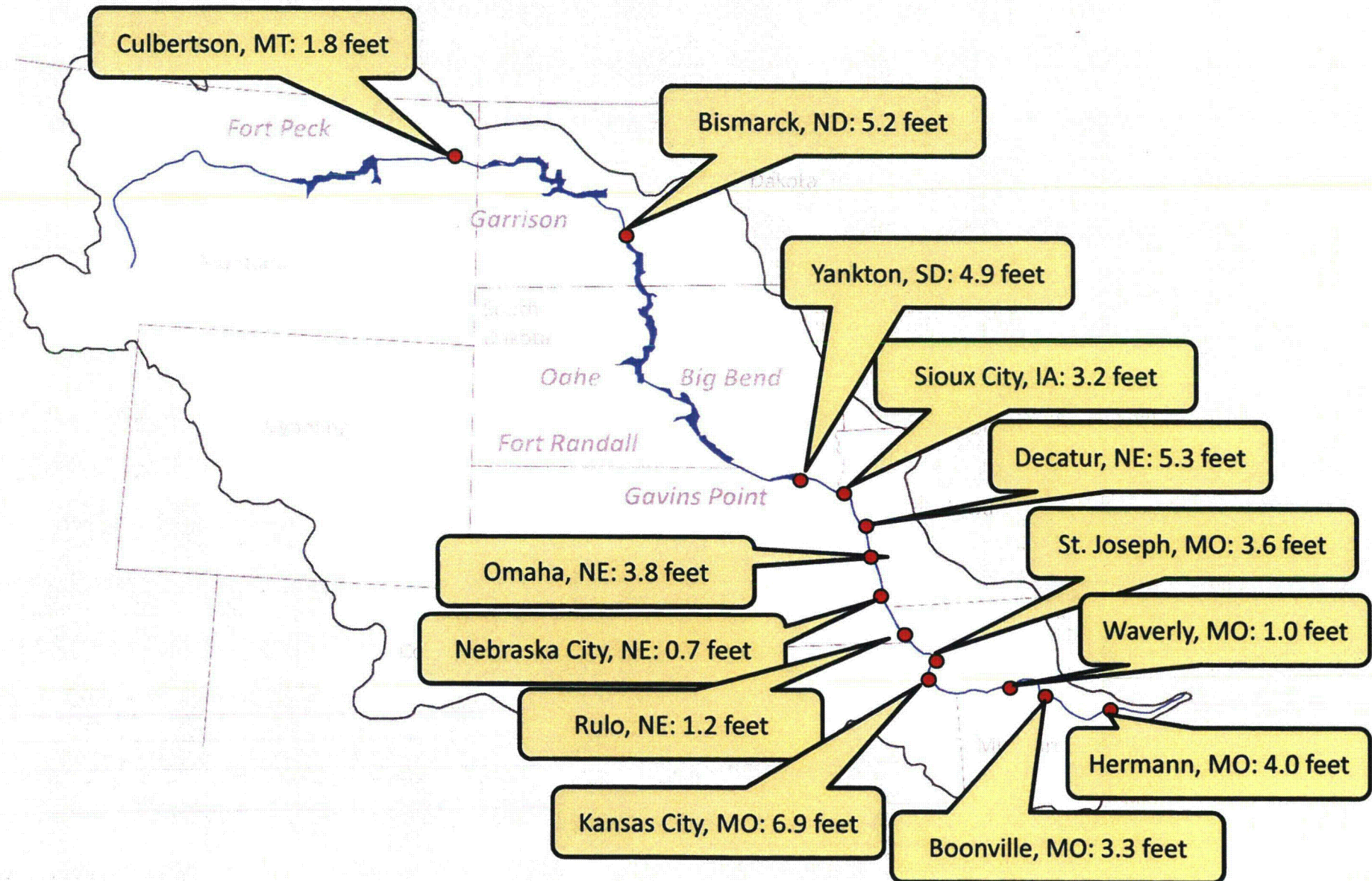
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Mississippi River Watershed



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Missouri River Stage Reduction Due to Reservoir Operations



2011 Flood of Record

- Much above average plains snowpack, late-arriving much above normal mountain snowpack and record May rainfall in the upper basin ... flood of record.
- Runoff in 2011 was 61.0 million acre-feet (MAF), 247 percent of normal and the highest runoff in 114 years
 - ▶ May was the ninth wettest single month on record with 9.3 MAF
 - ▶ June was the single wettest month on record with 14.8 MAF of runoff, surpassing the old record of 13.2 MAF set in April 1952.
 - ▶ July was the fourth wettest single month on record with 10.2 MAF
- Combined May through July runoff of 34.3 MAF is higher than the total annual runoff in 102 of 113 years in the period of record
 - ▶ Estimated 0.2 percent annual exceedance interval



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System Tested as Never Before...

- System storage peaked at a record 72.8 MAF on 1 July
 - ▶ 16 MAF stored flood waters in mainstem reservoirs
 - ▶ Corps and Bureau of Reclamation tributary reservoirs also utilized
- Four mainstem reservoirs utilized exclusive flood control zone
 - ▶ Fort Peck, Garrison, Oahe and Fort Randall
- Three mainstem reservoirs set record pool levels
 - ▶ Fort Peck, Oahe and Fort Randall
- Two mainstem reservoirs utilized surcharge storage
 - ▶ Fort Peck and Garrison
- Spillways at two mainstem dams were operated for the first time
 - ▶ Garrison and Big Bend
- Record releases from all mainstem reservoirs



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