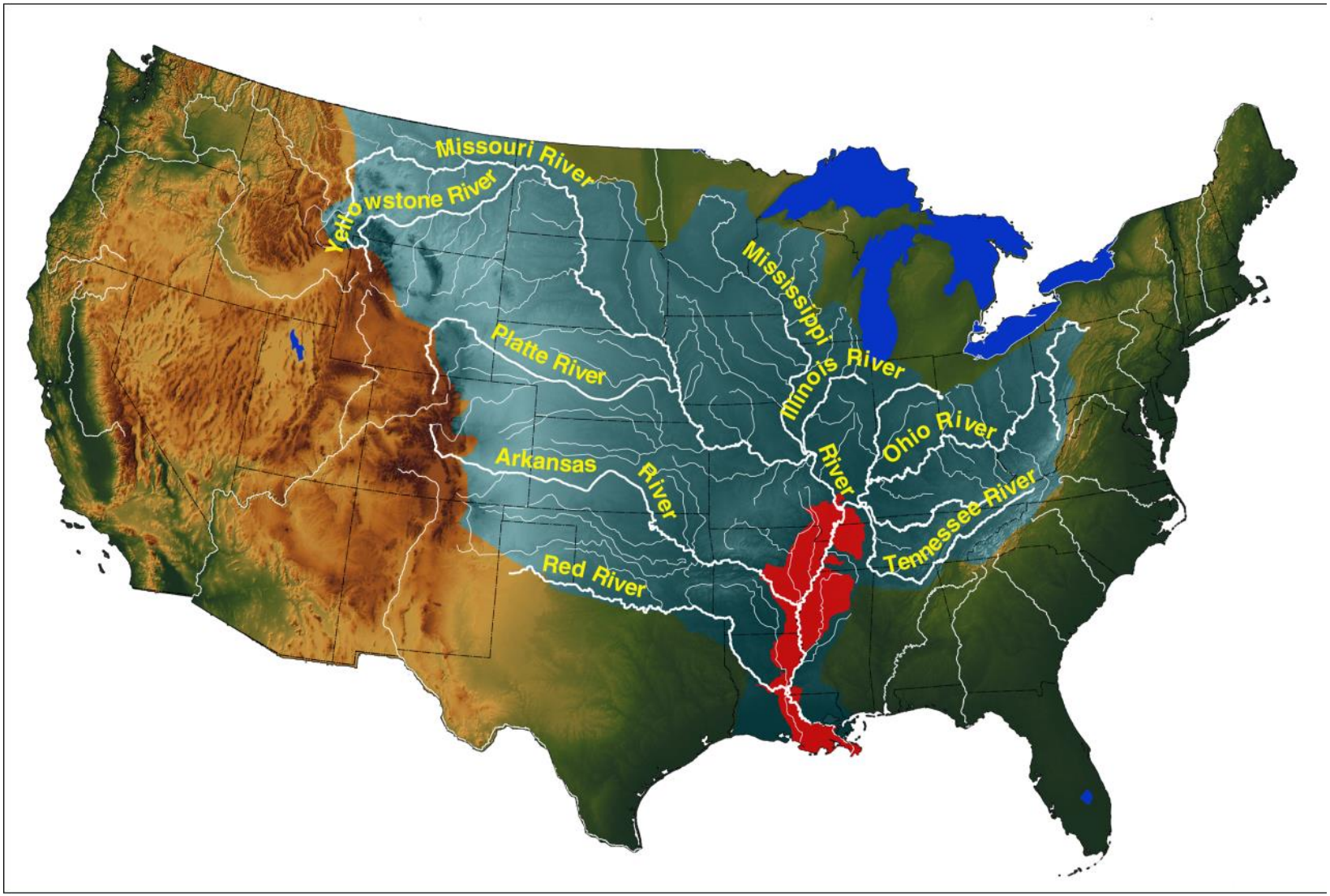
“Sustainability Metrics in Water Resources – An Engineer’s Perspective”

Roundtable on Science and Technology for Sustainability

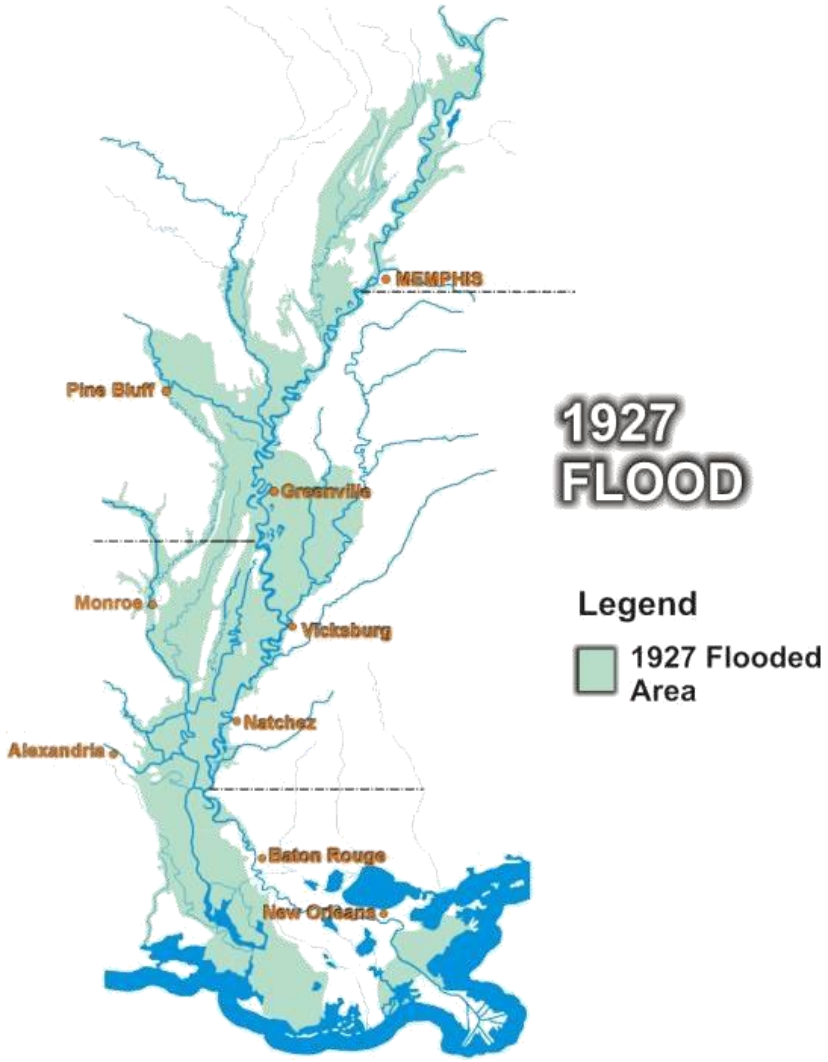
4 June 2015

Joe Manous, PhD, PE

Mississippi River Watershed

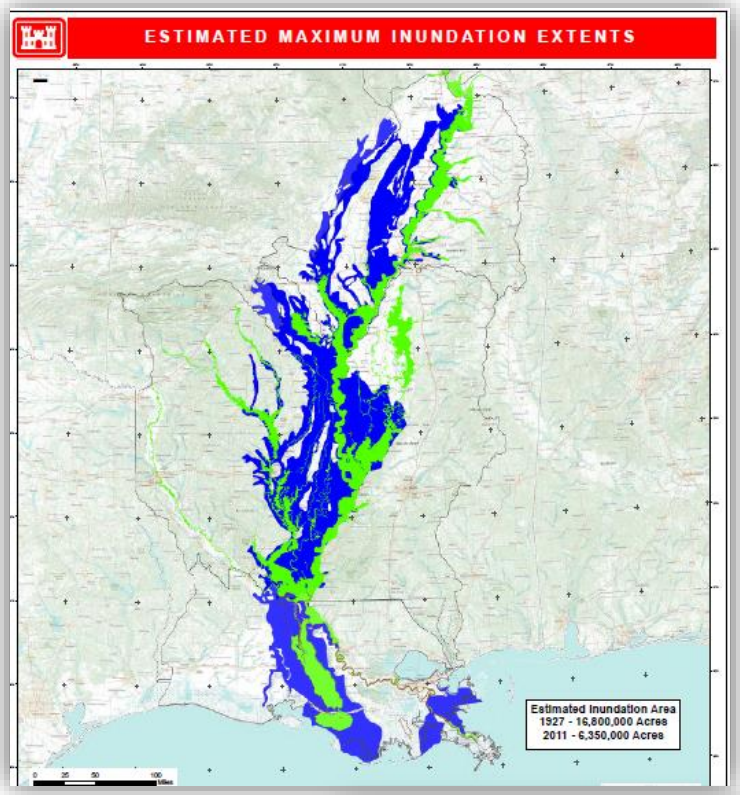


1927 Mississippi River Flood



- **Flooded 26,000 sq. miles**
- **600,000 homeless**
- **Over 250 people killed**
- **Economic Damages ~$1B**

2011 Mississippi River Flood



- **Flooded 9,900 sq. miles**
- **Protected 62% of area flooded in 1927**

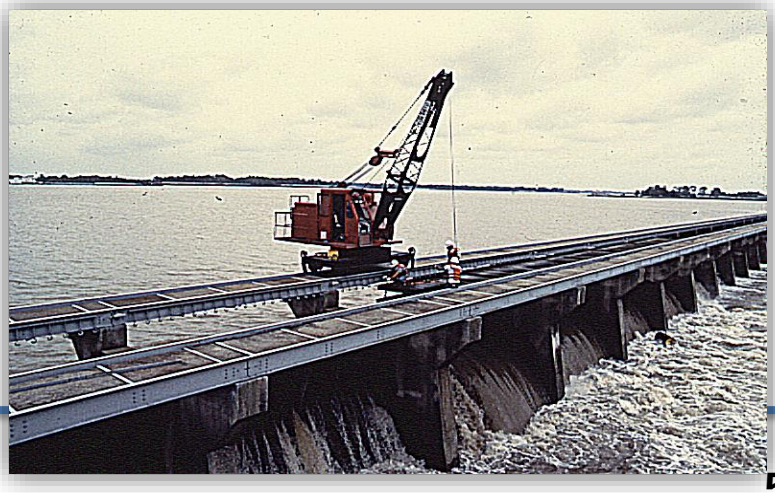
Mississippi River & Tributaries
"An Integrated System" – "Room for the River"

Levees – "backbone of flood protection"

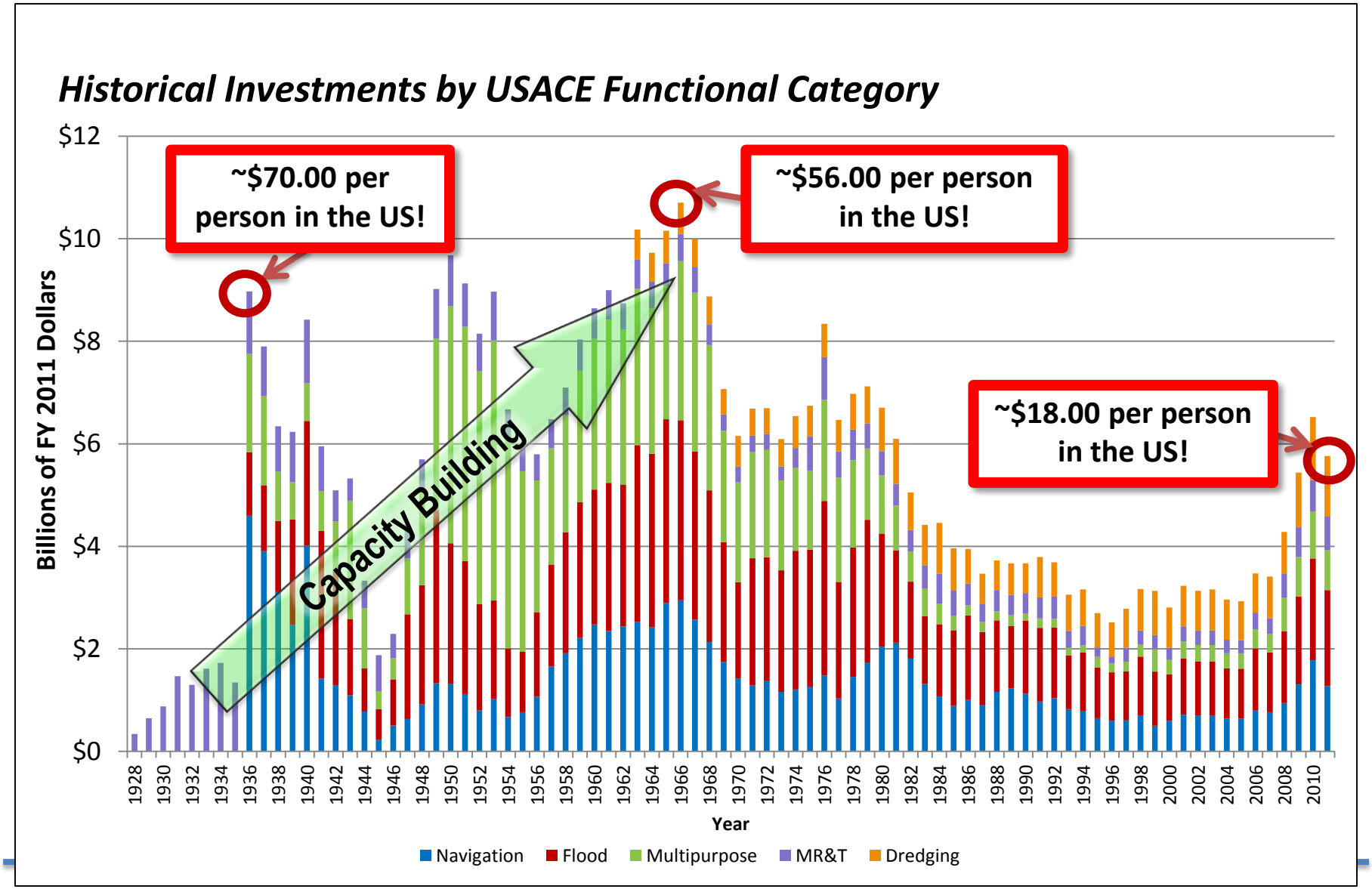
Channel Stabilization – "tickling the River for navigation & flood control"

Tributary Basin Improvements

Floodways – "overflow relief"

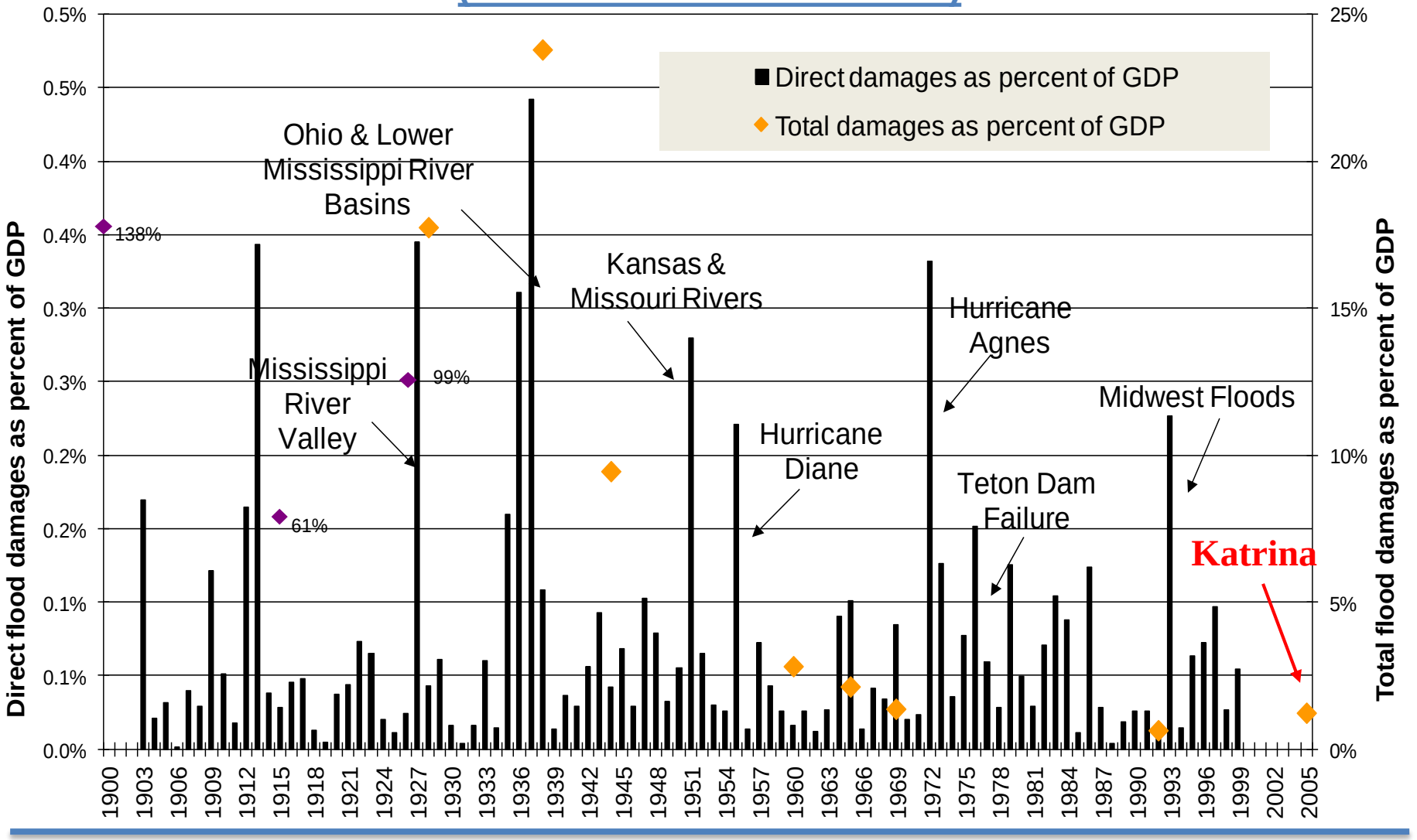


20th Century Investment in U.S. Water Resources

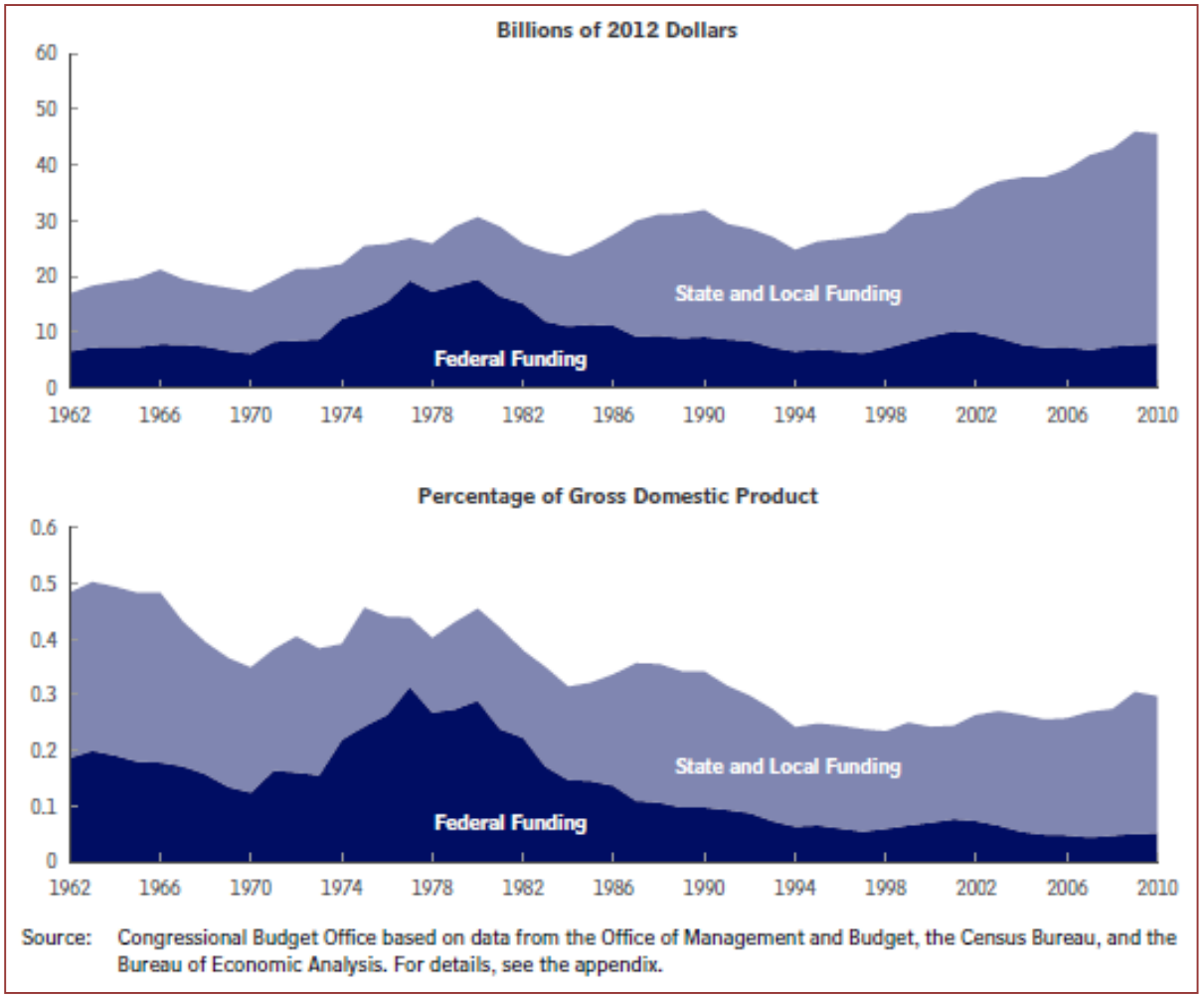


Damages from Water-Related Natural Disasters as % of GDP

(Based on data in 2000 USD)



U.S. Water Infrastructure Spending Trends



Source: Congressional Budget Office based on data from the Office of Management and Budget, the Census Bureau, and the Bureau of Economic Analysis. For details, see the appendix.

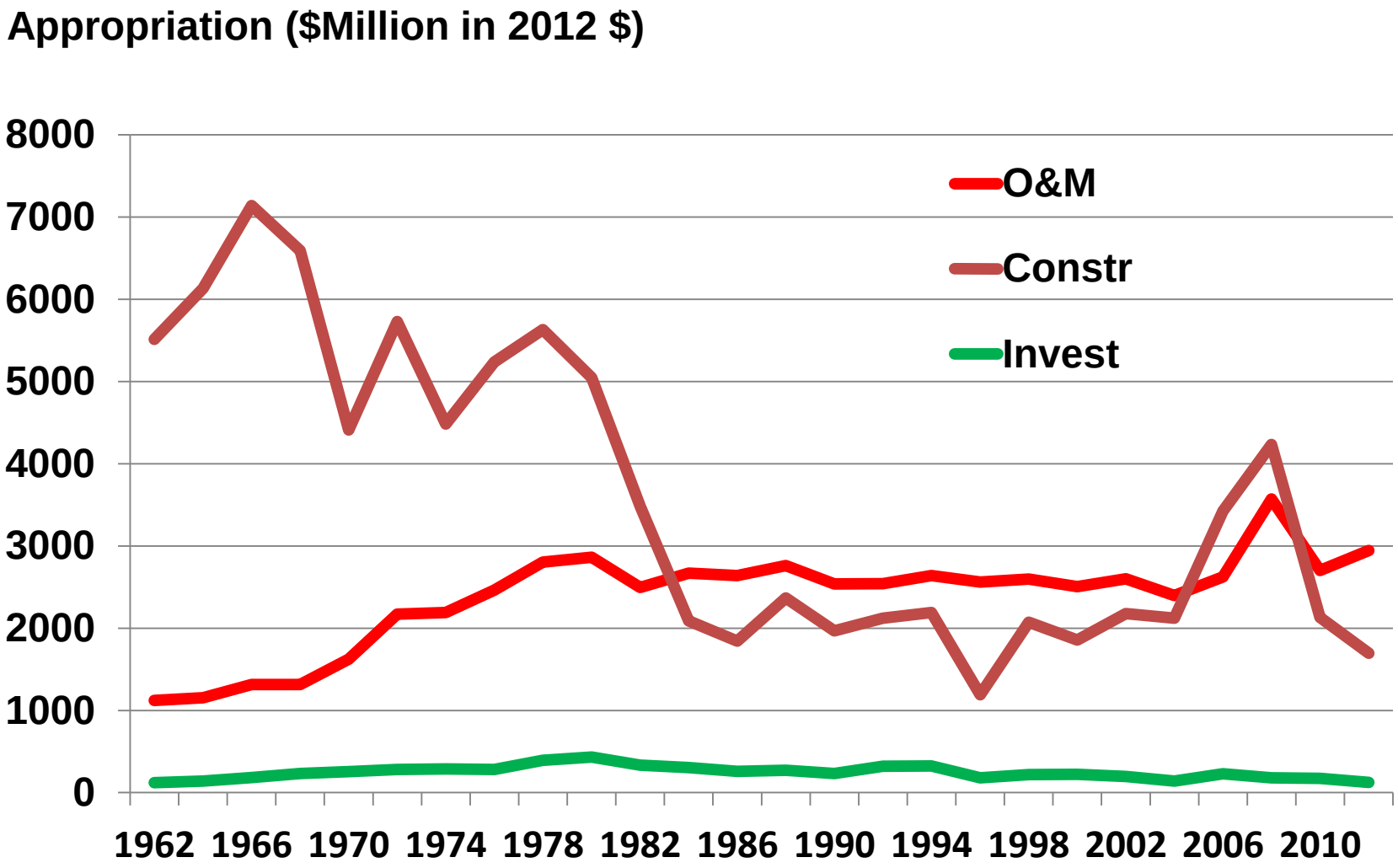
Between 1962 to 2010…

While total public funding (in 2012 $'s) of water infrastructure has increased

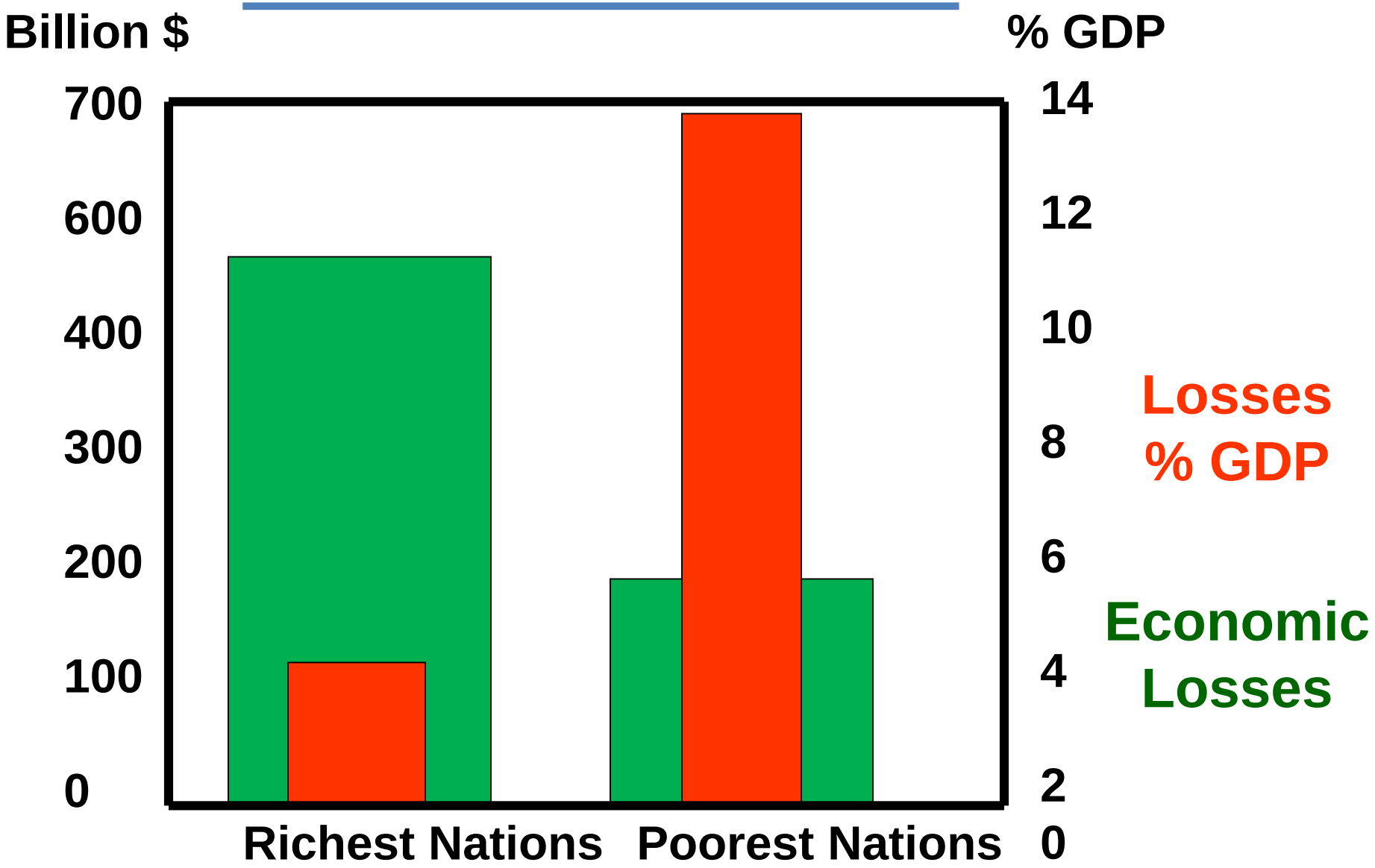
As a % GDP, spending has decreased

And Federal spending has dropped dramatically as % GDP

Long-Term Constrained Civil Works Funding

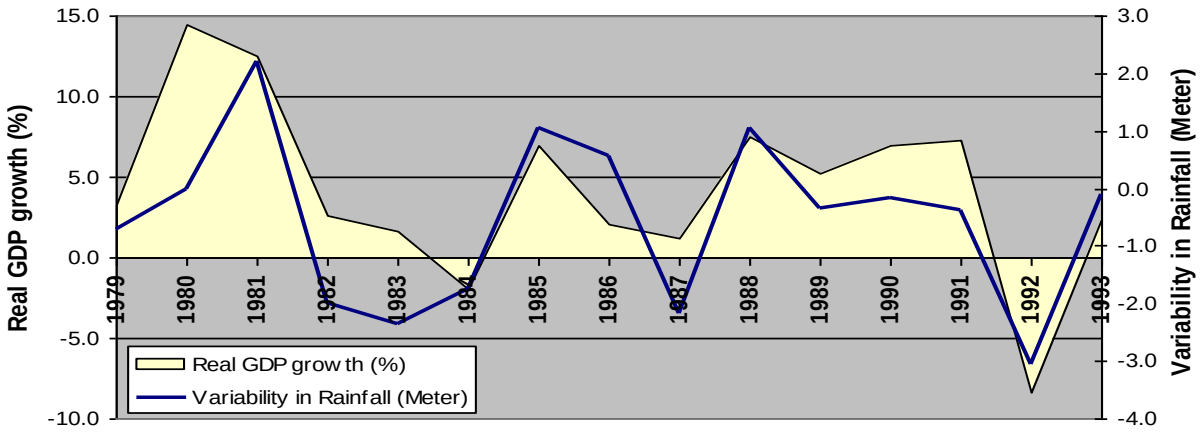


Economic Resilience

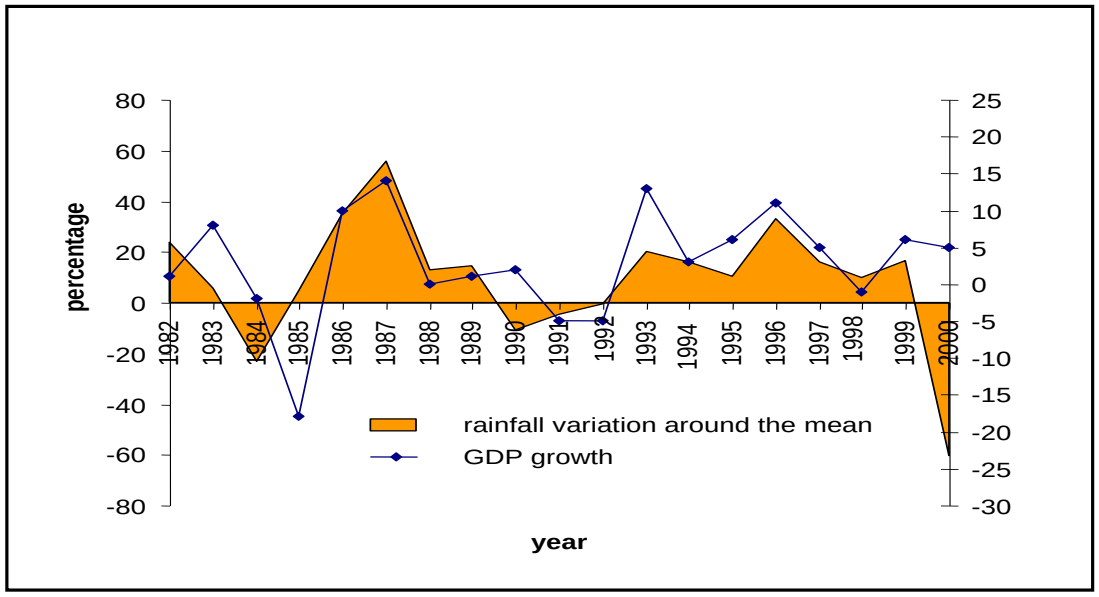


World Watch 2001

Economy-wide Impacts



Rainfall & GDP growth: Zimbabwe 1978-1993

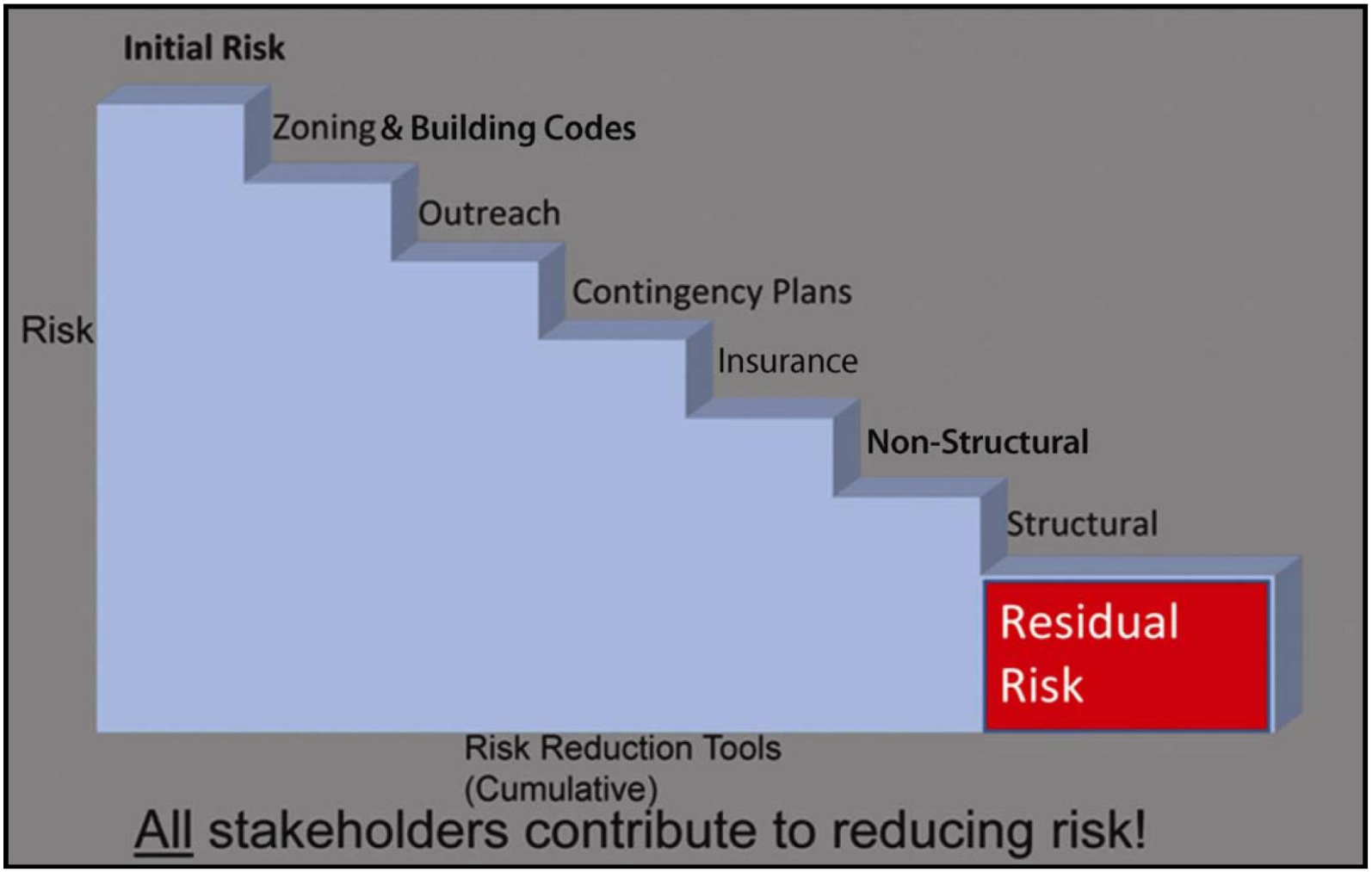


Rainfall & GDP growth: Ethiopia 1982-2000

Infrastructure Resilience Indicators (Water Resources Perspective)

- **Lives lost**
- **Extent of flood damages (inland and coastal)**
- **Available water supply (municipal, industrial, agriculture)**
- **Delays to inland and port shipping**
- **Impacts on aquatic and terrestrial species (especially endangered and threatened)**
- **Loss of hydropower production**

Key Resilience Measure – "Buy Down Risk"



Approach

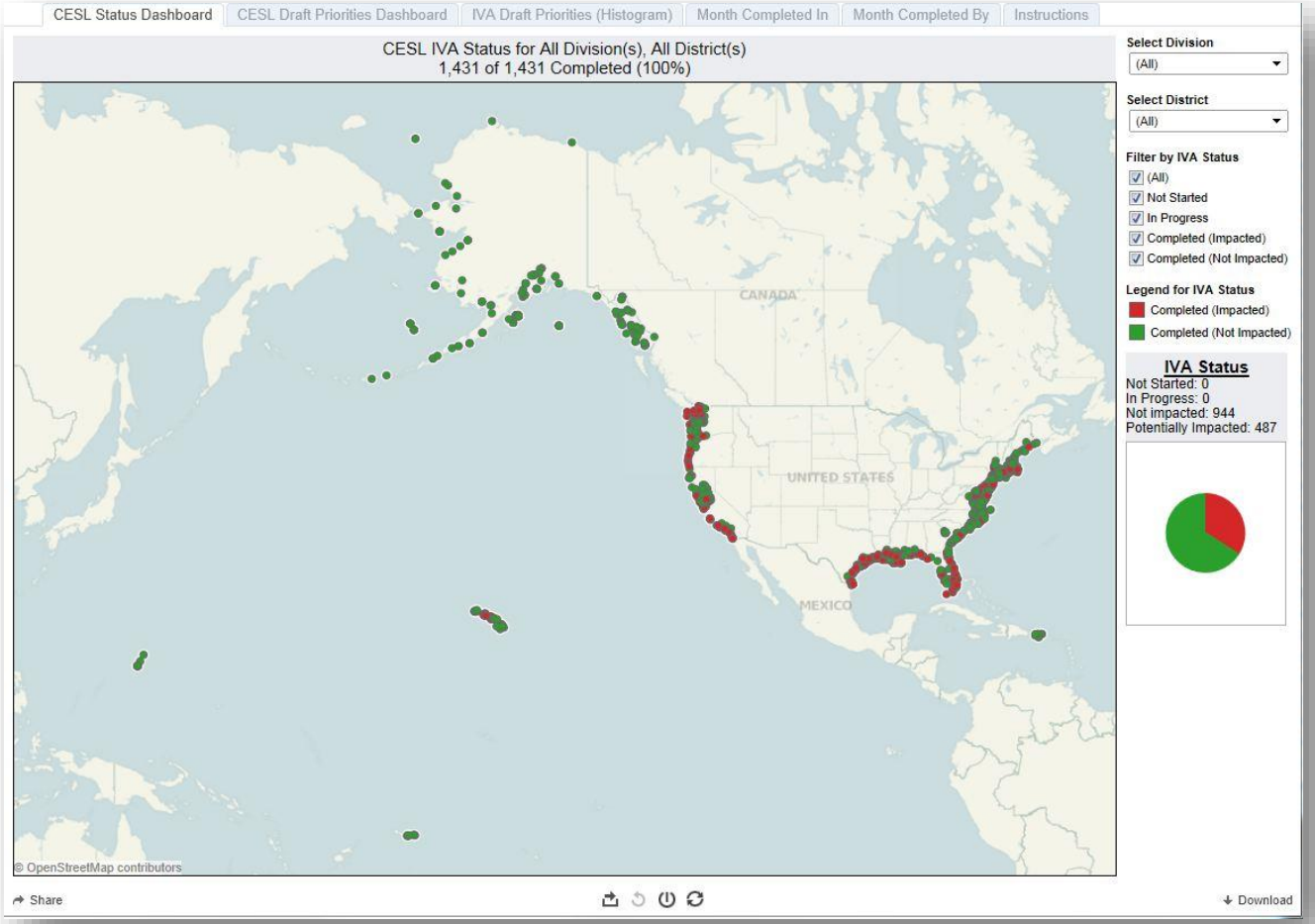
Design for multi-hazards

- **Example - Floods**
  - **Probable Maximum Flood**
  - **1% flood**
  - **Multi-use reservoir operation**
  - **Consequence of structural failure**

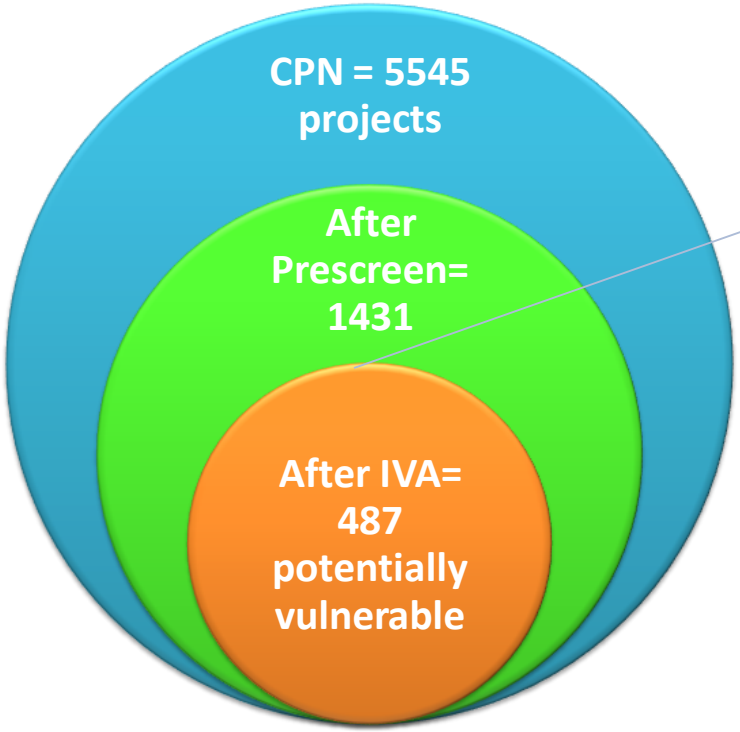
- **Designed with incomplete information**
- **Requires engineering judgment**
- **Conservatism of design influenced by consequences of failure (level of protection, redundancy, manner of failure)**
- **Must consider cost**

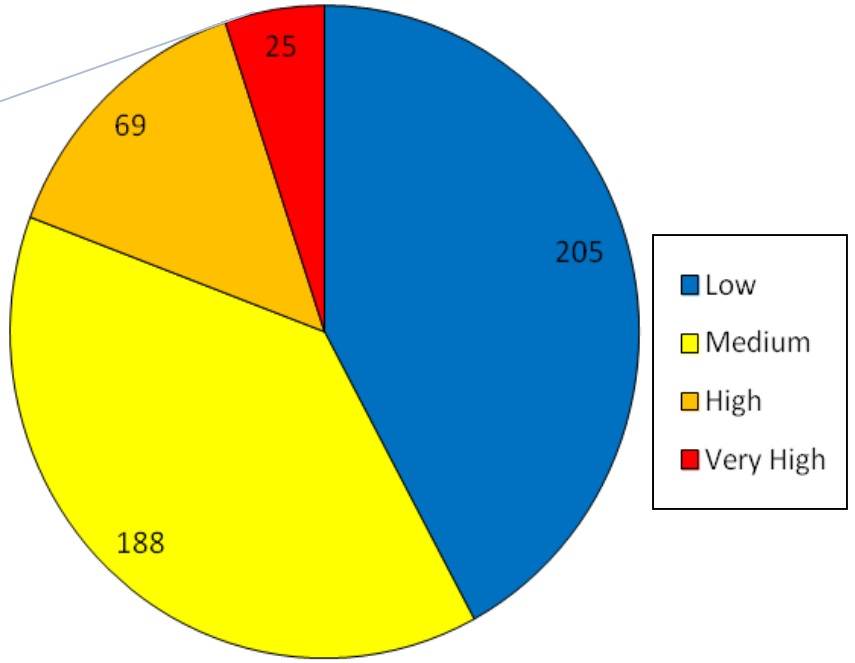
Assessment of Existing USACE Coastal Infrastructure

Completed initial screening level vulnerability assessments September 2014



Initial Screening Results



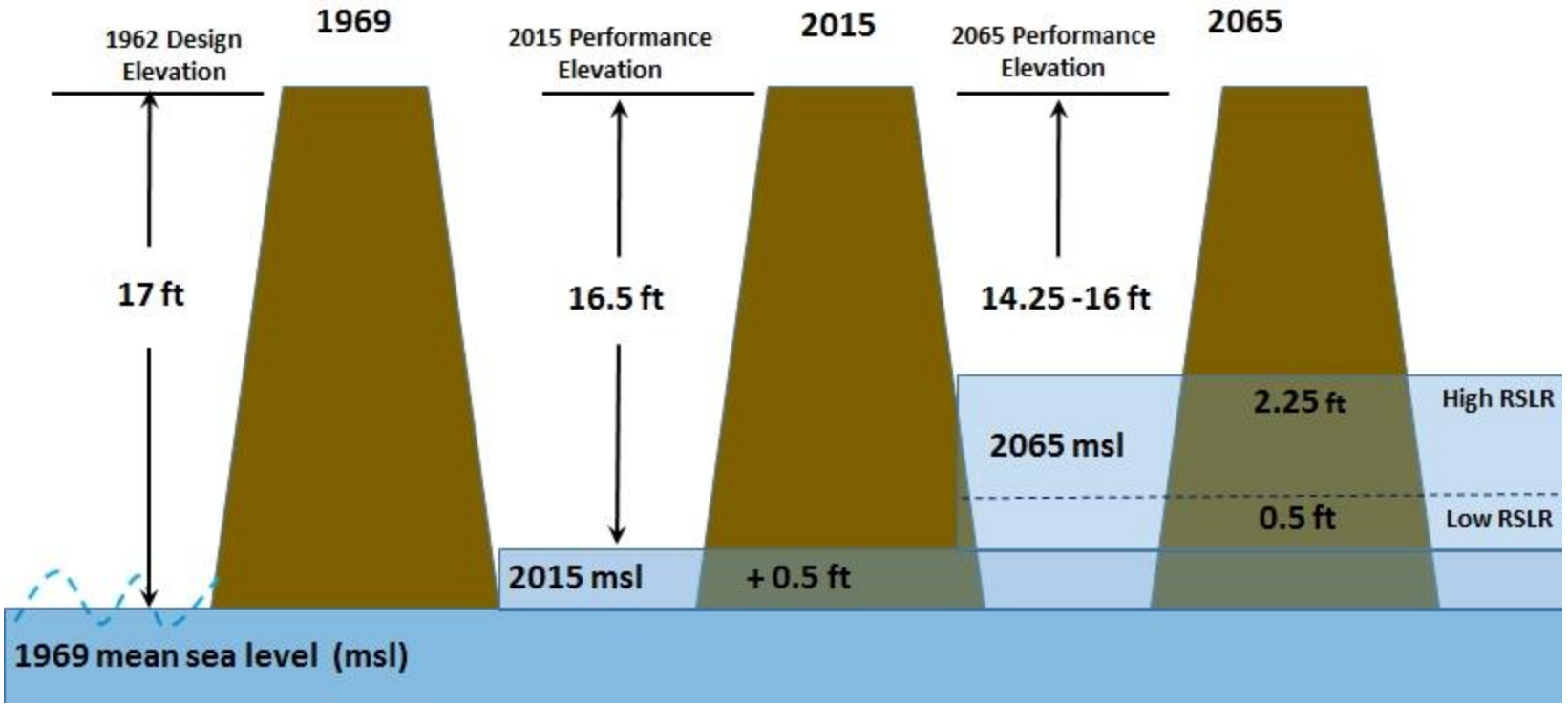


- **1431 Projects potentially impacted by sea level (SLC)change before Initial Vulnerability Assessment (IVA)**
  - **After IVA:**
    - **944 Identified as NOT IMPACTED by SLC**
    - **487 Identified as Impacted by SLC**

Specific Location Analysis - Example

Hurricane Barrier Project in New England

Original 1962 design elevation has changed about 0.5 ft as of 2015, and could lose between 0.5 and 2.5 ft more by 2065

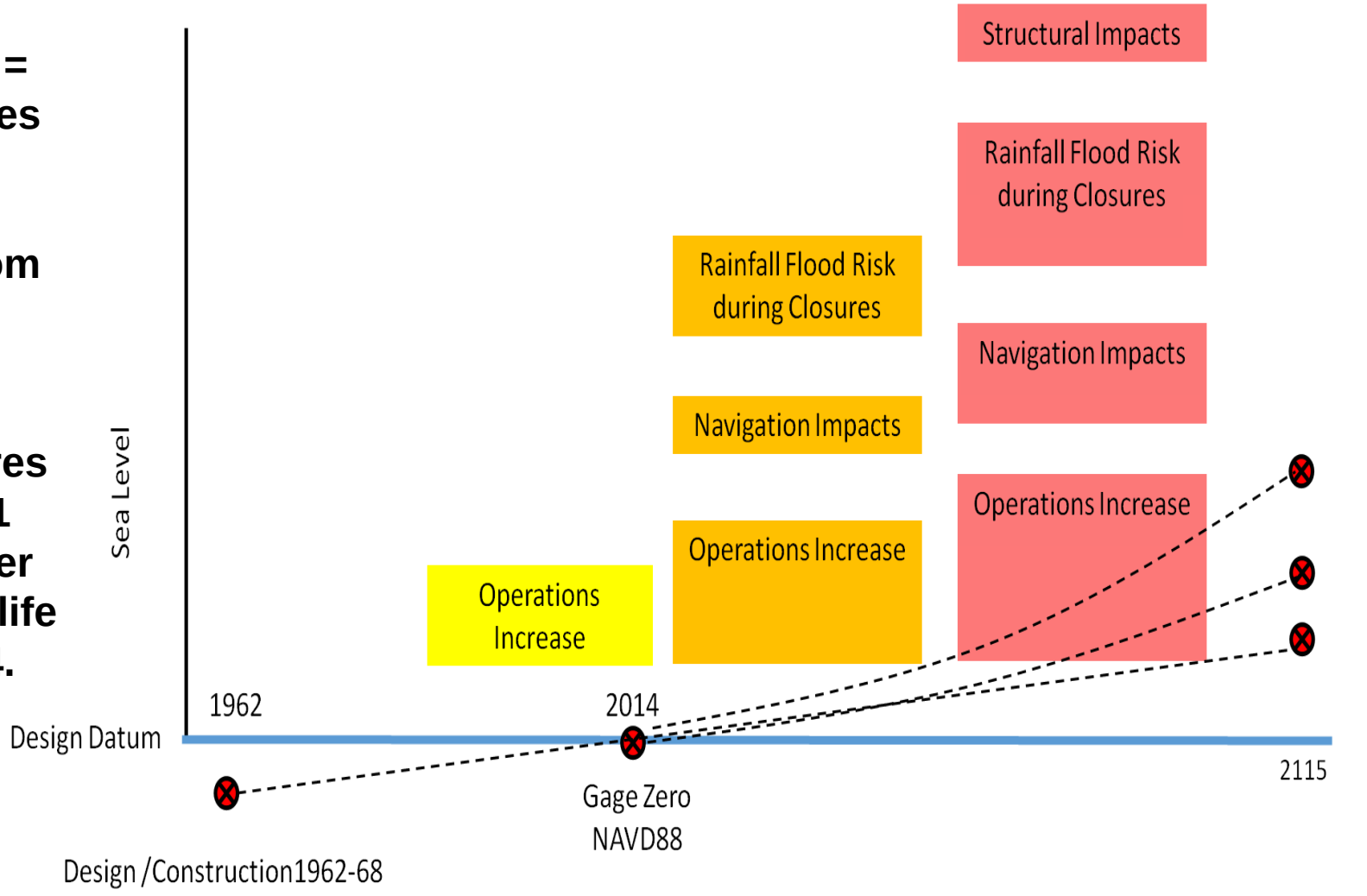


Specific Location Analysis - Example

Multipurpose Project with a Navigation Gate and Two Dikes

Operations = gate closures to keep coastal flooding from impacting harbor

Gate closures averaged 11 per year over the project life before 2014.



Considerations for Adaptation Metrics

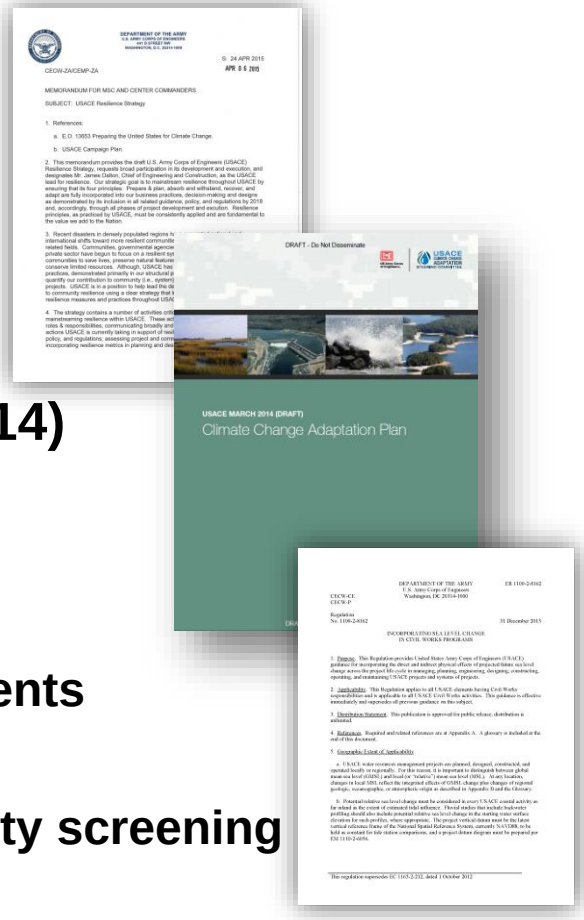
- **No systematic approach to date**
- **Adaptation Implementation**
  (have the desired outcomes been achieved)

  is not necessarily the same as

  Adaptation Planning
  (all impacts, vulnerabilities, consequences and uncertainty considered)
- **Practitioners need indicators that assess project outcomes**

USACE Guidance

- **USACE Resilience Strategy (6 Apr 2015)**
  - **Prepare and Plan**
  - **Absorb and withstand**
  - **Recover**
  - **Adapt**
- **USACE Climate Change Adaptation Plan (Jun 2014)**
  - **New Infrastructure**
    - **Apply policy and guidance**
    - **Implement adaptation as planned over entire project lifecycle, tied to trigger or threshold events**
  - **Existing Infrastructure**
    - **Progressively more detailed climate vulnerability screening**
    - **Conduct detailed assessments**
    - **Prioritize, Plan, and Implement adaptation**
- **USACE Engineering Circular "Incorporating Sea Level Change In Civil Works Programs" (31 Dec 2013)**



Alliance for Global Water Adaptation (AGWA)

- **A consortium promoting Climate Risk Informed Decision Analysis (CRIDA) for climate adaptation**
  - **Start by identifying vulnerabilities and water security issues and then determine plausibility and strategies to build robustness and resilience**
  - **Alternative to starting an analysis with forecasts of future climate states**
- **Core AGWA Partners**
  - **World Bank**
  - **DELTARES**
  - **Umass**
  - **Pegasys**
  - **IUCN**
  - **Conservation International**
  - **UNECE**
  - **ISET/ USAID RDMA**
  - **Inter-American Development Bank**
  - **Environmental Law Institute**
  - **USACE**
  - **ADB**

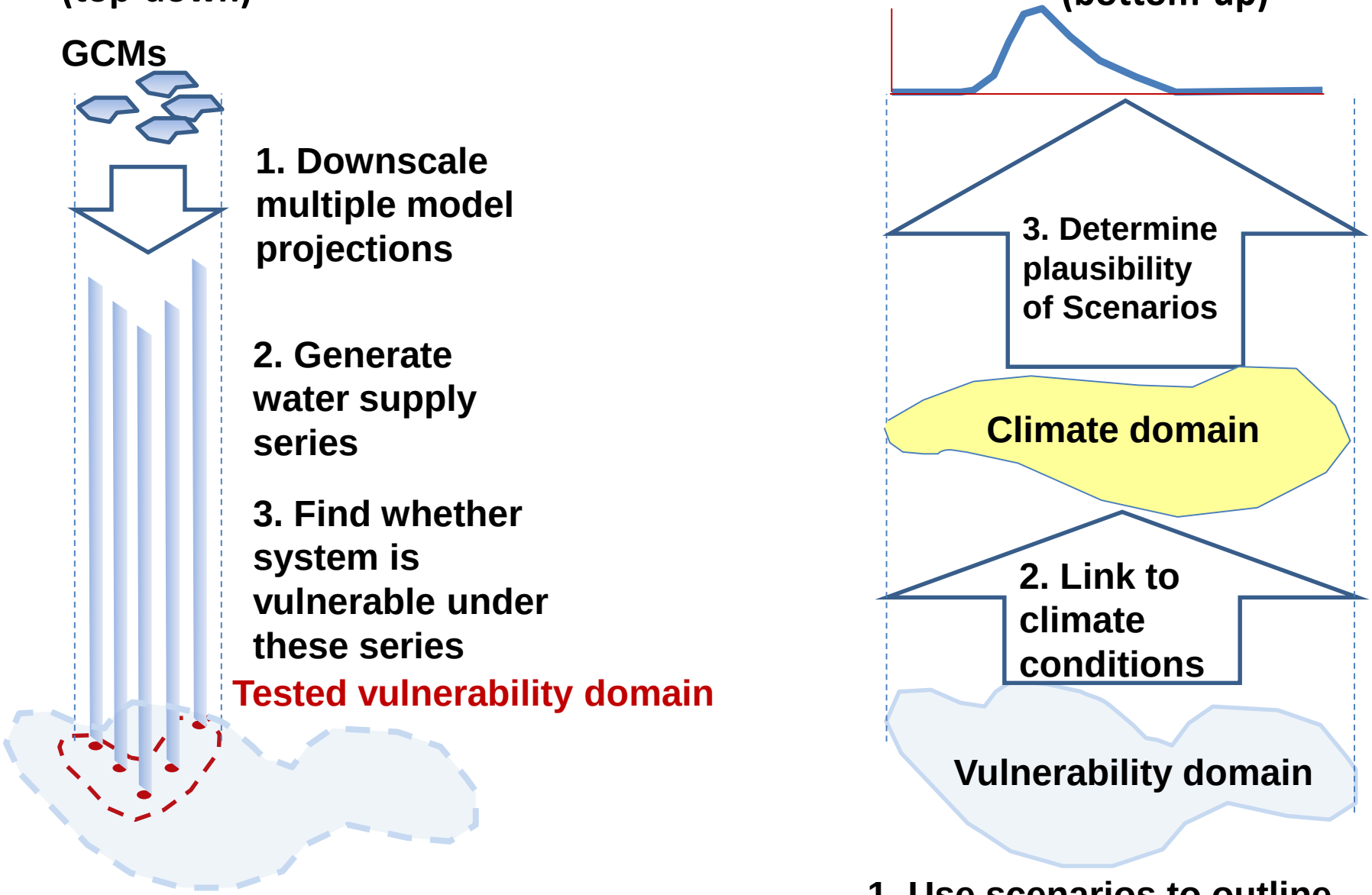
Including Climate Change in Hydrologic Design (World Bank Workshop, November 2011)

- **Challenges**
  - **Limited consensus on approach to policy, national strategies, planning and hydrologic design of water resources under climate change uncertainty**
  - **Limited direction on how to navigate available tools and best practices**
  - **Decision making for future climate states appears limited**
- **Outcome: AGWA to develop a decision tree / DSS to help navigate through tools for decision making**
- **AGWA four working groups**
  - **Hydrological and Climate (Institute for Water Resources)**
  - **Economic and Finance (World Bank WPP, European Investment Bank, and the OECD)**
  - **Engineering and Ecology (IWR, Conservation International, Inter-American Development Bank)**
  - **Governance (U.S. DoS and the Environmental Law Institute)**

AGWA Approach

Downscaling (top-down)

Decision Scaling (bottom-up)

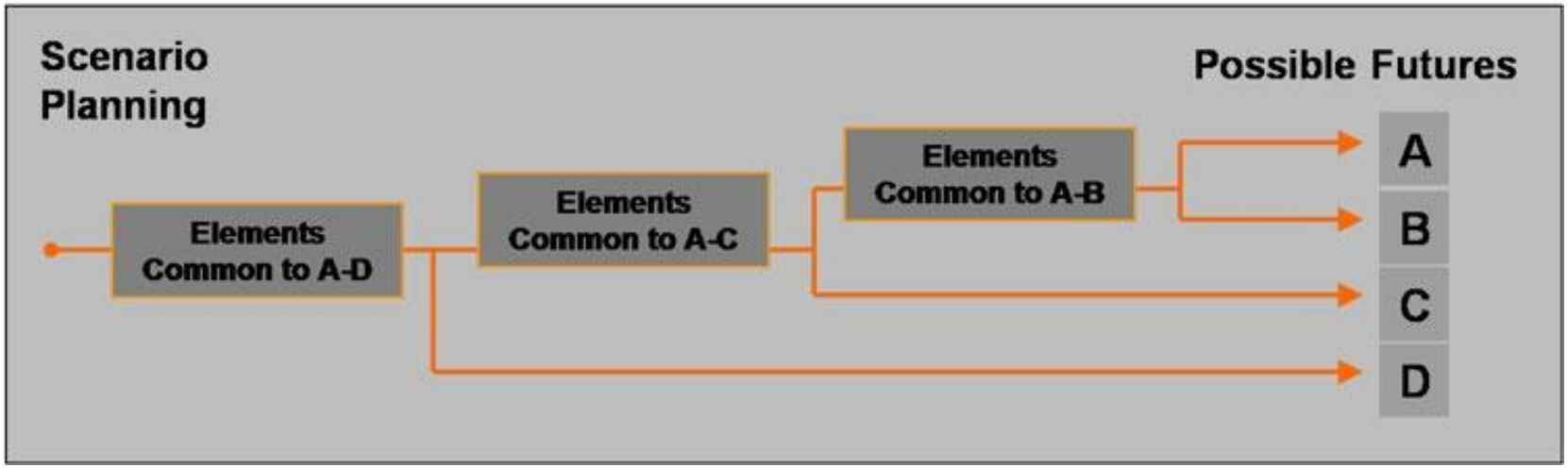


Source: Brown and Werick (2011): A decision analytic approach to managing climate risks . JAWRA

Scenario

… not forecasts, but possible future, from a set of plausible futures.

- Scenarios tests choices made today under many possible futures conditions



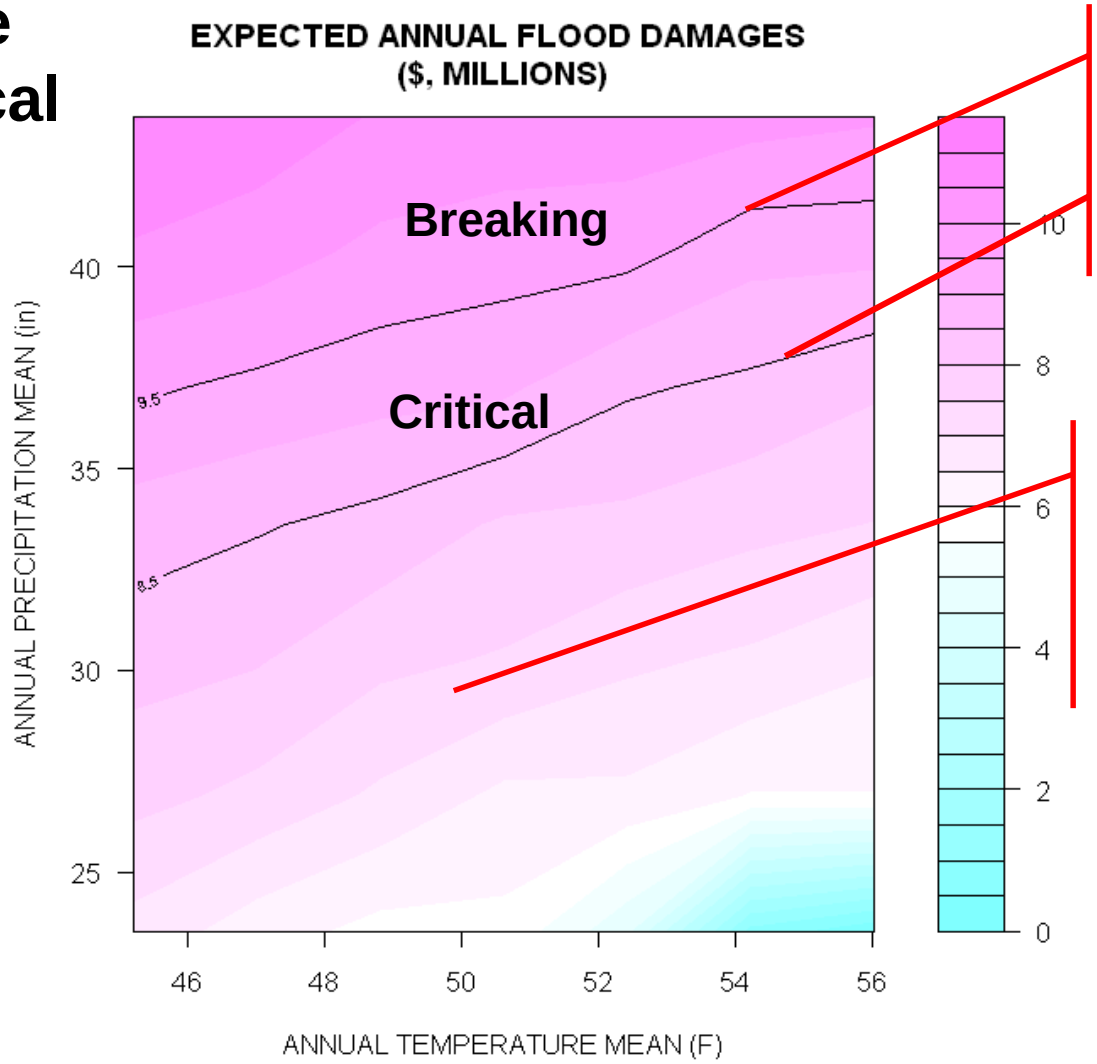
Build Multi-Criteria Decision Support Models

Typical criteria to test system

- **Economic growth**
- **Environmental quality**
- **Social well-being**
- **Financial sustainability**
- **Safety**

Conduct Risk Assessment Stress Tests

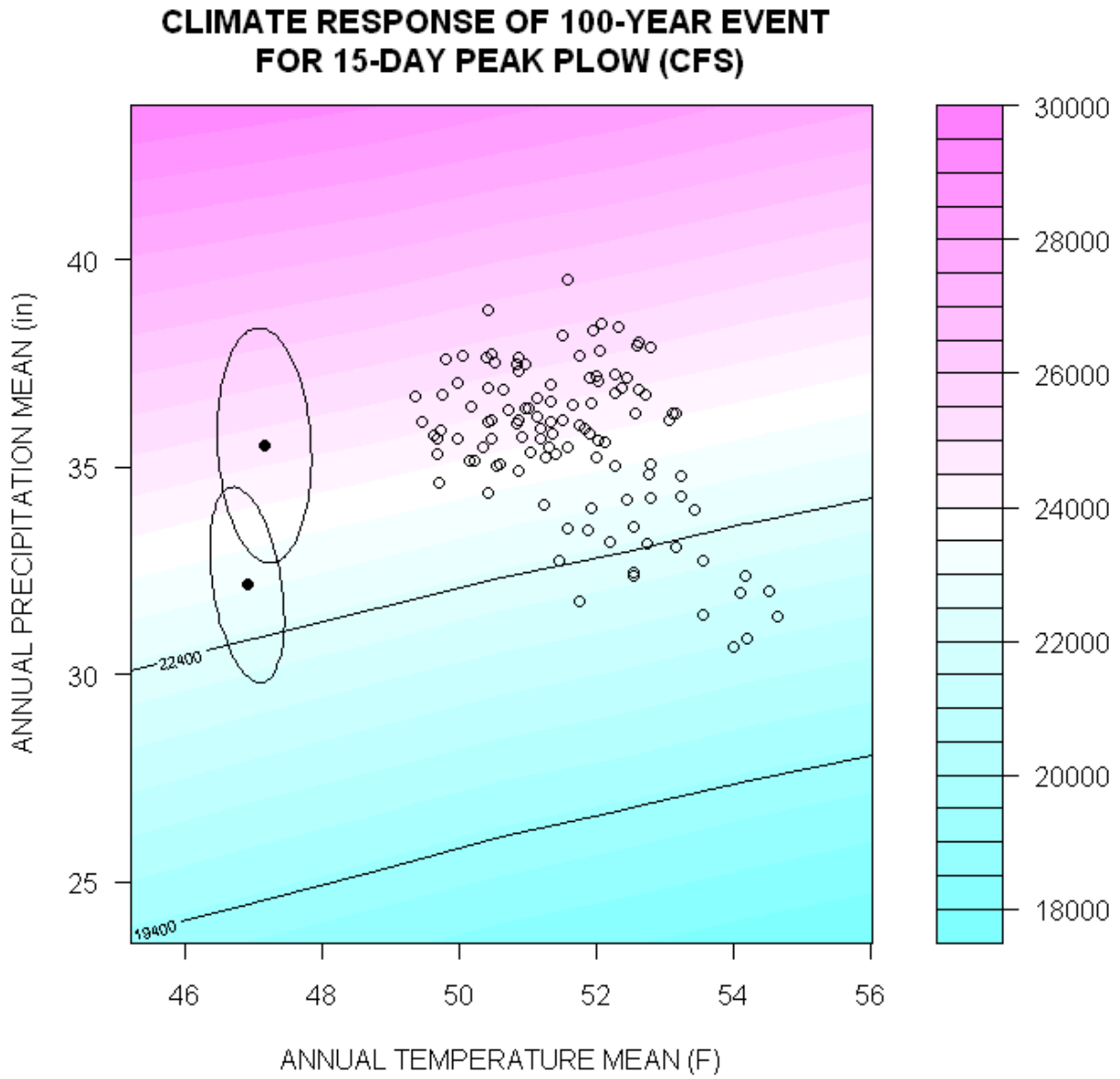
Generate hypothetical climates



Defined by Stakeholder / Decision makers

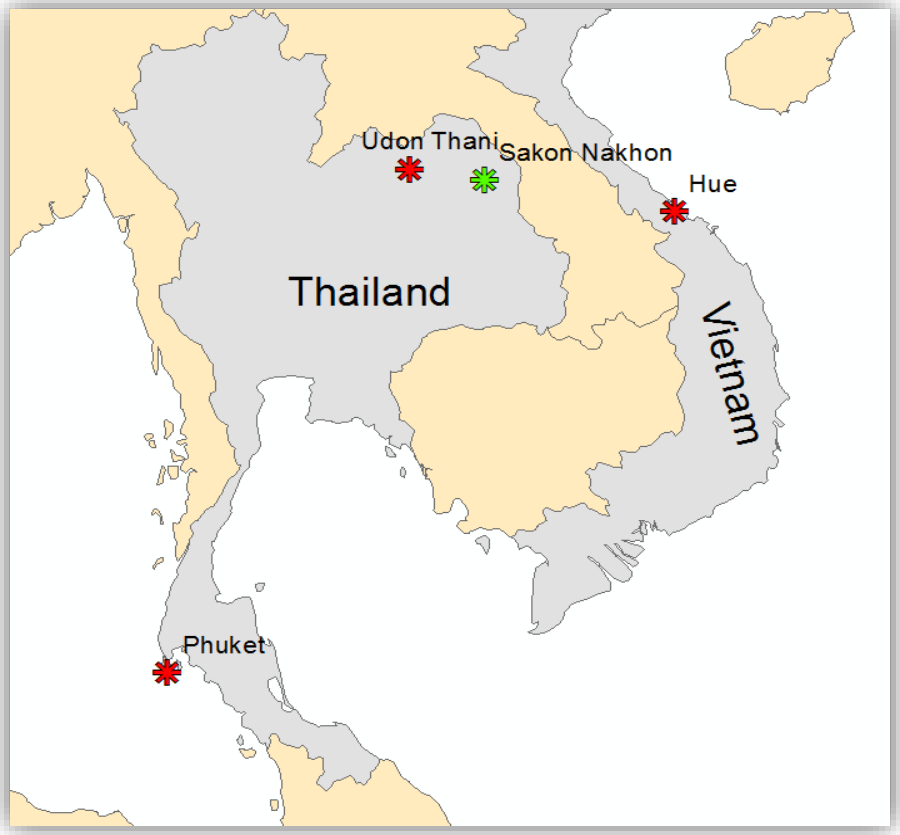
Each pixel is an artificial climate generated time series

Analyze Risks



Pilots for AGWA Strategy

- **Udon Thani, Thailand**
  - Urban development strategies
- **Phuket Island, Thailand**
  - Water security and coordination
- **Hue, Vietnam**
  - Flood Risk Management
- **Nam Kam-Xebangfai-Xebanghieng Mekong sub-basins**
  - IWRM planning
- **Selenge / Tui basins, Mongolia**
  - IWRM planning



"It is change, continuing change, inevitable change, that is the dominant factor in society today. No sensible decision can be made any longer without taking into account not only the world as it is, but the world as it will be."

- Sir Isaac Asimov, 1981

Questions

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Thanks to Dr Kate White for assistance in preparing this discussion