Interactions and Adaptations of Natural and Constructed Elements of Water Resources Systems

20 May 2014

Kristin Gilroy, PhD
U.S. Army Corps of Engineers,
Institute for Water Resources
What is the goal of water management?
Connections between Water Management and Ecosystems

Natural Low Flow
- Fish have adequate oxygen and can move up- or downstream to feed
- Riparian vegetation sustained by shallow groundwater table
- Insects feed on organic material carried downstream
- Birds supported by healthy riparian vegetation and aquatic prey

Natural Flood
- Fish are able to feed and spawn in floodplain areas
- Riparian plant seeds germinate on flood-deposited sediments
- Insects emerge from water to complete their lifecycle
- Wading birds and waterfowl feed on fish and plants in shallow flooded areas

Inadequate Low Flow
- Fish are overcrowded in poor-quality water, cannot move to other feeding areas
- Riparian plants wilt when ground water table drops too low
- Insects suffer when water levels rise and fall erratically
- Birds unable to feed, rest, or breed in tree canopy

Absence of Flood
- Fish unable to access floodplain for spawning and feeding
- Riparian vegetation encroaches into river channel
- Insect habitats smothered by silt and sand
- Many birds cannot use riparian areas when plant species change
Connections between Water Management and Ecosystems

How do we manage water to meet economic, societal, and environmental needs?
The Water Scarcity Index is a measure of the proportion of water withdrawal in relation to water available to human use.

Global Trends 2030: Alternative Worlds by the National Intelligence Council, 2012
Cost-Benefit Analysis for Flood Risk Management Design
Uncertainty in Climate Change Impact Analysis

- Greenhouse gas emissions
- Greenhouse gas concentration
- Global climate
- Regional climate
- Regional climate impact
- Regional measures for mitigation

GCM

Down-scaling

Runoff model

Range of uncertainty
Future Global Water Scarcity

How do we manage water to meet economic, societal, and environmental needs?

...with added uncertainty of climate change?
Presentation Goals

• Incorporating environment into water management
  - Using water infrastructure to restore ecosystems
  - Using natural systems to support engineering objectives

• Addressing climate change adaptation
Environmental Flows -- the flows of water in a river that sustain healthy ecosystems and the goods and services that humans derive from them (SRP)
# Environmental Flow Recommendations

**Savannah River, USA (below Thurmond Dam)**

## Floods

<table>
<thead>
<tr>
<th>Flow Type</th>
<th>Flow Rate</th>
<th>Details</th>
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| Floods    | 50,000-70,000 cfs; 2 weeks, avg every 2 yrs | Maintain channel habitats  
- Create floodplain topographic relief  
- Provide fish access to the floodplain  
- Control invasive species  
- Maintain wetlands and fill oxbows and sloughs  
- Enhance nutrient cycling & improve water clarity  
- Disperse tree seeds |

## High Flow Pulses

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<tr>
<th>Flow Rate</th>
<th>Details</th>
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| >30,000 cfs; 5 pulses, >2 days with 2 events of 2 week duration (March and early April) | Purposes:  
- Provide predator-free habitat for birds  
- Disperse tree seeds  
- Transport fish larvae  
- Flush woody debris from floodplain to channel  
- Floodplain access for fish  
- Fish passage past NSBLD |

## Low Flows

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<tbody>
<tr>
<td>&gt;8,000 cfs</td>
<td>Larval drift for pelagic spawners</td>
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## Key

- Wet Year
- Avg Year
- Dry Year

## Environmental Flow Recommendations

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| 8,000-12,000 cfs; 2-3 days, 1/month | Purposes:  
- Provide predator-free habitat for birds  
- Disperse tree seeds  
- Transport fish larvae  
- Flush woody debris from floodplain to channel  
- Floodplain access for fish  
- Fish passage past NSBLD |

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| <5,000 cfs | Adequate floodplain drainage  
- Create shallow water habitat for small-bodied fish |

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| 3,000 cfs; 3 successive years every 10-20 years | Purposes:  
- Floodplain tree recruitment |

### Savannah River, USA (below Thurmond Dam)

- **20,000-40,000 cfs; 2-3 days, 1/month**
  - Purposes:  
    - Provide predator-free habitat for birds  
    - Disperse tree seeds  
    - Transport fish larvae  
    - Flush woody debris from floodplain to channel  
    - Floodplain access for fish  
    - Fish passage past NSBLD
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The Everglades

Late 1800’s: Everglades Drainage District
- Climate and topography make region prone to flooding
- First canal system constructed to drain Lake Okeechobee and NE Everglades

1920s-1940s: Natural Disasters
- Hurricanes kill 2400 people and ruin property/agriculture
- Devastating droughts

1950: Central & South Florida Project
- USACE constructed 1,000 miles of levees, 720 miles of canals, 200 water control structures
- Negatively effected timing, quantity, and quality of freshwater flows

1996+: Multiple Restoration Plans
- Comprehensive Everglades Restoration Plan: World’s largest Ecosystem Restoration project
- Restoring natural timing and quantity of freshwater flows and improving water quality
The Everglades: Kissimmee River Restoration Project

Before

After
New York City Water Supply System

- One of the largest unfiltered surface water supply systems in the world
  - 1.3 billion gallons per day
  - 9 million consumers
  - 2,000 square miles of watershed
  - 578 billion gallon storage capacity

- In 1989, EPA's Surface Water Treatment Rule (SWTR), issued under the federal Safe Drinking Water Act, required filtration of surface water to mitigate microbial contamination of drinking water

- New York City estimated construction costs for Catskill/Delaware filtration facilities to be as much as $6 billion with annual operating expenses estimated to be more than $300 million
New York’s Comprehensive Watershed Protection Program

- Protection and Remediation Programs
  - Land management
  - Watershed agricultural program
  - Riparian buffer protection program
  - Non-point source pollution control program

- Comprehensive watershed monitoring network
  - Scientific basis for assessing changes in watershed conditions and water quality
  - Contributes to the ongoing refinement of watershed protection program.

http://www.awra.org/committees/techcom/watershed/pdfs/0203WU.pdf
Hurricane Sandy Recovery

“Natural and nature-based measures are capable of improving the quality and resilience of economic, ecologic, and social systems”

$68 billion in damages
286 fatalities
### Natural and Nature-Based Features for Coastal Risk Reduction and Resilience

#### Dunes and Beaches
- **Benefits/Processes:**
  - Breaking of offshore waves
  - Attenuation of wave energy
  - Slow inland water transfer
  - Increased infiltration
- **Performance Factors:**
  - Berm height and width
  - Beach slope
  - Sediment grain size and supply
  - Dune height, crest, and width
  - Presence of vegetation

#### Vegetated Features
- **Benefits/Processes:**
  - Breaking of offshore waves
  - Attenuation of wave energy
  - Slow inland water transfer
- **Performance Factors:**
  - Marsh, wetland, or SAV elevation and continuity
  - Vegetation type and density

#### Oyster and Coral Reefs
- **Benefits/Processes:**
  - Breaking of offshore waves
  - Attenuation of wave energy
  - Slow inland water transfer
- **Performance Factors:**
  - Reef width, elevation, and roughness

#### Barrier Islands
- **Benefits/Processes:**
  - Wave attenuation and/or dissipation
  - Sediment stabilization
- **Performance Factors:**
  - Island elevation, length, and width
  - Land cover
  - Breach susceptibility
  - Proximity to mainland shore

#### Maritime Forests/Shrub Communities
- **Benefits/Processes:**
  - Wave attenuation and/or dissipation
  - Shoreline erosion stabilization
  - Soil retention
- **Performance Factors:**
  - Vegetation height and density
  - Forest dimension
  - Sediment composition
  - Platform elevation
Presentation Goals

- Incorporating environment into water management
  - Using water infrastructure to restore ecosystems
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- Addressing climate change adaptation
Cost-Benefit Analysis for Flood Risk Management Design

1. Hydrology
   - Discharge (Q) vs. Stage (H, channel)
   - Exceedence Probability (p)

2. Hydraulics
   - Discharge (Q) vs. Stage (H, floodplain)
   - EAD = \int D(p)dp

3. Geotechnical
   - Typical Levee
   - Stage, H, channel vs. Probability of Failure, (%)

4. Economics
   - Damage (D) vs. Stage (H, floodplain)
   - Exceedence Probability (p)

Source: Adapted from Moser (1997)
Climate Change Adaptation: Buying Down Risk

All stakeholders contribute to reducing risk!
Climate Change Adaption

Confidence in Data

Nonstructural and Policy Solutions

Traditional Cost-Benefit Analysis/Return Period Design

Incremental Cost Analyses

Structural Solutions

Consequences
Conclusions

WATER RESOURCES MANAGEMENT GOALS

- Support Development
- Balance Economic, Societal, and Environmental Needs

Eco-Engineering/ Hybrid Engineering

- Policy Development
- Structural Solutions

CLIMATE CHANGE

Build Robustness into Systems
Future Challenges

• Balancing environmental, societal, and economic needs
  – Evaluating the trade-offs between the three sectors
  – Understanding long term environmental effects

• Defining the natural system
  – Most aquatic systems are already managed
  – Some change is natural, which change is man-made?

• Climate Change
  – Decision-making under uncertainty. How far in future do we plan for?
  – How do we determine how climate change will effect ecosystems?

• Communication
  – Between stakeholders, scientists, engineers, and policy makers

• Policy Reform
  – Authority to implement ecohydrology and eco-engineering projects
Thank you for your time!

This computer-generated pictorial shows how the wetland expansion would impact Manhattan. These wetlands will mitigate flooding and absorb storm surges (NYTimes)