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Session B1: Lessons Learned from Tropical Storm Irene 2.0: How Flood Resiliency Benefits of Stream Simulation Designs Are Changing Policy within the U.S.

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Lessons Learned from Tropical Storm Irene in Vermont 2.0: How Flood Resiliency Benefits of Stream Simulation Designs Are Changing Policy within the U.S.

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Outline

- Background: Culverts, Aquatic Organism Passage and Flood Damage
- Tropical Storm Irene – Impacts and Lessons Learned
- Linking Flood Resiliency and Societal Benefit to Aquatic Organism Passage
- Policy Implications

Typical Barriers to Aquatic Organism Passage on U.S. National Forest Lands

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Caring for the land and serving people

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Undersized Culverts = Flood Damage

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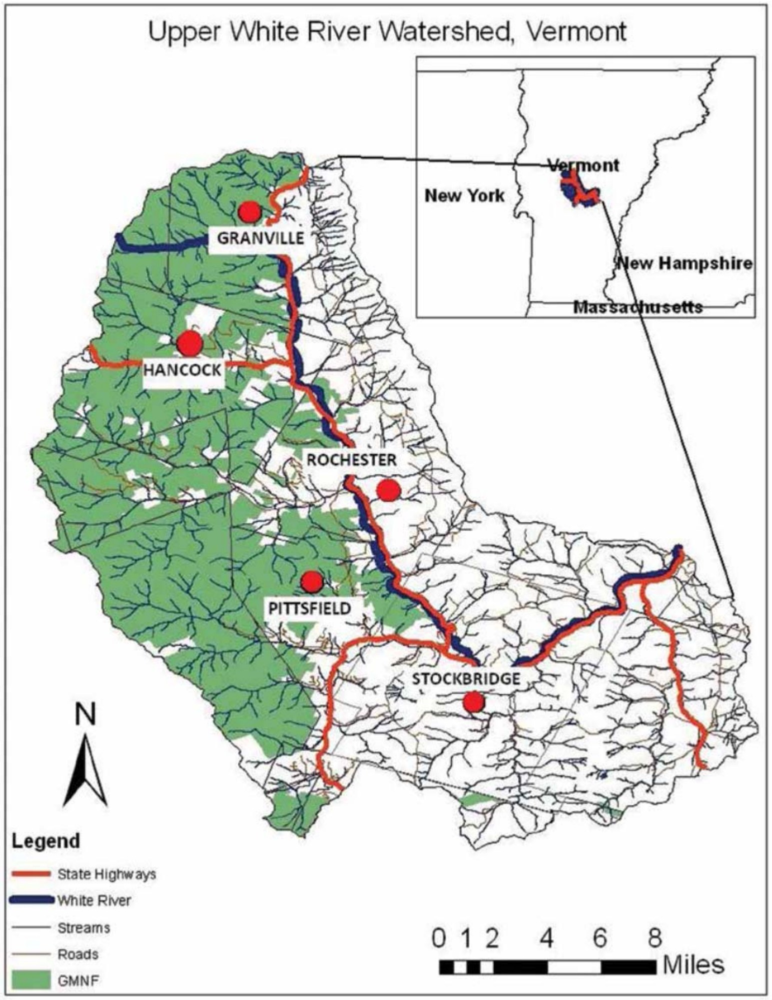
Case Study approach: Upper White River Watershed

- Green Mountain National Forest represents 40% of the Upper White River Watershed.
- 70% of damages caused by debris plugging culverts.
- Substantially more damages within the 5 towns.
- Interviewed town leaders and road engineers.



How and Why Road-Stream Crossings Fail

How Structures Fail

- Hydraulic capacity exceeded
- Sediment “Slug”
- Debris flow (wood, etc.)

Why Structures Fail

- Undersized hydraulic capacity
- Abrupt transitions
- Poor vertical alignment with channel
- Poor stream to structure geometry
- Poor geomorphic location/design not account for diversion potential

Sediment “Slug”

Woody Debris

Stream Simulation Designs Proved Resilient

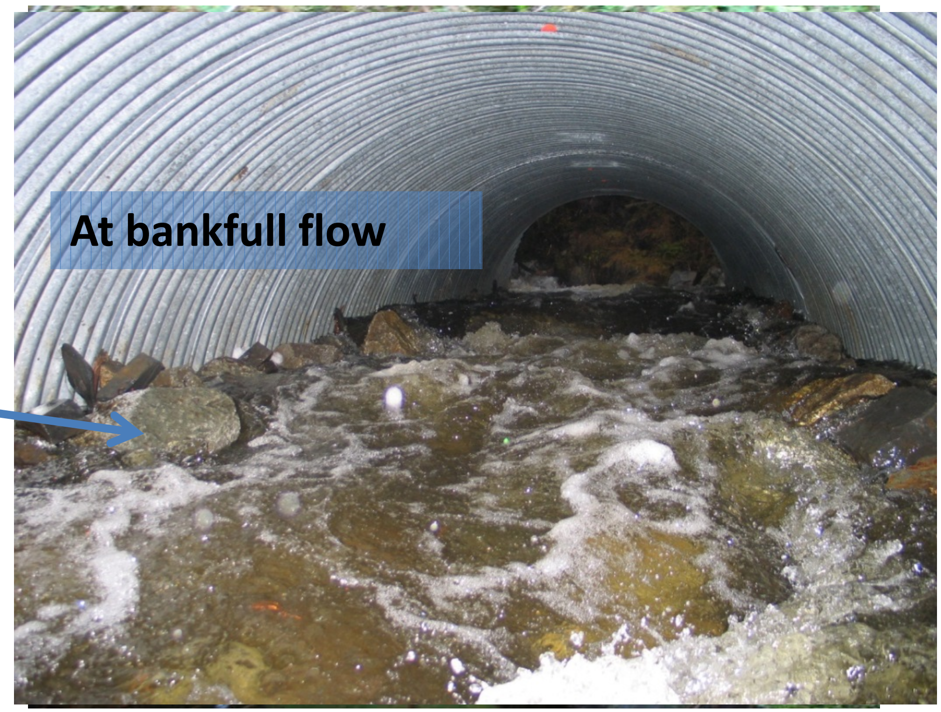
- 24 Forest Service System Roads (40 km)
- Estimates repair costs = $6.4+ million
- 11 stream crossing failures
- No stream simulation design failures (3)

Typical Post TS Irene Culvert Failure
Non-Stream Simulation Design

Typical Post TS Irene Culvert Success
Stream Simulation Design

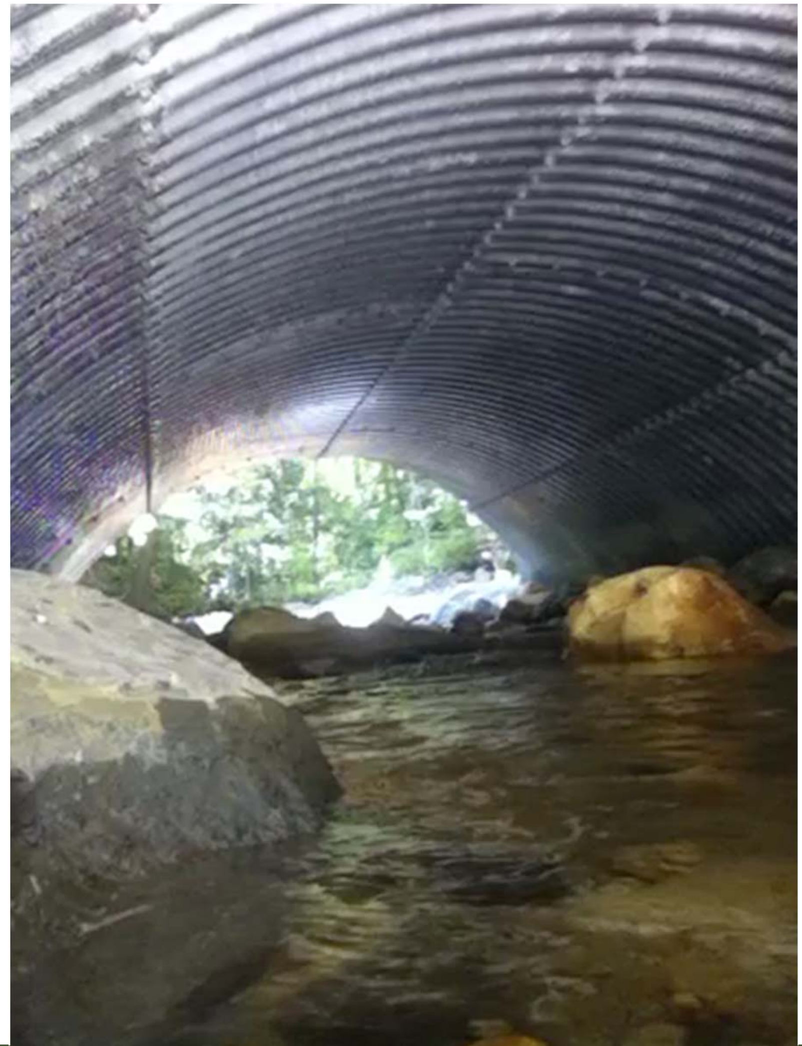
Stream Simulation Design Principles

- Combines engineering, geomorphic and ecological analyses
- 100+ Recurrence Interval with freeboard or room for debris
- Mimics natural channel structure, sediment characteristics, water velocity & depths, and resting areas for aquatic organisms



Analytically Driven Stream Simulation Design

Design the channel considering geomorphic risk, long term channel changes, and engineering constraints then build the structure around it. The reference reach provides the standards.

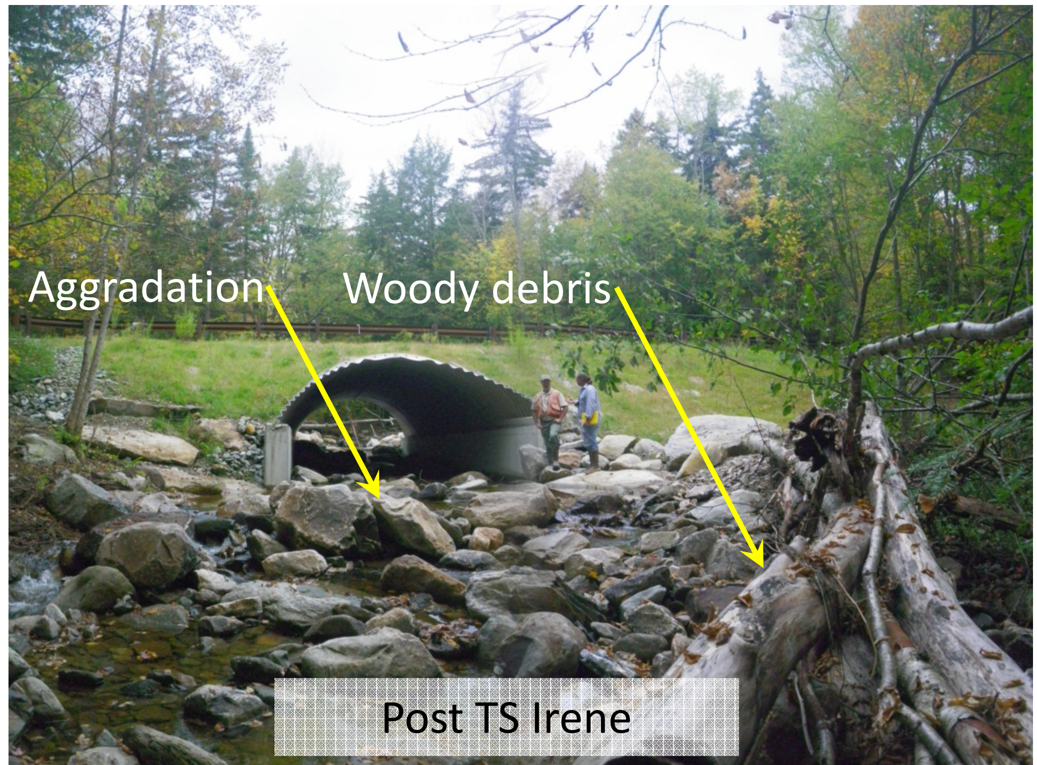


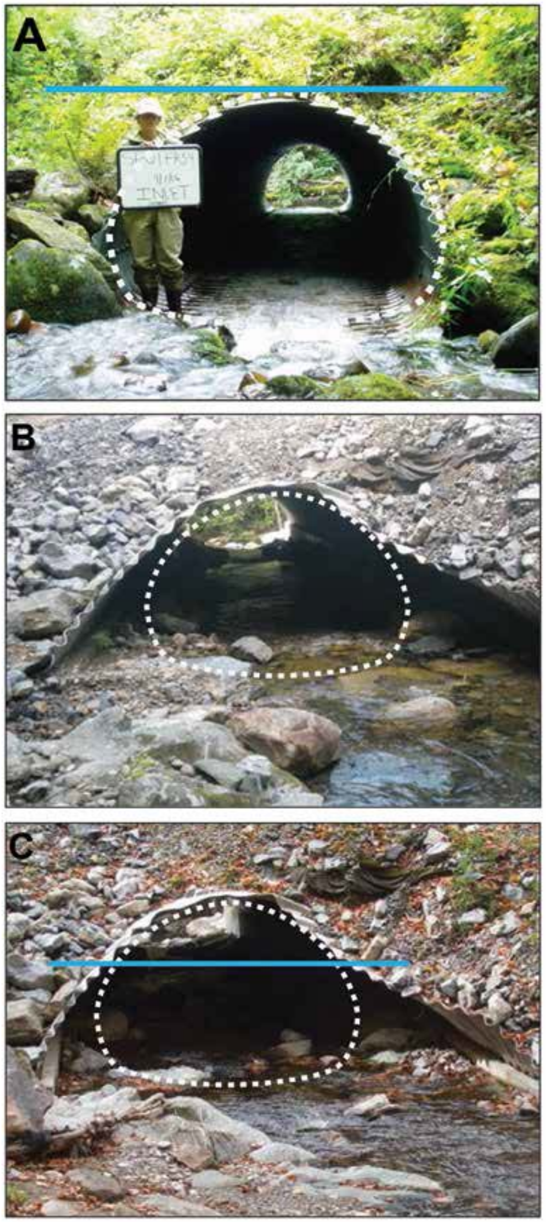
<u>Geomorphic Risks Analysis</u>

- ✓ **Channel Stability**
- ✓ **Vertical Adjustment Potential**
- ✓ **Headcut Potential**
- ✓ **Lateral Migration Potential**
- ✓ **Floodplain Conveyance /connectivity**

Jenny Coolidge Brook Stream Simulation Design

Forest Road 17A over
Jenny Coolidge Brook





Sparks Brook Stream Simulation Design

Original Q25 Hydraulic Design

Stream Simulation Design with >Q100 Design

Height of Tropical Storm Irene Flood Level

The Link between Aquatic Organism Passage (AOP) and Flood Resiliency

- Of 43 Road-Stream Crossings identified by Vermont FWD as barriers to fish movement in Upper White River Watershed, 15 failed. Average bankfull width/culvert width ratio of 0.54.

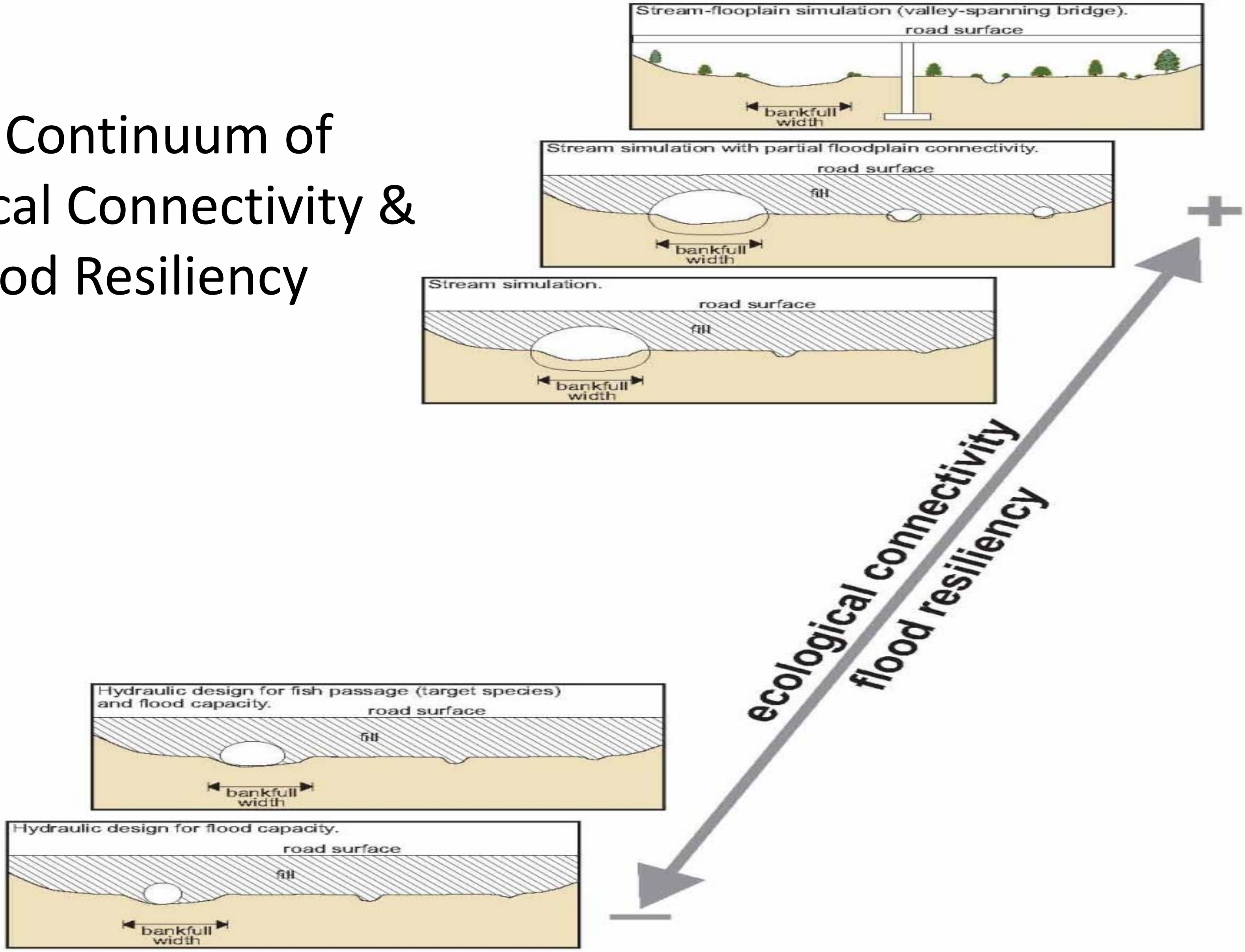
- VT FWD inventoried 43 culverts >2.3 m bankfull width for fish passage in watershed, 15 failed.
- These 15 failed culverts provided reduced or no aquatic passage.
- Of the failed culverts, ratio of culvert width to bankfull width averaged 0.54, ranging from 0.27 to 0.90.

Other Examples of Flood Resiliency of Stream Simulation Designs

- **<u>Tongass National Forest in Alaska</u>**: Of 93 crossings installed for AOP since 1998, 98% provide fish passage to State Standards, NO failures with floods estimated in 25 to 50 year recurrence interval

- **<u>Siuslaw National Forest in Oregon</u>**: 8 crossings installed for AOP since 2003 have survived 25 year recurrence interval floods with no damage.

The Continuum of Ecological Connectivity & Flood Resiliency



Recommendations and Lessons Learned

- Prioritize upgrades for AOP that have multiple benefits – high ecological gain and roads with high social significance (high volume traffic, major commuting delays, provision of emergency services, high cost from failure)
- Work with FEMA and other federal funding sources for greater flexibility in helping meet the match requirement through investment in more flood resilient crossing designs
- Support long-term sustainability by expanding the time scale of analysis – Move from year 0 to 50 to 75 years
- Expand multi-disciplinary workshops targeting federal, state and local designers, engineers and decision-makers

In the Context of Climate Change- How to Best Evaluate the Avoidance of Catastrophic Failure?

Floods of 96 and 97

Cost Comparison

- Green Mountain National Forest examples demonstrate real costs for upgrading to Stream Simulation Design Standards ranged from 9-22% above conventional hydraulic design
- Similar data suggest that a 50% increase in structure width results in 20% to 33% increase in total project cost (Gubernick 2011) from across U.S. Forest Service Lands
- Most cost comparisons are made a Year 0, not extended out to the 50-75 year time frame.

True Life Cycle Cost Analyses

- A culvert failure can result in significant costs to state/towns including replacement costs and other damaged infrastructure.
- Emergency replacement costs are generally higher than normal replacement costs*
- Temporary or long term loss of emergency services, business or recreational access need consideration*
- If a culvert remains undersized, these costs may be incurred multiple times during its life cycle*
- Maintenance costs over time to remove debris, repair erosion, protect headwall, etc. need consideration.

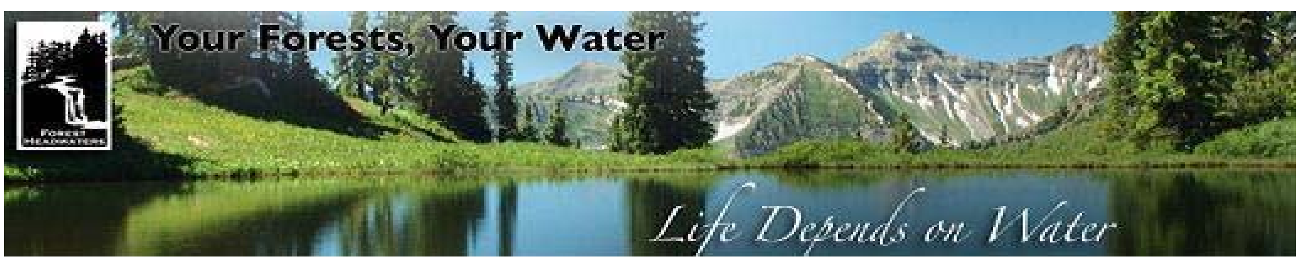
*Source: Perrin Jr., J and C. Jhaveri. "The Economic Costs of Culvert Failures." Jan 2004.

A New Dialogue in "Fish Passage" Social and Economic Benefits

- To the extent that we can quantify costs and benefits of a given investment in economic terms, we can build a better understanding of the true implications of our actions (or inactions) in a climate resiliency-based context.
- The link has been made successfully been AOP and flood resilience across a number of New England and Midwestern and Pacific Northwestern States.

Investments in Ecosystem Services: Denver Forests to Faucets

- Improve watershed conditions through proactive forest management
- $16.5 million/year over 5 years between the Denver Water Utility and USFS
- Projects in the Upper South Platte headwaters to enhance resiliency to wildfire



Expanding Research into Risk and Ecosystem Service Analyses

- The Nature Conservancy Report on New York from Tropical Storm Irene and Lee (2013. Levine, J. *An Economic Analysis of Road-Stream Crossings.)*
- Massachusetts Division of Ecological Restoration Report (2015, Baker et al. *Economic and Community Benefits of Stream Barrier Removal Projects in Massachusetts).*
- Ongoing FS research about survival and failure of culverts from Hurricane Sandy 2013, particularly examining risk associated with culvert diameter vs. bankfull width & location of culvert and valley slope

Changes in Policy Standards

- Several states have begun changes to state standards in the wetlands and water quality regulations for AOP for road-stream crossings to increase conveyance capacity of culverts, e.g. MA, VT, NY
- The Federal Highway Transportation Bill has language about flood resiliency, climate change and fish passage.
- President Obama’s 2013 Executive Order: “Preparing the United States for the Impacts of Climate Change”
  - To improve the resilience of communities and federal assets to the impacts of flooding. "Where possible, an agency shall use natural systems, ecosystem processes, and nature-based approaches when developing alternatives for consideration."

Changes in Leveraged Funding

- New York's Lake Champlain Basin: Focus by the Adirondack Chapter The Nature Conservancy (TNC) has raised $850,000 in public and private grant funding for upgrading 5-7 high priority culverts for flood resiliency and fish passage.
- In 2014, State of Maine passed a "Clean Waters and Safe Communities Act" providing $5.4 million for culvert upgrades. TNC has assessed 15,000 culverts across state.
- In Massachusetts, Vermont and New Hampshire, American Rivers, TNC, and Trout Unlimited have surveyed 1000's of culverts, and using this to prioritize culverts – key to working with local and state road and highway departments.


Questions?