The Rise of Dam Removal in New England

Dam Busters 201

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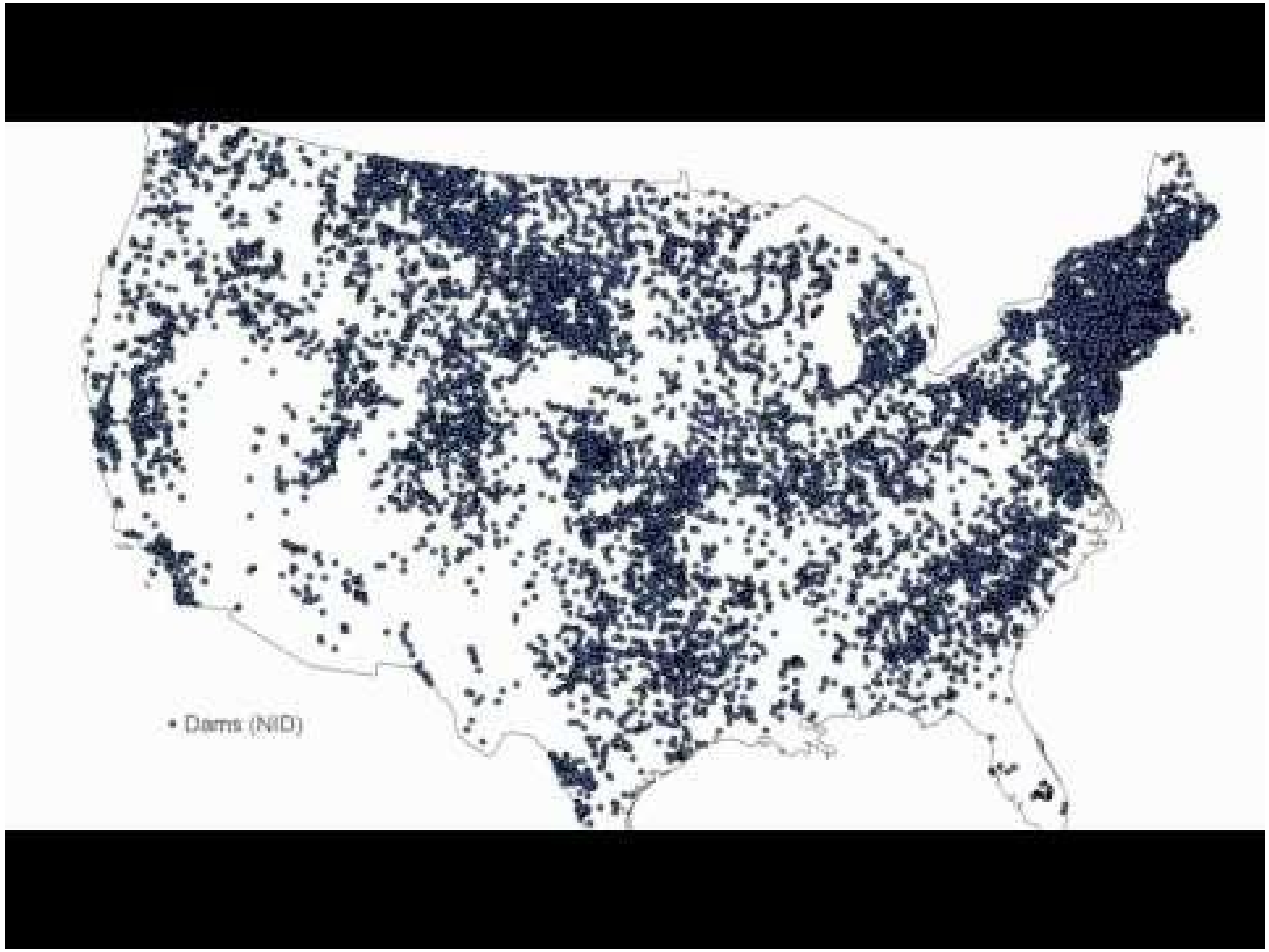
Earth and Environmental Sciences

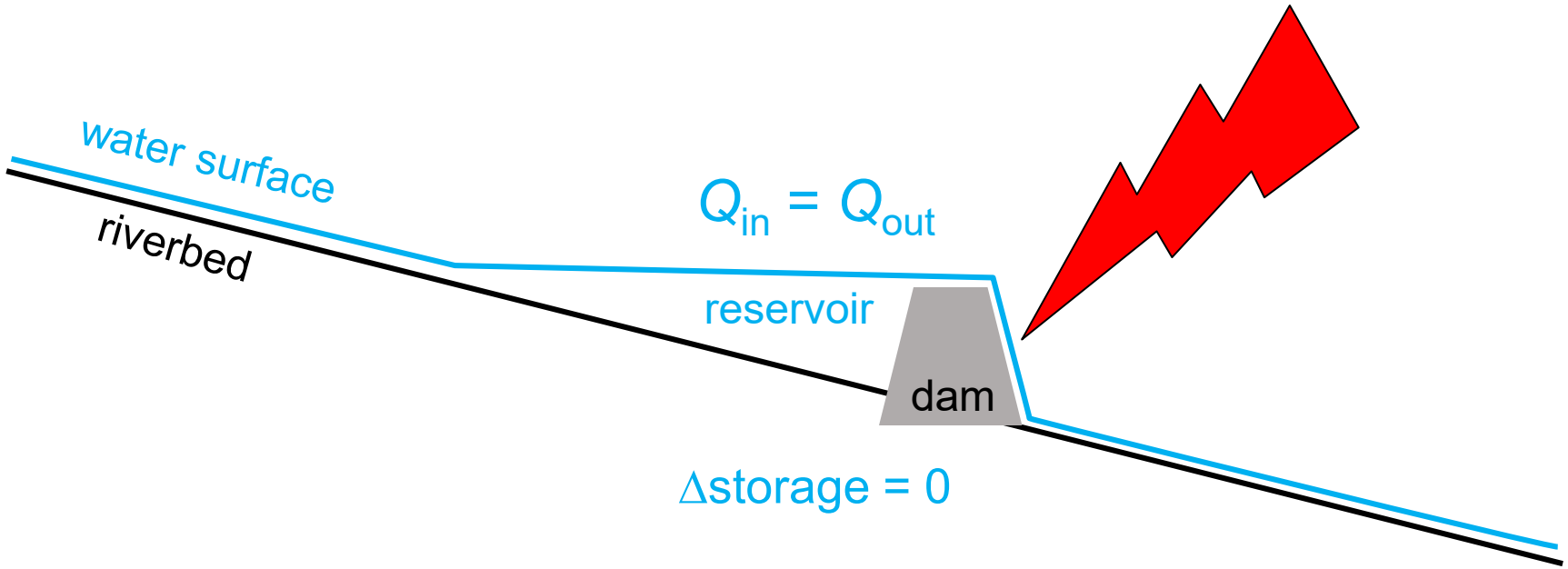
The Rise of Dam Removal in New England

- Primer on dams and sedimentation in reservoirs
- History of dam removal in New England; local examples; dam removal as a stream restoration activity
- What we have learned from 10 years of studying the removal of the Merrimack Village Dam on the Souhegan River, NH?



Dam construction in the U.S., 1800-2003 (Syvitski, 2011)

Run-of-the-river dams



Examples:

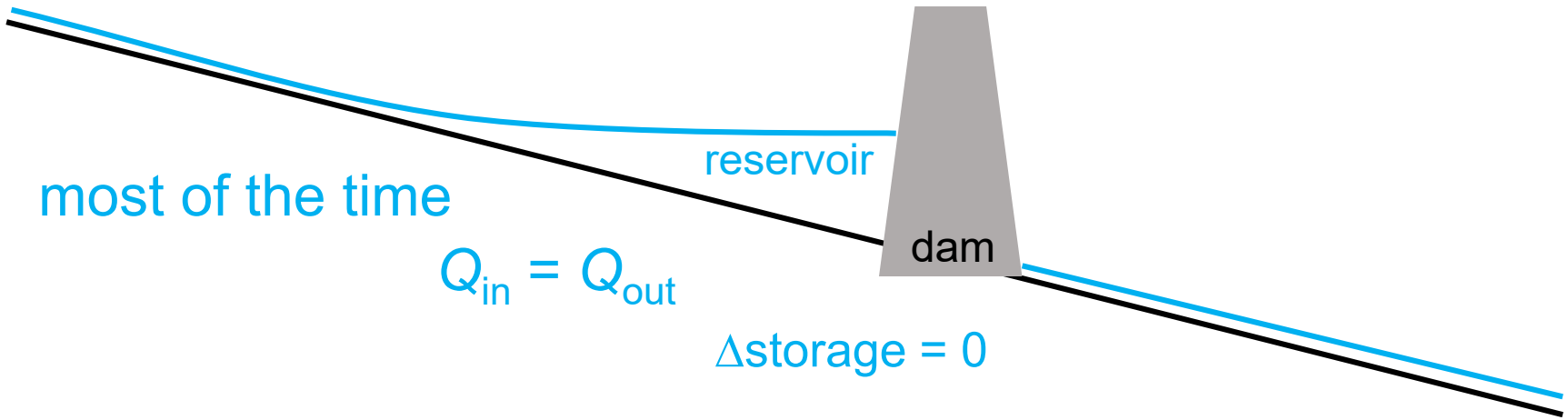
- small dams
- some water supply
- hydropower
- most dams in New England

Jerrey Roberts, Daily Hampshire Gazette, March 19, 2018

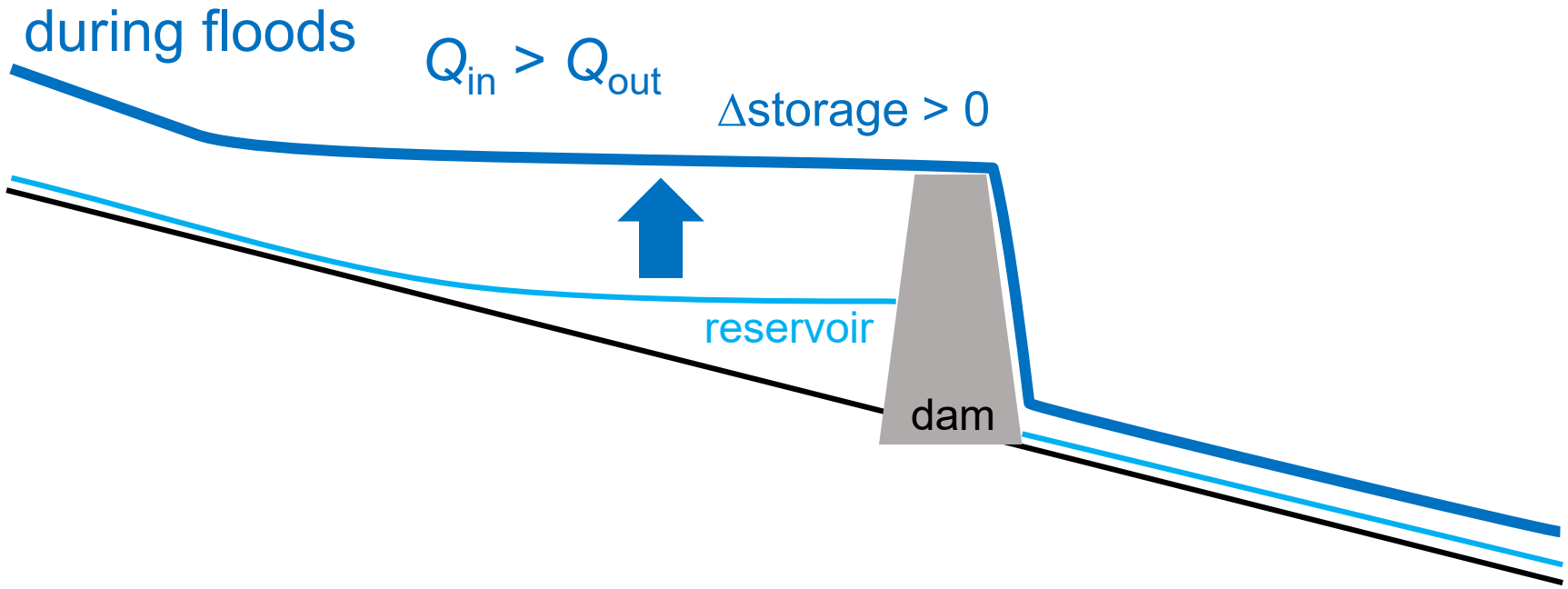
Run-of-the-river dam:
Upper Bondsville Dam, Swift River, MA

1868 from the South Hadley Historical Society

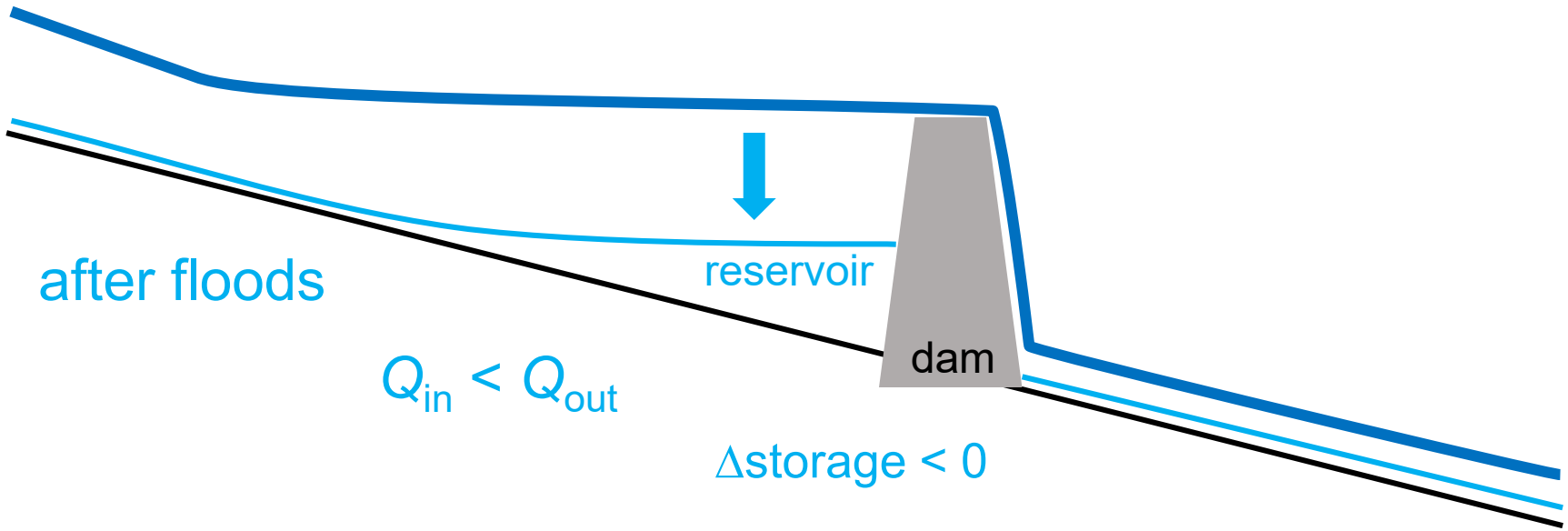
Flood-detention reservoirs



Flood-detention reservoirs



Flood-detention reservoirs



Summary:

- empty until filled with flood water
- mostly run-of-the-river

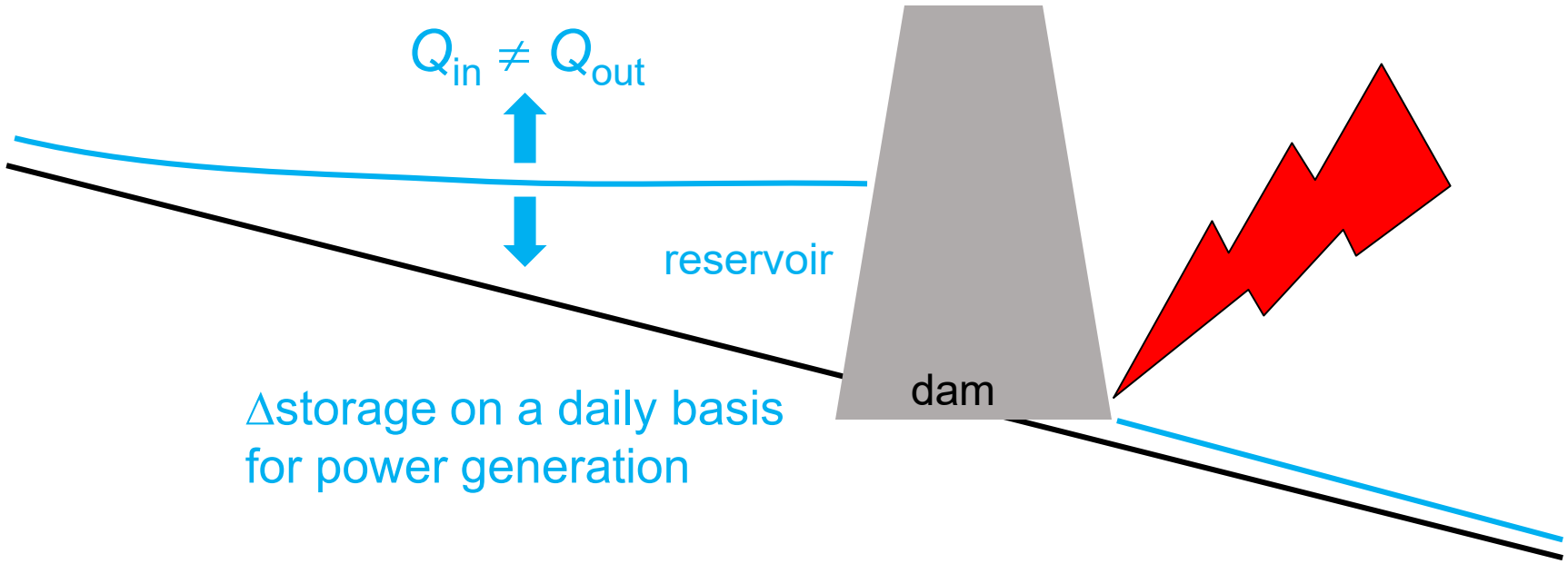
Examples:

- Dams on the Connecticut and Merrimack Rivers
  - US Army Corps of Engineers

Flood control dam:
Tully Lake, MA
(USACE)

Flood control dam:
Ball Mountain Lake,
West River, VT
(USACE, 1999)

Multi-purpose storage reservoirs



Summary:

- store water for supply, power generation
- keep space for flood storage
- requires forecasting of floods and droughts
  - seasonal effects (snowmelt)

Examples:

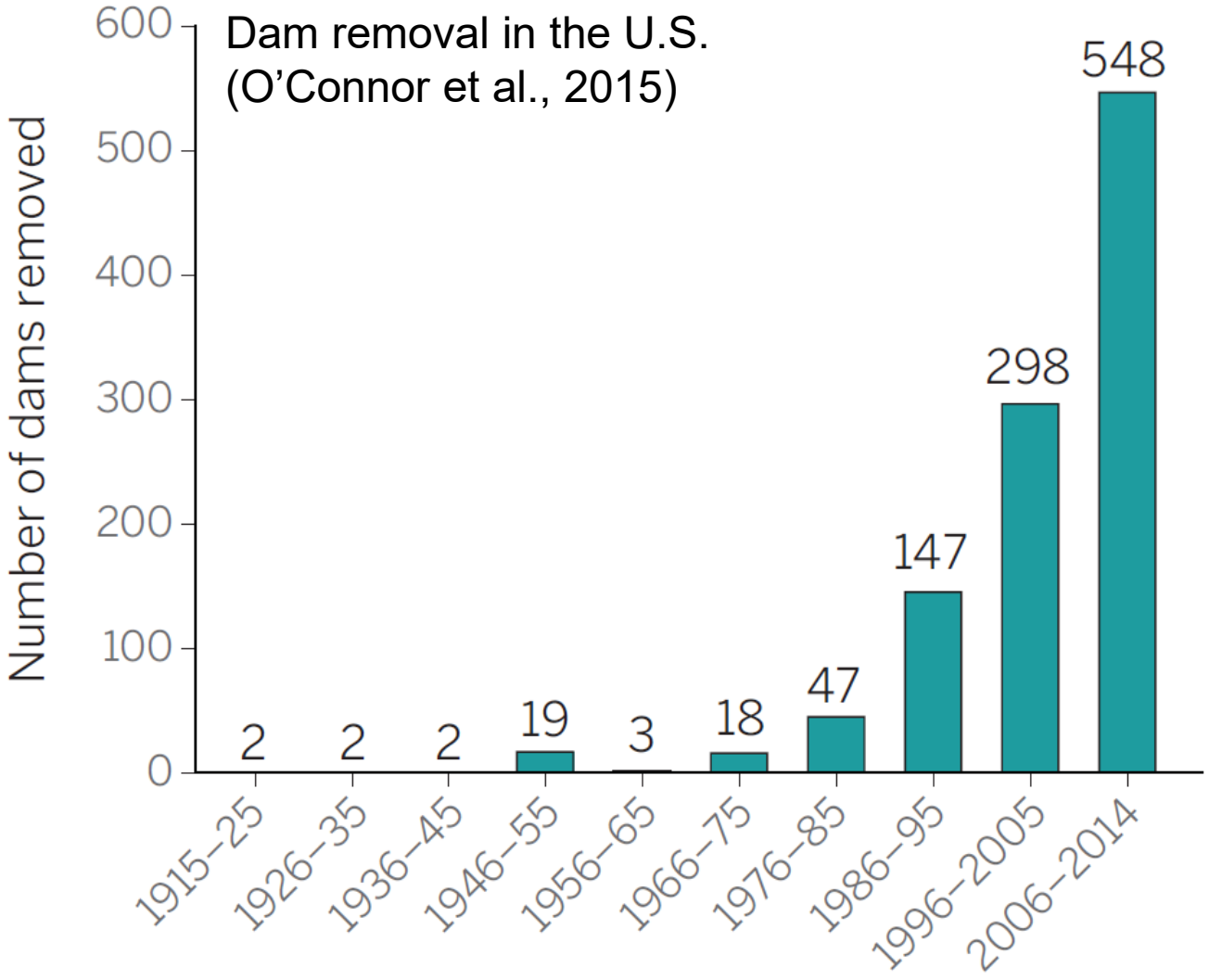
- Quabbin Reservoir, MA
- Big dams in the western US (e.g., Hoover Dam, Glen Canyon Dam)
  - US Army Corps of Engineers, Bureau of Reclamation
- Three Gorges Dam, China

Quabbin Reservoir and Winsor Dam, Swift River, MA, 1946 (massmoments.org)
170 ft (52 m) high, 412 billion gallons of water storage (1.56 km^3)

Glen Canyon Dam, Colorado River, AZ/UT
316 m tall, 32 km^3 of storage, 1300 MW power generation

Some motivations for dam removal

- Public safety
- Owner liability
- Maintenance expense
- Stream restoration
- Fish passage
- Research opportunity: river response to a change in sediment load



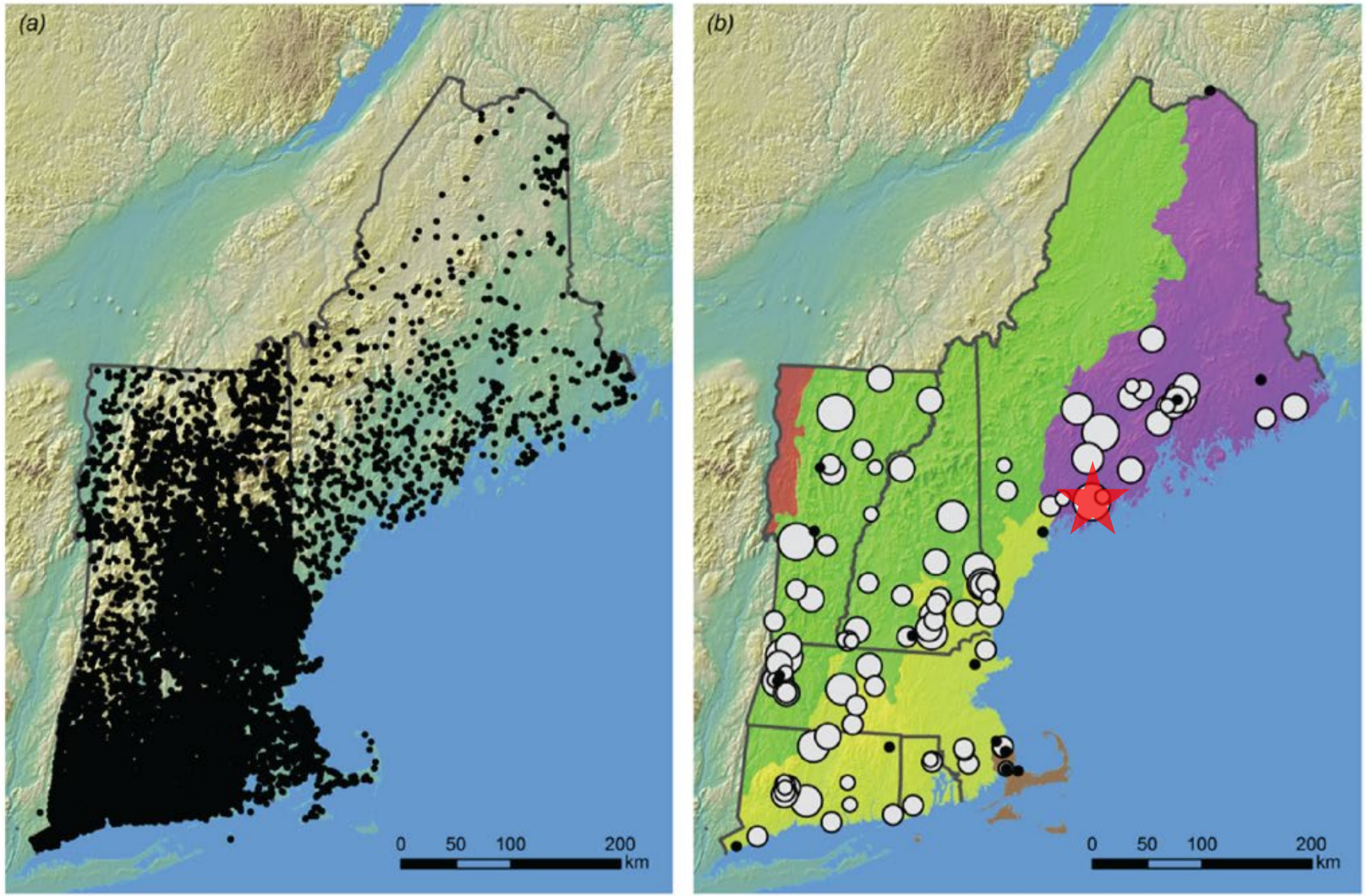


Figure 1

Location map of existing and removed dams.

(A) All dams in New England, (B) Removed dams mapped by height and ecoregion.

doi: 10.12952/journal.elementa.000108.f001

(Magilligan et al., 2016)

ELEMENTA
Science of the Anthropocene

River restoration by dam removal: Enhancing connectivity at watershed scales

F.J. Magilligan[1*] • B.E. Graber[2] • K.H. Nislow[3] • J.W. Chipman[1] • C.S. Sneddon[4] • C.A. Fox[4]

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[2]American Rivers, Northampton, Massachusetts, United States
[3]USDA Forest Service, Northern Research Station, Amherst, Massachusetts, United States
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*magilligan@dartmouth.edu

Edwards Dam removal, Kennebec River, Augusta, Maine, July 1999 (NRCM)

Price $3.00

THE NEW YORKER

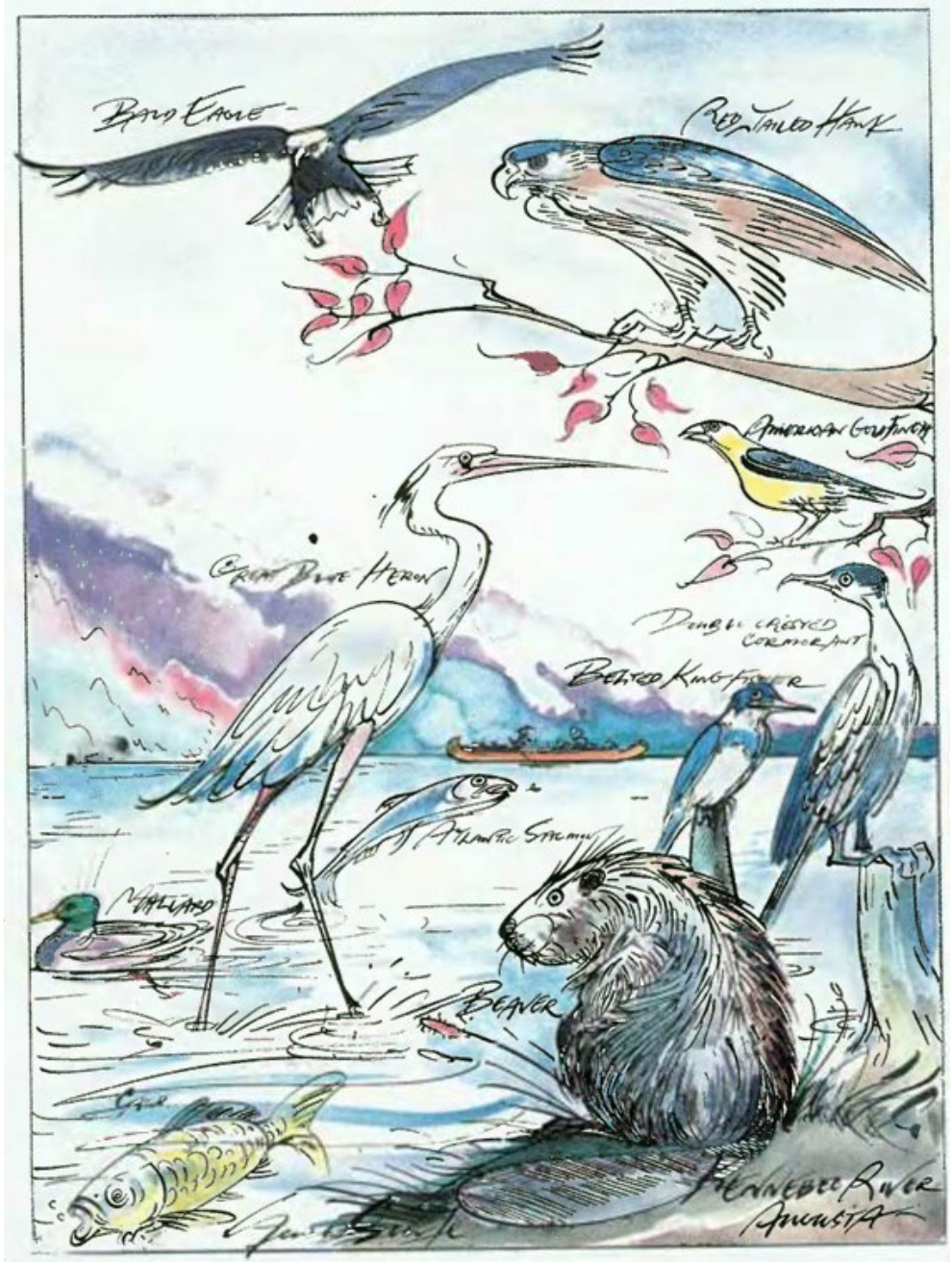
Sept. 27, 1999

THE CONTROL OF NATURE

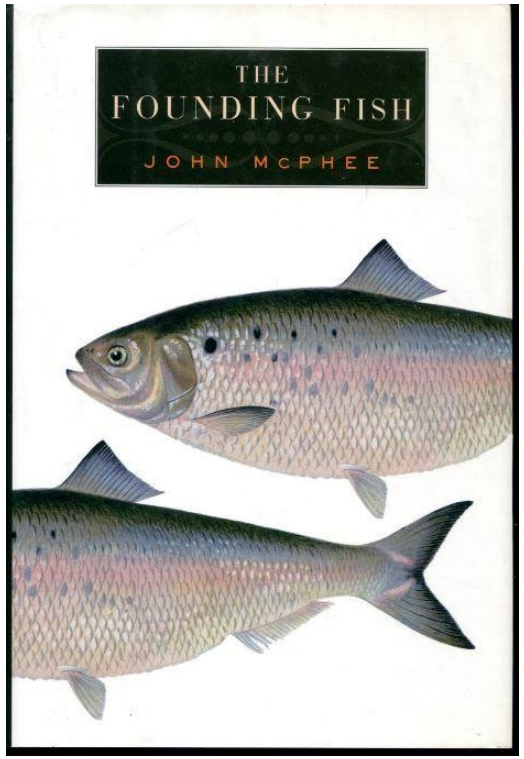
FAREWELL TO THE NINETEENTH CENTURY

The breaching of Edwards Dam.

BY JOHN McPHEE



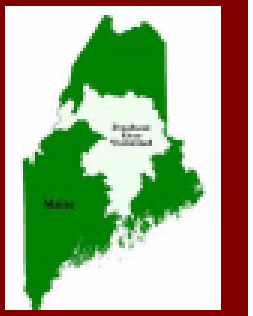
"You're going to look back in years hence and say, 'It all began right here on this riverbank.'"

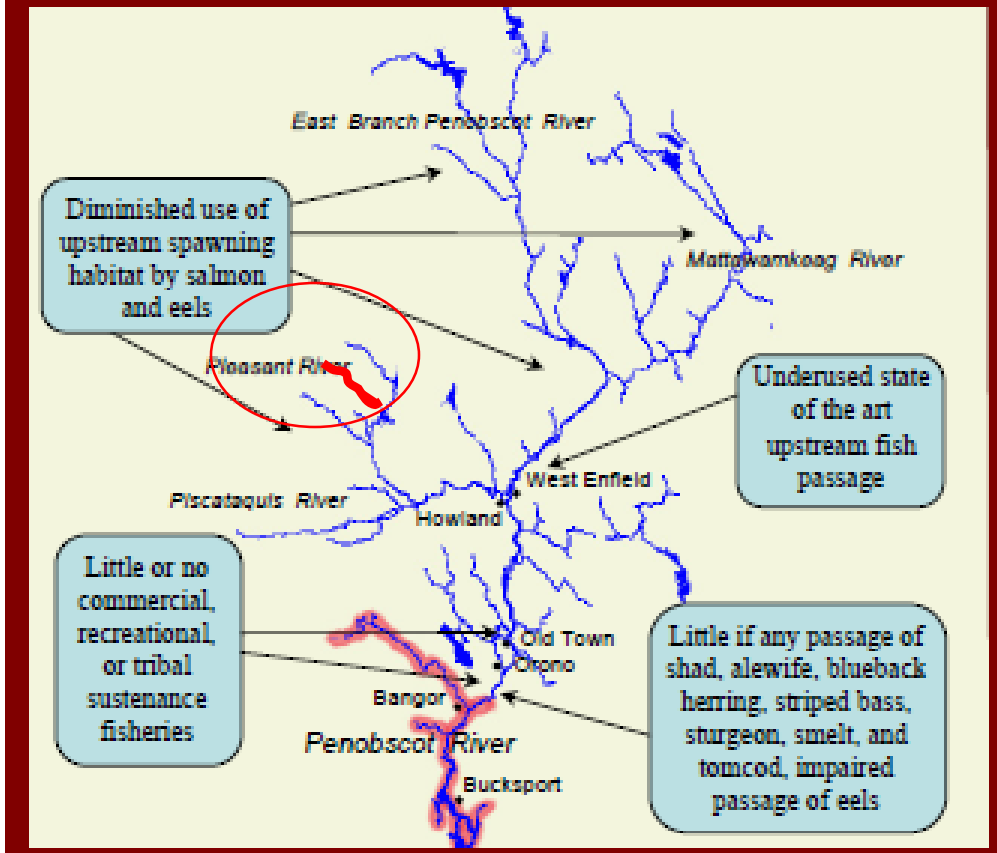


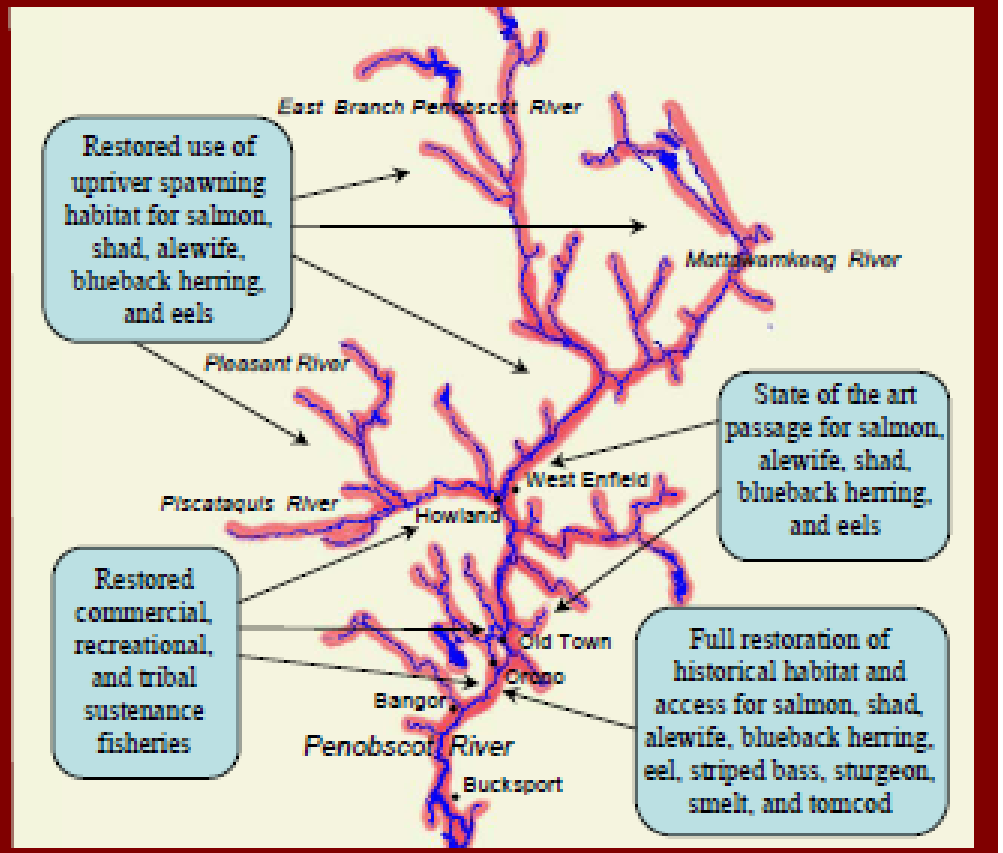
From Friends of the Kennebec Salmon: “On 10 June 2004 we observed a large number blueback herring, a native sea-run fish of the Kennebec River, spawning in Messalonskee Stream in Waterville, Maine. To our knowledge, this is the first documentation of these fish spawning in Messalonskee in nearly two centuries.”

Penobscot River Restoration Project

Before and After Habitat Access







Existing Access for Sea-Run Fish

Significantly Improved Access for Sea-Run Fish to Nearly 1,000 Miles

Source: PRRT/penobscotriver.org

PENOBSCOT RIVER RESTORATION PROJECT

Penobscot River Restoration Accomplishment - Great Works Dam Site

Before and after photos

June 11, 2012

September 7, 2012

Photos by: Monty Rand/Gyro Geo

Partners in the Penobscot River Restoration Project include the Penobscot River Restoration Trust, the Penobscot Indian Nation, American Rivers, Atlantic Salmon Federation, Maine Audubon, Natural Resources Council of Maine, The Nature Conservancy and Trout Unlimited, working with the U.S. Department of Interior, US. Department of Commerce, the State of Maine, PPL Corporation and Black Bear Hydro.

Veazie Dam, Penobscot River, Maine (July 2013)

Breaching of dam, restoring salmon's passage unite many

The Boston Globe

By Alyssa Botelho | GLOBE CORRESPONDENT JULY 23, 2013

JESSICA RINALDI FOR THE GLOBE

Joseph Dana watched from a traditional handmade birch canoe on the Penobscot as the Veazie Dam was breached.

South of Boston, Wary Officials Watch a Weakened Da

By PAM BELLUCK OCT. 19, 2005

The New York Times

BOSTON, Oct. 18 - Some 2,000 residents of Taunton, Mass., were unable to return to their homes on Tuesday because of fears that a deteriorating dam on a rain-swollen river could rupture and flood the city's downtown area.

The residents were evacuated on Monday from a section of Taunton, a city of 50,000 about 40 miles south of Boston. On Tuesday, city and state officials canceled school and closed some roads as they warily watched the 173-year-old wooden dam on Whittenton Pond.

Battered by weekend storms that dumped more than seven inches of rain on Taunton, the 12-foot-high dam had lost some of its timbers and was leaking water "out of places it shouldn't be going," said Peter Judge, a spokesman for the Massachusetts Emergency Management Agency.

Going with the flow, 10 years after Taunton's dam crisis

By Charles Winokoor

Taunton Gazette Staff Reporter

Follow

Posted Oct 18, 2015 at 9:39 PM

Updated Oct 18, 2015 at 9:52 PM

Ten years after a buckling dam and threat of flooding thrust Taunton into the national spotlight, the state has since taken steps to prevent a similar occurrence.

Damage from Tropical Storm Irene still being assessed in Franklin and Berkshire counties

Publis

The Anatomy Of A Dam Failure

October 31, 2011 | Dams & Dam Removal, Restoring Rivers

Amy Singler
Associate Director, River Restoration Program

Parts of the northeast took a beating from Hurricane Irene in late August, and along with road failures, culvert failures, and significant property damage, we also saw a number of dam failures. The flood peaks were so high, that in some cases it was after the flooding subsided that the actual damage was noticeable.

American Rivers staff have seen lots of failed or breached dams in our work and I wanted to address a common concern that is frequently raised about dam integrity.

Failed dam on the Green River in Massachusetts shows the river flowing around the spillway and through the retaining wall breach.

OFFERED BY Division of Ecological Restoration

GUIDE

Deciding to Remove Your Dam

Most dams in Massachusetts have outlived their original purpose and many are in need of costly repairs or removal. Dam owners are increasingly choosing to remove their dams to reduce financial and legal liability and to eliminate the ongoing costs of dam maintenance. The Division of Ecological Restoration (DER) can help interested dam owners understand and evaluate what's involved with a dam removal. DER may also be able help owners remove an unwanted dam if its removal would result in significant environmental and public benefits. Please contact Kris Houle at kris.houle@mass.gov or 617-626-1543 if you would like to learn more about DER's dam removal program or discuss a potential dam removal project.

Amy Singler, associate director of the river restoration program at American Rivers, speaks on the history of the more than 200-year-old timber dam discovered in Amethyst Brook.
(L. Newberry, MassLive, 2014)

Bartlett Rod Shop Company Dam removal, Amethyst Brook, Pelham, MA, November 2012
(Photo by A. Hackman, MA Department of Fish and Game)


Harvard Pond dam, March 2019

Repairs at Belchertown's Upper Bondsville Dam almost complete

DAILY HAMPSHIRE GAZETTE

ELSEVIER

Geoforum

Volume 70, March 2016, Pages 93-104

GEOFORUM

"You kill the dam, you are killing a part of me": Dam removal and the environmental politics of river restoration

Coleen A. Fox [a], Francis J. Magilligan [b], Christopher S. Sneddon [a]

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Received 27 April 2015, Revised 9 February 2016, Accepted 14 February 2016, Available online 26 February 2016.

Athol Daily News

Wendell dam removal among priority projects

Published: 12/7/2018 3:00:16 PM

WENDELL – The Osgood Brook Restoration/Bowen's Pond dam removal is among the 12 river and wetland restoration projects across the Commonwealth will be designated Priority Projects through the Department of Fish and Game's (DFG) Division of Ecological Restoration (DER).

Through this project, the dam will be removed. As a result, wild Eastern brook trout and other species threatened by the effects of climate change will benefit.

Upon receiving designation, Priority Projects are eligible for technical services, including data collection, engineering, design work, permitting, project management and grants.

"Ecological restoration is an important tool for local stakeholders working to protect and preserve rivers and wetlands across the Commonwealth," said Governor Charlie Baker, who made the announcement. "In addition to the assistance provided at the local level, the Priority Project Program assists the state in ensuring that environmental assets are able to adapt to the impacts of climate change."

P. Franz, Greenfield Recorder, 12/13/2018

Stream restoration

Definition: The process of assisting the recovery of an **ecosystem** that has been degraded, damaged, or destroyed.

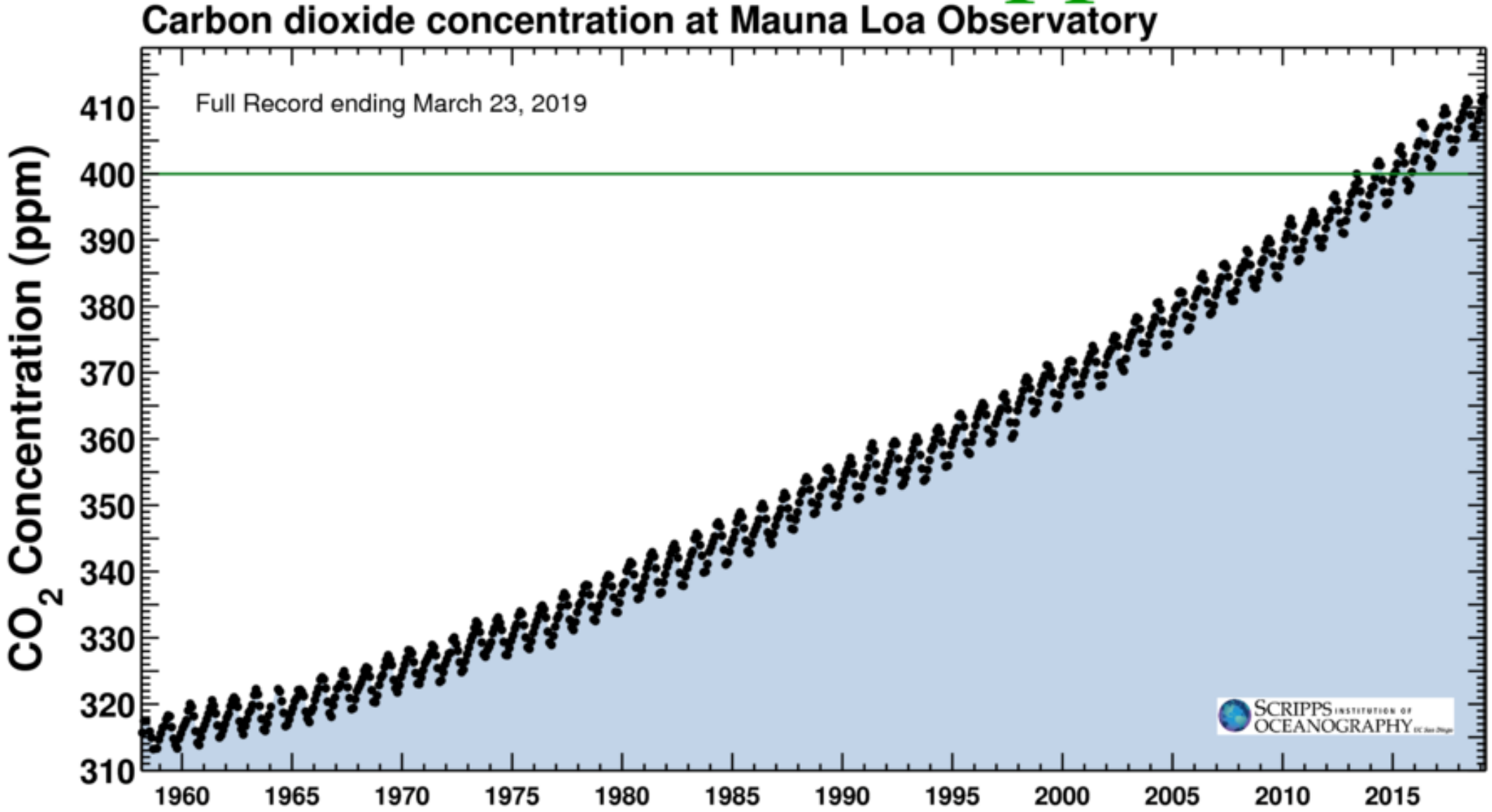
What is the goal of stream restoration?

- Return to pre-disturbance reference conditions
  - ⇨In North America: What did the ecosystem look like prior to European settlement?

- Make the ecosystem resilient to future changes
  - ⇨Acknowledges that pre-European conditions are no longer relevant (urbanization, climate change, invasive species, etc.)

Latest CO_2 reading
March 23, 2019

411.28 ppm



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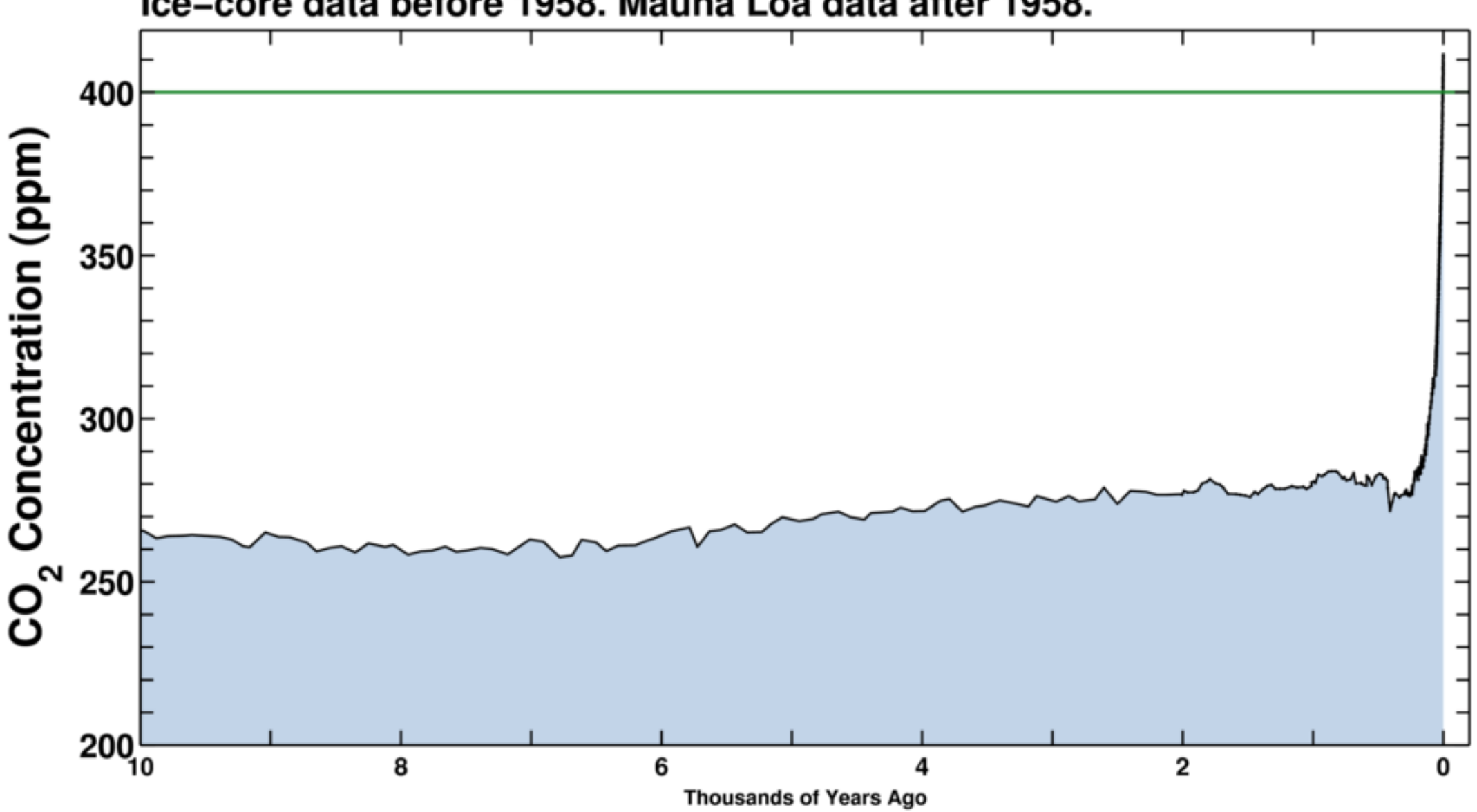
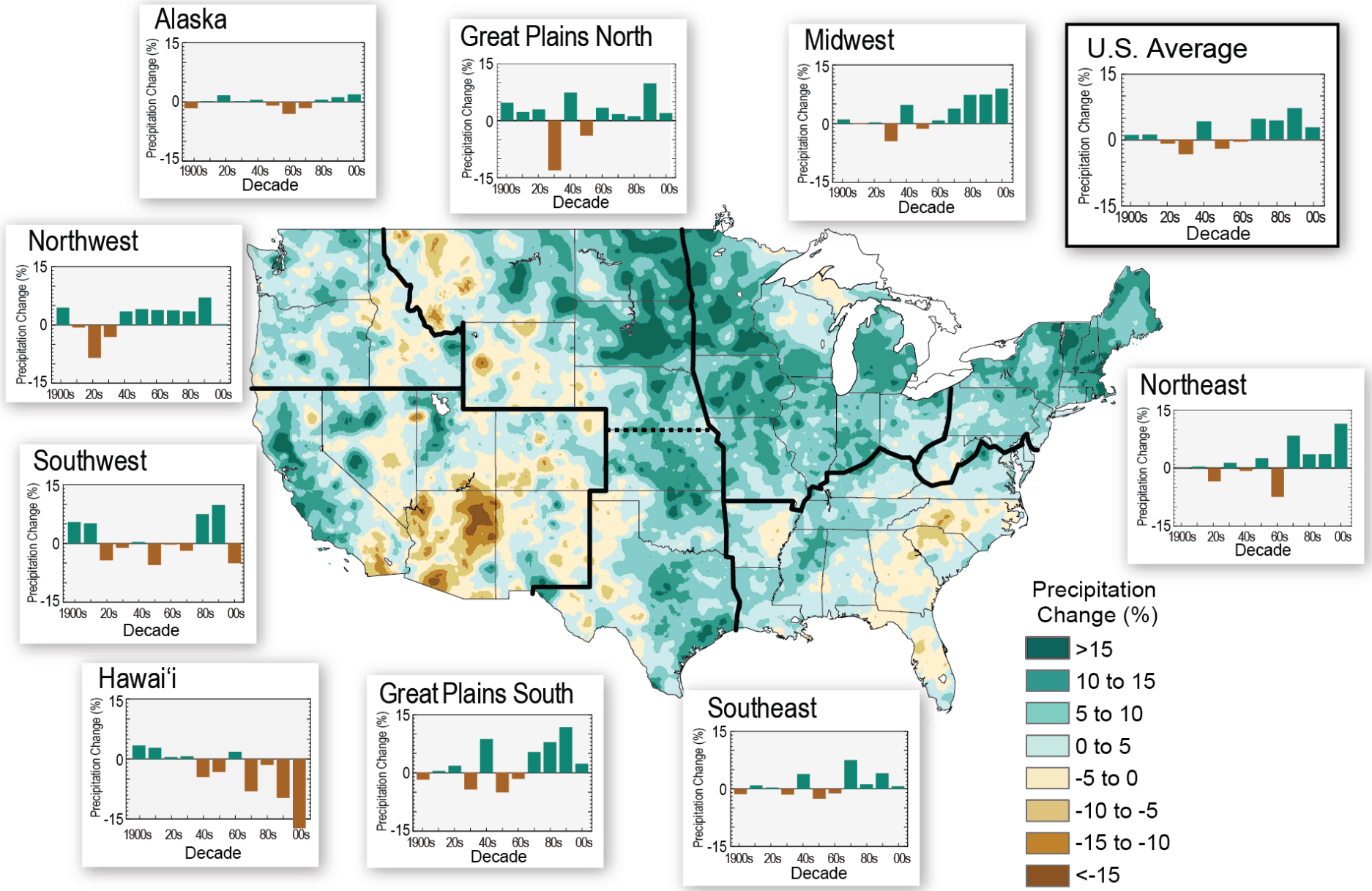


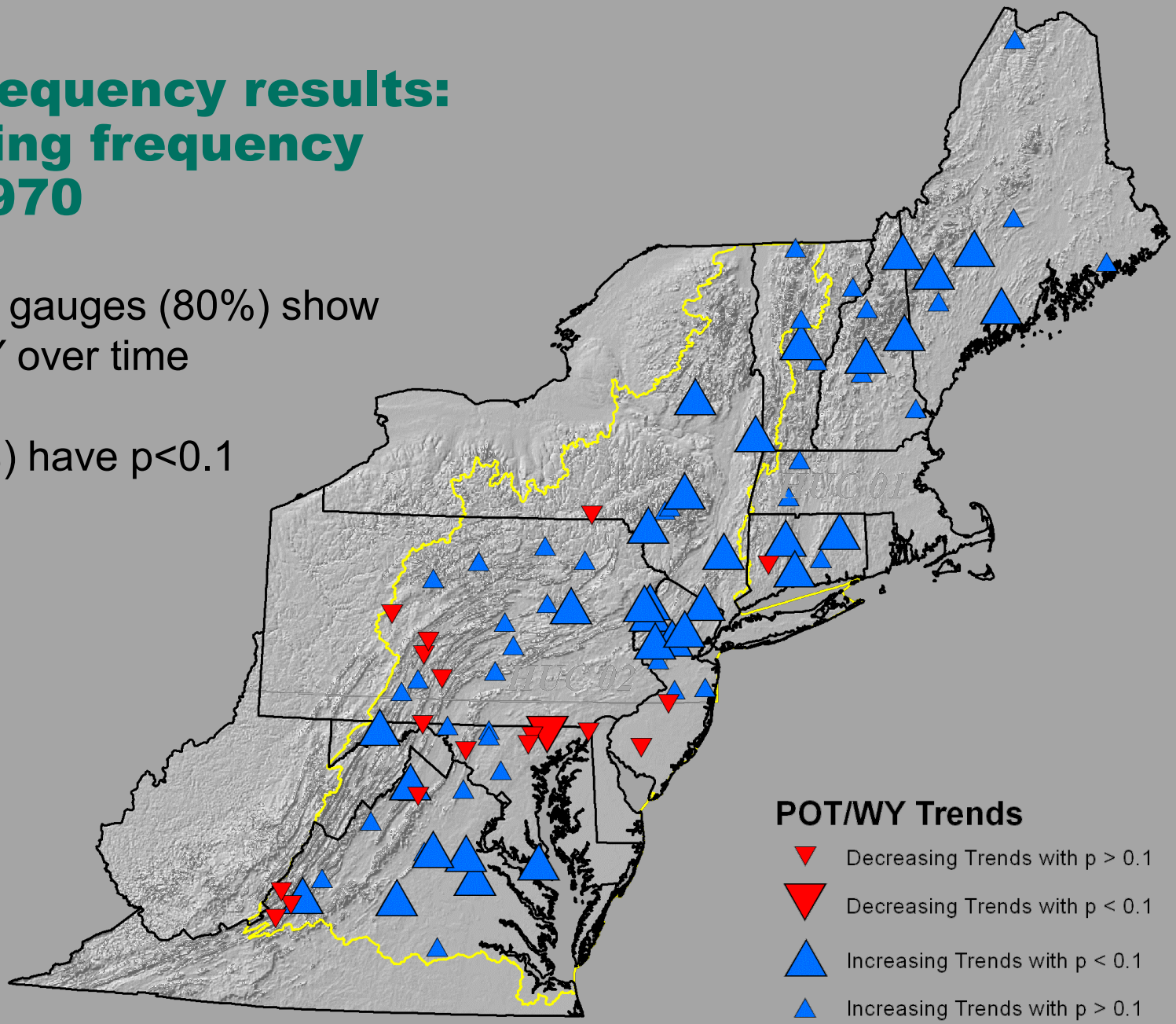
Observed U.S. Precipitation Change



(*National Climate Assessment*, 2014)

Flood frequency results: increasing frequency since 1970

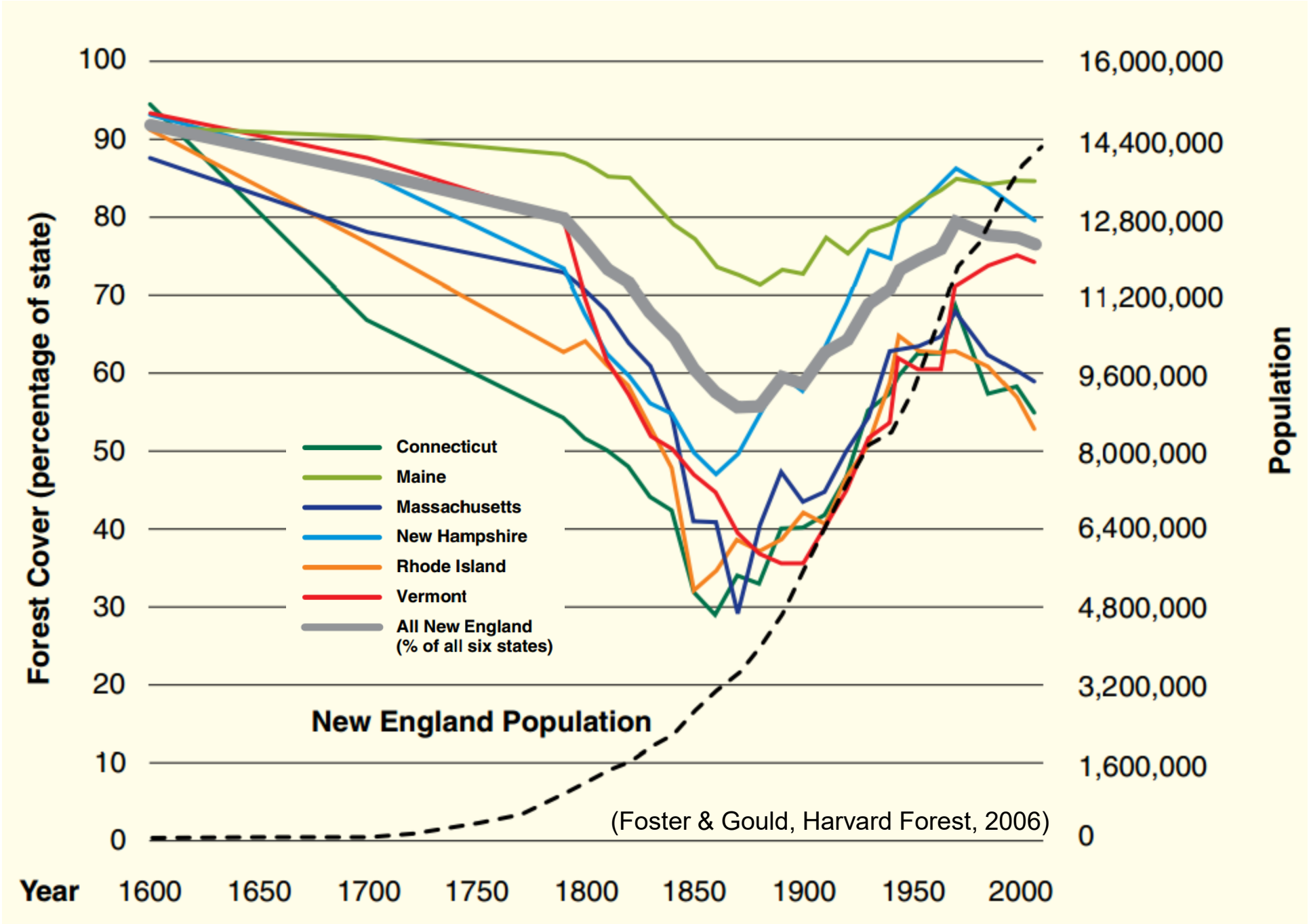
- 72 of 90 gauges (80%) show ↑ POT/WY over time
- 32 (36%) have p<0.1



after Armstrong et al. (2012) and Armstrong et al. (2014)

Hurricane Irene making landfall in NYC, 8:32 am EDT, 8/28/11 (NASA, 2011)

Hurricane Irene damage on Vermont Route 107 (VTRANS, 2011)


Forest Cover (percentage of state)
100
90
80
70
60
50
40
30
20
10
0
Year
1600
1650
1700
1750
1800
1850
1900
1950
2000
16,000,000
14,400,000
12,800,000
11,200,000
9,600,000
8,000,000
6,400,000
4,800,000
3,200,000
1,600,000
0
Population
Connecticut
Maine
Massachusetts
New Hampshire
Rhode Island
Vermont
All New England
(% of all six states)
New England Population
(Foster & Gould, Harvard Forest, 2006)

(http://www.moodyscollectibles.com)

GREETINGS FROM HEAD TIDE, MAINE. MILL AND DAM.

Published by J. A. Jewett, Head Tide, Me.

West Branch, Sheepscot River, midcoast Maine (November 2004)

Journal of Applied Ecology 2005
42, 208–217

FORUM

Standards for ecologically successful river restoration

M.A. PALMER,* E.S. BERNHARDT,* J. D. ALLAN,† P.S. LAKE,‡ G. ALEXANDER,† S. BROOKS,‡ J. CARR,§ S. CLAYTON,¶ C. N. DAHM,** J. FOLLSTAD SHAH,** D. L. GALAT,†† S. G. LOSS,‡‡ P. GOODWIN,¶ D.D. HART,§ B. HASSETT,* R. JENKINSON,§§ G.M. KONDOLF,¶¶ R. LAVE,¶¶ J.L. MEYER,*** T.K. O'DONNELL,†† L. PAGANO¶¶ and E. SUDDUTH***

**Department of Entomology, University of Maryland, USA and Department of Biology, Duke University, USA; †School of Natural Resources, University of Michigan, USA; ‡Department of Biological Sciences, Monash University, Australia; §Patrick Center for Environmental Research, Academy of Natural Sciences, USA; ¶Ecohydraulics Research Group, University of Idaho, USA; **Department of Biology, University of New Mexico, USA; ††US Geological Survey, Cooperative Research Units, Department of Fisheries & Wildlife Sciences, University of Missouri, USA; ‡‡Grand Canyon Monitoring and Research Center, USA; §§Department of Fish and Wildlife Resources, University of Idaho, USA; ¶¶Department of Landscape Architecture and Environmental Planning, University California, USA; and ***Institute of Ecology, University of Georgia, USA*

Summary

1. Increasingly, river managers are turning from hard engineering solutions to ecologically based restoration activities to improve degraded waterways. River restoration projects aim to maintain or increase ecosystem goods and services while protecting downstream and coastal ecosystems. There is growing interest in applying river restoration techniques to solve environmental problems, yet little agreement exists on what constitutes a successful river restoration effort.

2. We propose five criteria for measuring success, with emphasis on an ecological perspective. First, the design of an ecological river restoration project should be based on a specified guiding image of a more dynamic, healthy river that could exist at the site. Secondly, the river's ecological condition must be measurably improved. Thirdly, the river system must be more self-sustaining and resilient to external perturbations so that only minimal follow-up maintenance is needed.

...the river system must be more self-sustaining and resilient to external perturbations so that only minimal follow-up maintenance is needed.

ECOLOGY

1000 dams down and counting

Dam removals are reconnecting rivers in the United States

By J. E. O'Connor,[1] J. J. Duda,[2] G. E. Grant[3]

Forty years ago, the demolition of large dams was mostly fiction, notably plotted in Edward Abbey's novel *The Monkey Wrench Gang*. Its 1975 publication roughly coincided with the end of large-dam construction in the United States. Since then, dams have been taken down in increasing numbers as they have filled with sediment, become unsafe or inefficient, or otherwise outlived their usefulness (*1*) (see the figure, panel A). Last year's removals of the 64-m-high Glines Canyon Dam and the 32-m-high Elwha Dam in northwestern Washington State were among the largest yet, releasing over 10 million cubic meters of stored sediment. Published studies conducted in conjunction with about 100 U.S. dam removals and at least 26 removals outside the United States are now providing detailed insights into how rivers respond (*2*, *3*).

A major finding is that rivers are resilient, with many responding quickly to dam removal. Most river channels stabilize within months or years, not decades (*4*), particularly when dams are removed rapidly; phased or incremental removals typically have longer response times. The rapid physical response is driven by the strong upstream/downstream coupling intrinsic to river systems. Reservoir erosion commonly begins at knickpoints, or short steep

Goodbye to a large dam. Elwha River passing through the remains of Glines Canyon Dam on 21 February 2015. The former Lake Mills can be seen in the background.

PHOTO: JOHN GUSSMAN/GUSSMANNEDCPHOTOCOLLECTIONS.COM

Published by AAAS

The biggest dam removal of them all (so far): Elwha River, Washington

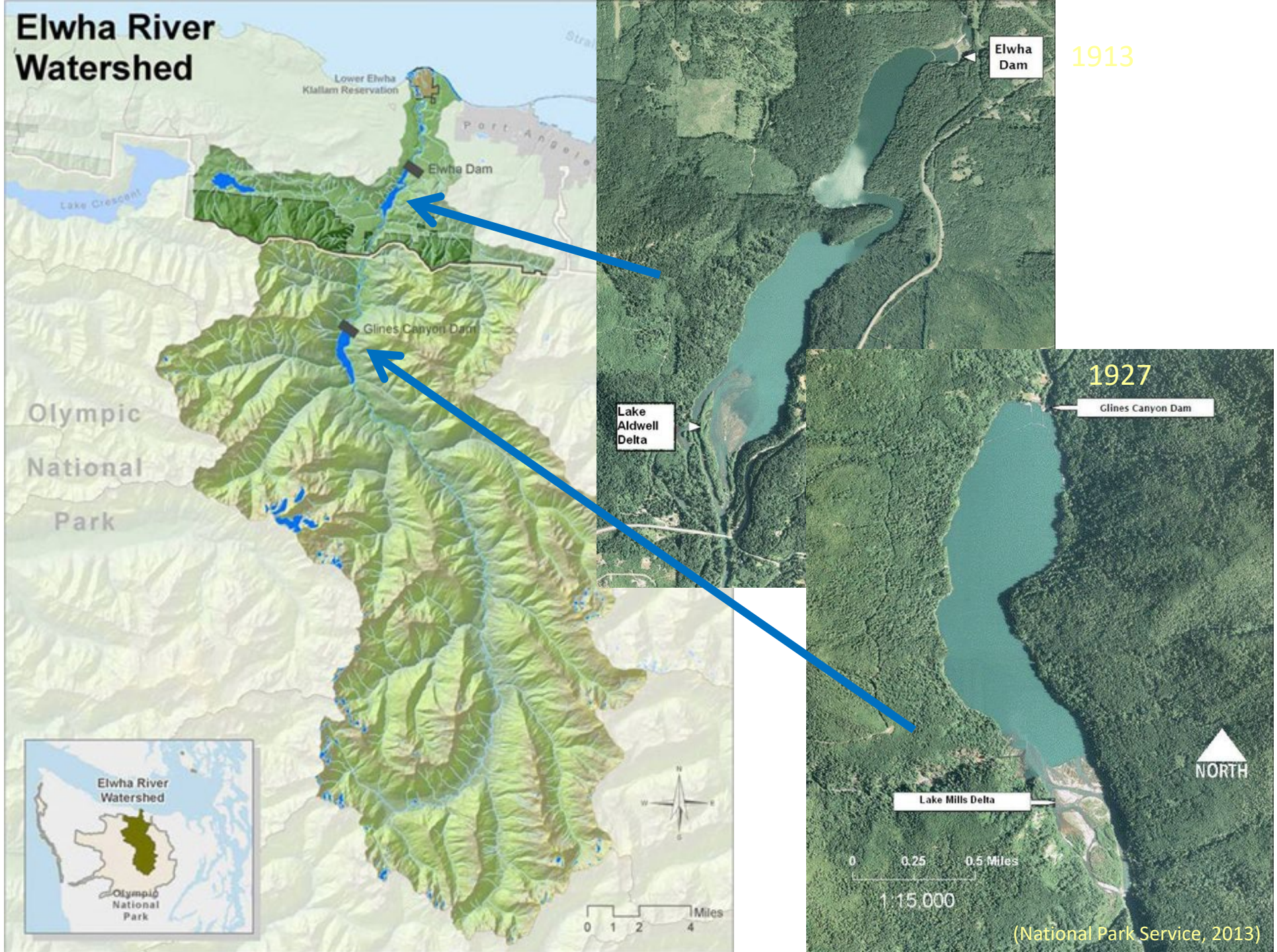
Removing Barriers to Salmon Migration

Michael Hanson for The New York Times

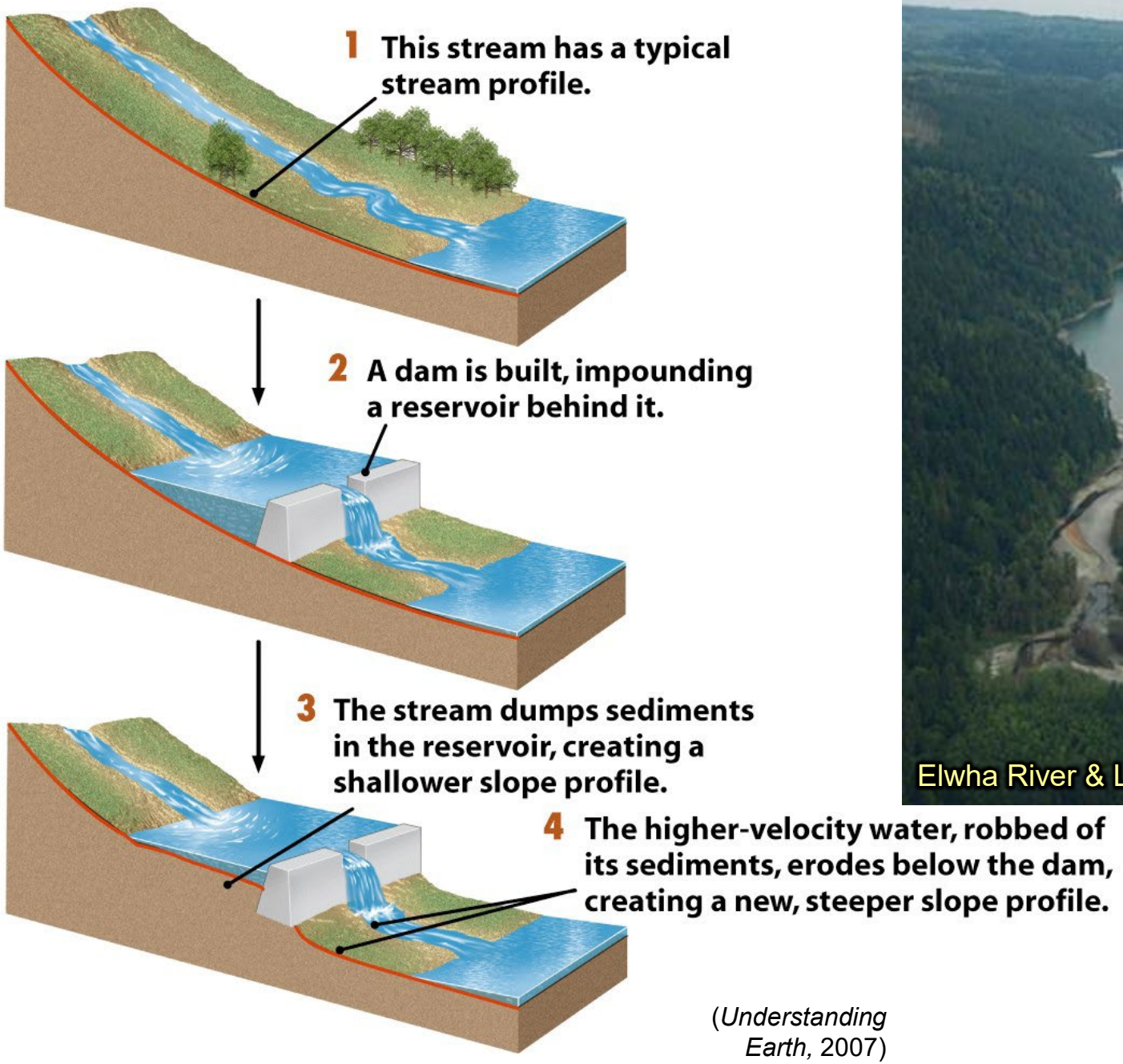
The view from the top of Glines Canyon Dam, which is one of two massive hydroelectric dams on the Olympic Peninsula that will be demolished beginning at the end of the summer. More Photos »

By WILLIAM YARDLEY
Published: July 29, 2011

The New York Times


Elwha River Watershed
Lower Elwha Klallam Reservation
Port Angeles
Lake Crescent
Elwha Dam
Glines Canyon Dam
Olympic National Park
Elwha River Watershed
Olympic National Park
Miles
0 1 2 4
1913
Elwha Dam
Lake Aldwell Delta
1927
Glines Canyon Dam
Lake Mills Delta
NORTH
0 0.25 0.5 Miles
1:15,000
(National Park Service, 2013)

National Geographic (2016): https://www.youtube.com/watch?v=VipVo8zPH0U



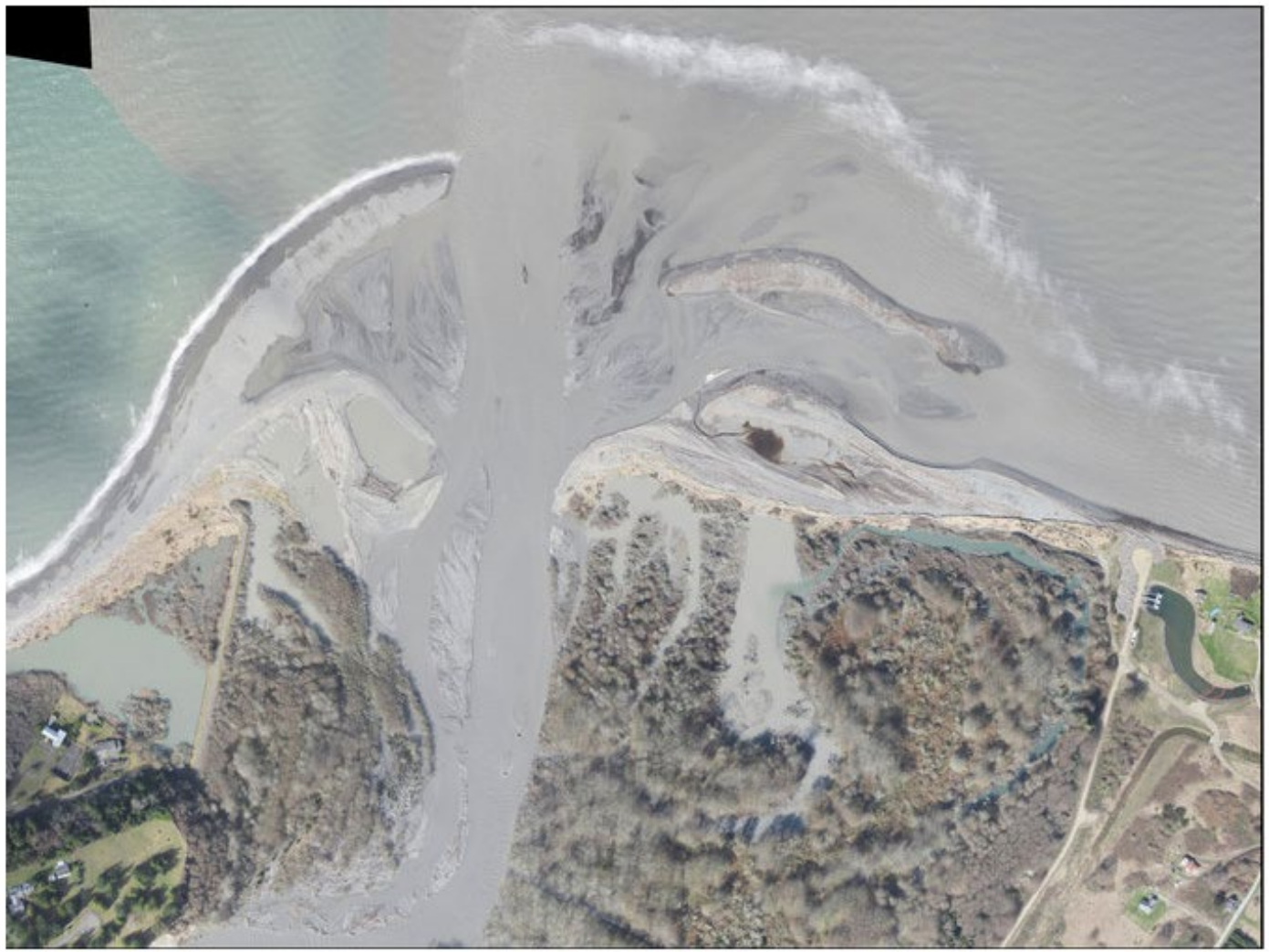
(*Understanding Earth*, 2007)


Elwha River & Lake Aldwell, Washington

The New York Times

When Dams Come Down, Salmon and Sand Can Prosper

By CORNELIA DEAN AUG. 10, 2015



The mouth of the Elwha River in Washington in March 2014 as the dam removal project sent sediment its way.

Andy Ritchie/National Park Service

Sediment from the Elwha River flows into the ocean after dam removal.
(J. Felis, U.S. Geological Survey, public domain.)

Model of Elwha River at Lake Mills sediment erosion (Bromley et al., 2005)

(Foley et al., 2017, *WRR*)

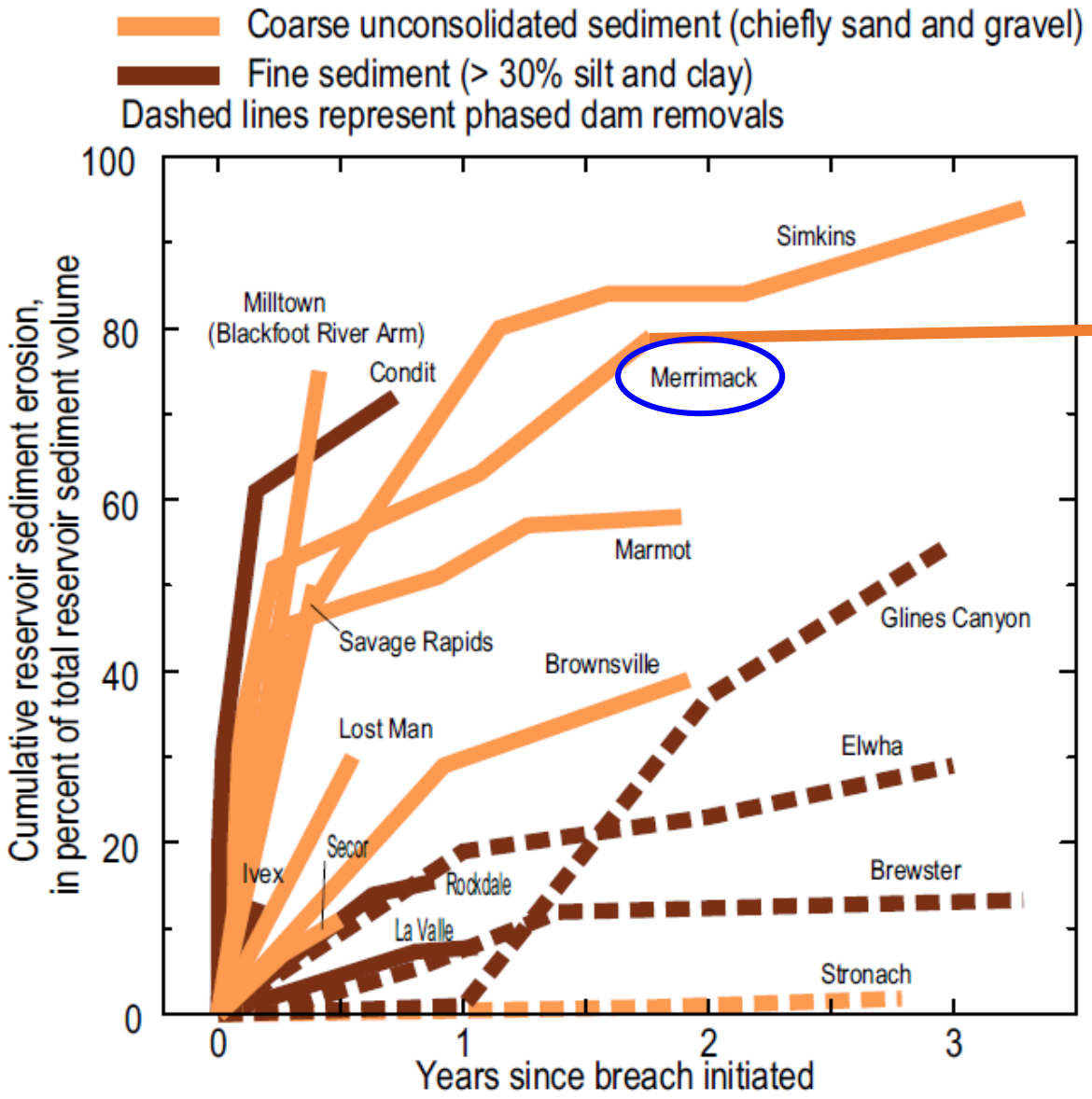


Figure 3. Percentage of reservoir sediment eroded with time after dam removal. Modified from *Major et al.* [2017], *Sawaske and Freyberg* [2012], and *Grant and Lewis* [2015].

Merrimack Village Dam, Souhegan River, NH

- First dam built in ca. 1734, likely multiple breaches over the next ~2 centuries
- Modern concrete structure built on top of an existing dam in 1907, spray skirt added in 1934
- Stored ~62000 m^3 of sediment (Gomez and Sullivan Engineers, 2006) in the reservoir
- Removed in August 2008, 3.9 m base-level drop
- We conducted 10 repeat surveys from 2007 to 2018

More: Pearson et al., *WRR*, 2011; Conlon, BC MS thesis, 2013; Santaniello et al, GSA book chapter, 2013; Collins et al., *WRR*, 2017; Lisius et al., *RRA*, 2018


amazonstudent


April 1947


May 2005
100
m


April 2010
100
m


Upstream from MVD03, April 2008

Upstream from MVD03, October 2008

sediment budget:
input from Souhegan River = ΔUS storage + ΔDS storage + output to Merrimack River

ΔDS

output

Merrimack River

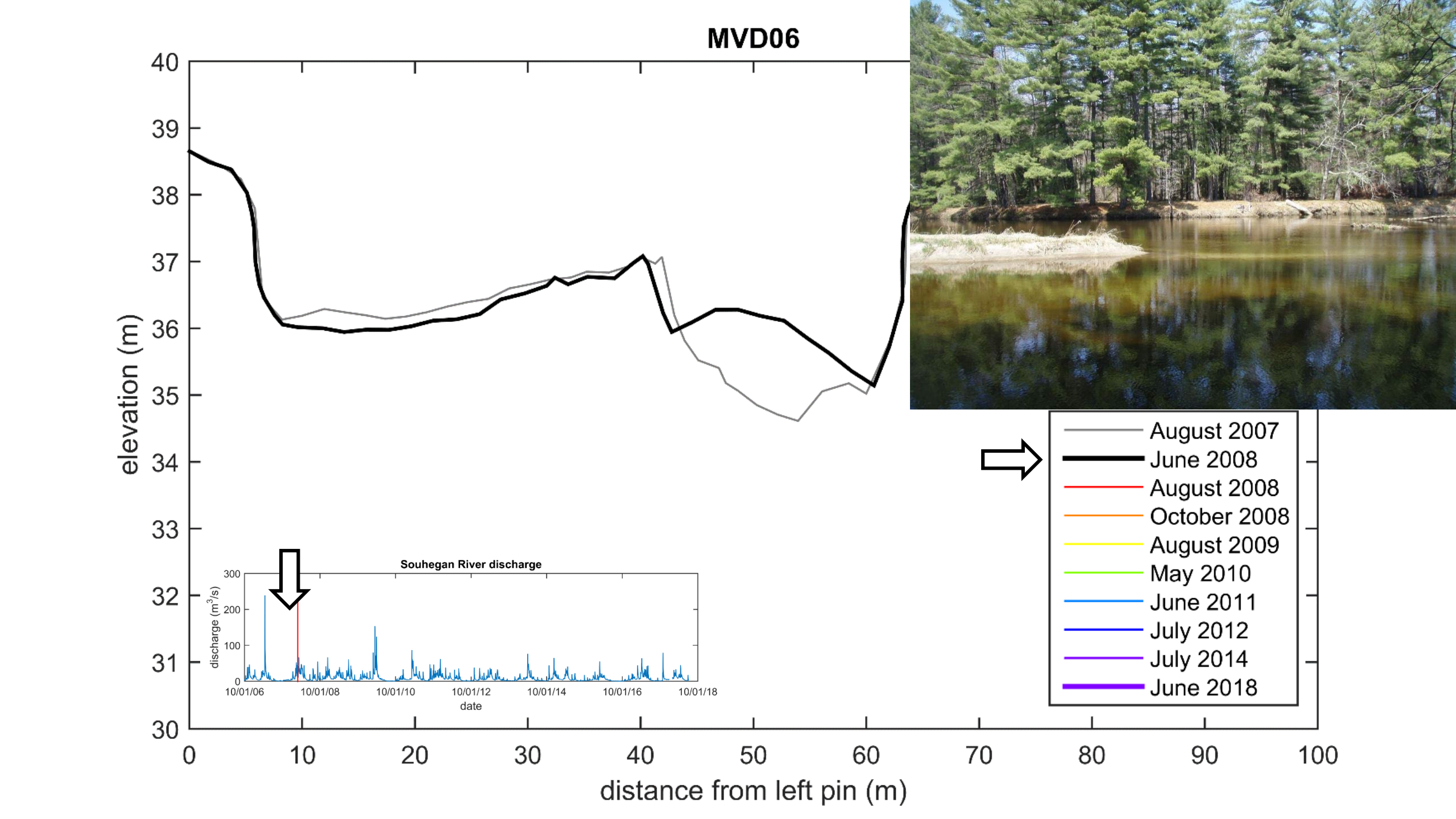
MVD06

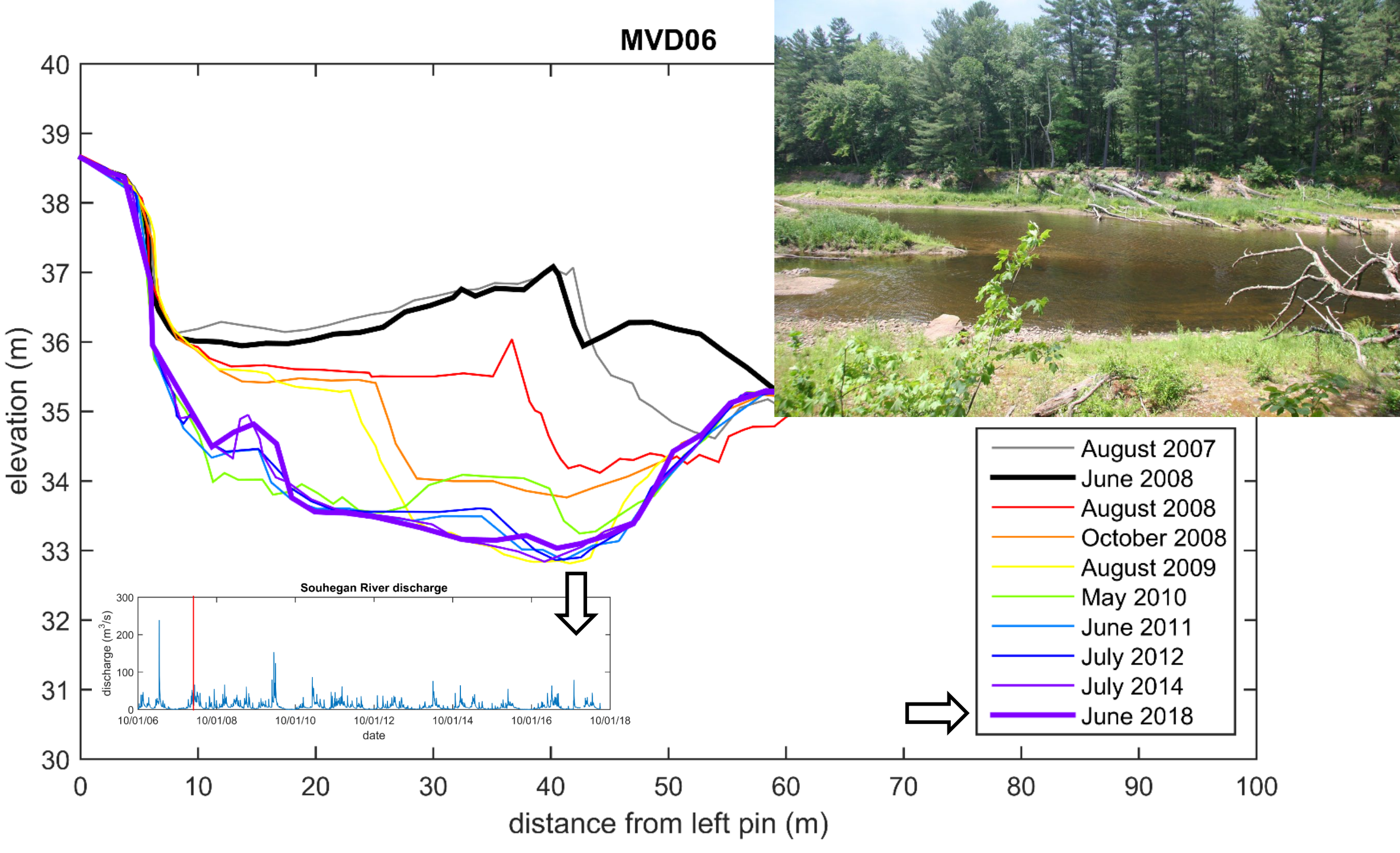
ΔUS

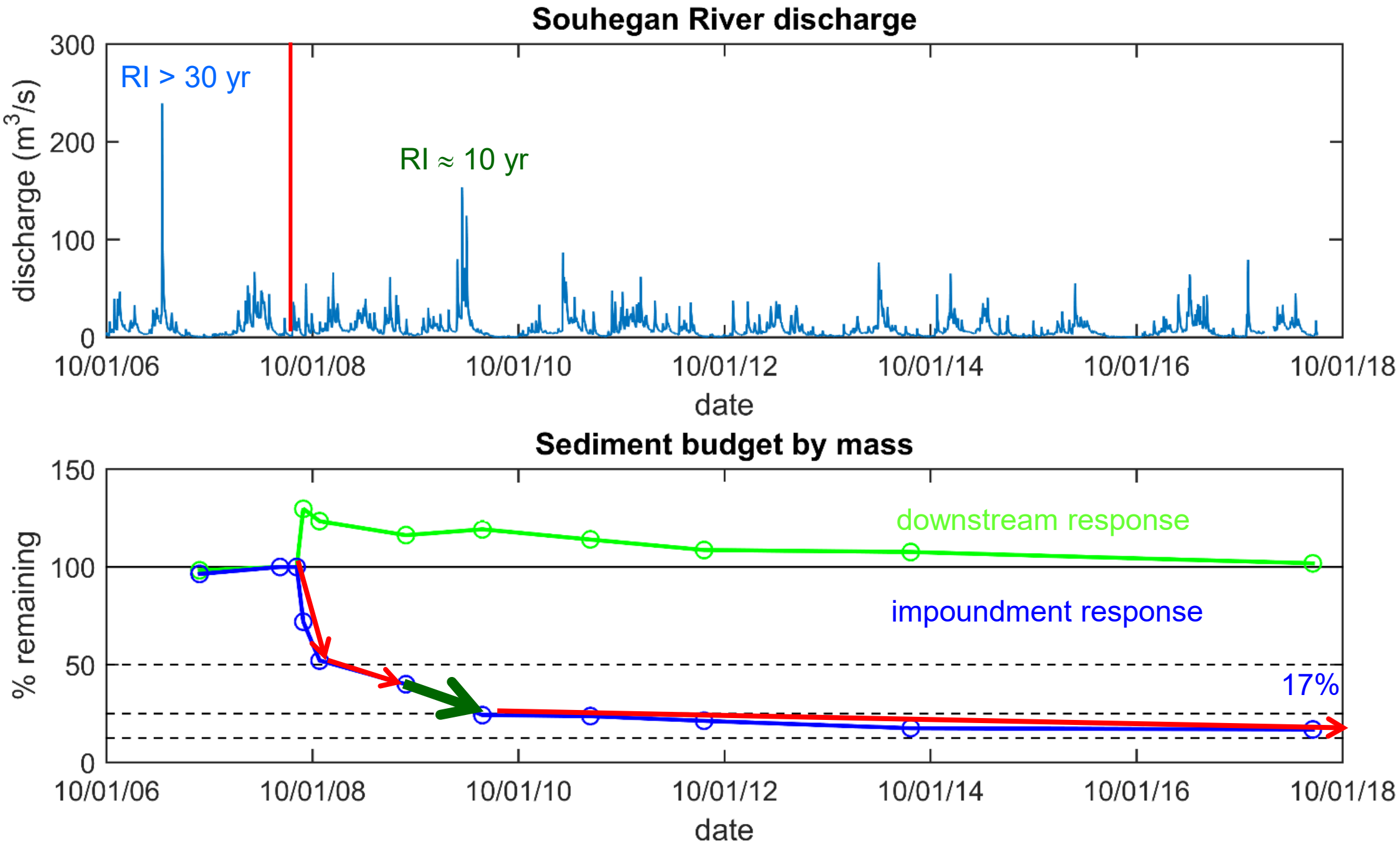
input

100 m

April 2010 (NH GRANIT)

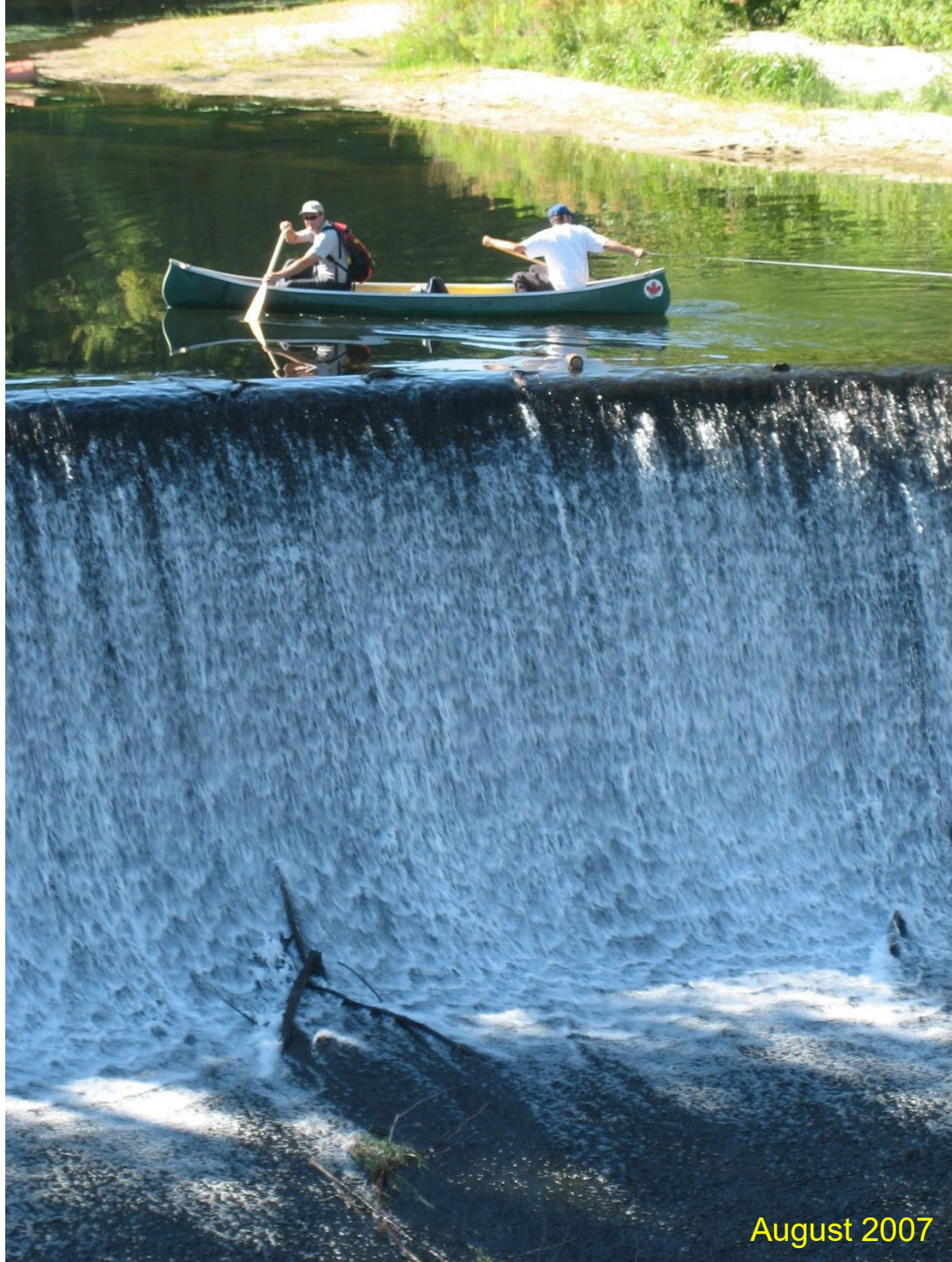

MVD06
elevation (m)
distance from left pin (m)
40
39
38
37
36
35
34
33
32
31
30
0
10
20
30
40
50
60
70
80
90
100
August 2007
June 2008
August 2008
October 2008
August 2009
May 2010
June 2011
July 2012
July 2014
June 2018
Souhegan River discharge
discharge (m3/s)
300
200
100
0
10/01/06
10/01/08
10/01/10
10/01/12
10/01/14
10/01/16
10/01/18
date


MVD06
elevation (m)
distance from left pin (m)
August 2007
June 2008
August 2008
October 2008
August 2009
May 2010
June 2011
July 2012
July 2014
June 2018
Souhegan River discharge
discharge (m3/s)
date


Souhegan River discharge
RI > 30 yr
RI ≈ 10 yr
discharge (m3/s)
300
200
100
0
10/01/06
10/01/08
10/01/10
10/01/12
10/01/14
10/01/16
10/01/18
date
Sediment budget by mass
% remaining
150
100
50
0
downstream response
impoundment response
17%
10/01/06
10/01/08
10/01/10
10/01/12
10/01/14
10/01/16
10/01/18
date

Lessons from the MVD removal

- Two-phase response: initial rapid incision and widening in the channel (months); longer ongoing response driven by flood events, as well as feedbacks with vegetation, floodplain development
- Reservoirs can be sediment sources during flood events, while overbank deposition occurs on adjacent surfaces inundated frequently due to raised base level (April 2007 flood on the Souhegan River at MVD)
- Legacy sediment, stored outside of the former reservoir, extends the event-driven phase, and remains in valley bottoms for decades to centuries, even after dam removal (Johnson et al., 2019; Dow et al., in review)




• Impoundment area: 32000 m^2
• 62000 m^3 of sediment (17% remaining)
• Dam-affected area: +60500 m^2
• ~3.2 m average thickness above present water elevation (conservative max estimate, assumes all sediment above 34.5 elevation was deposited since dams were built, ca. 1734)
• ~190000 m^3 of legacy sediment
• ~3x original impoundment sediment
100
m

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Invited Research Article

Legacy sediment storage in New England river valleys: Anthropogenic processes in a postglacial landscape

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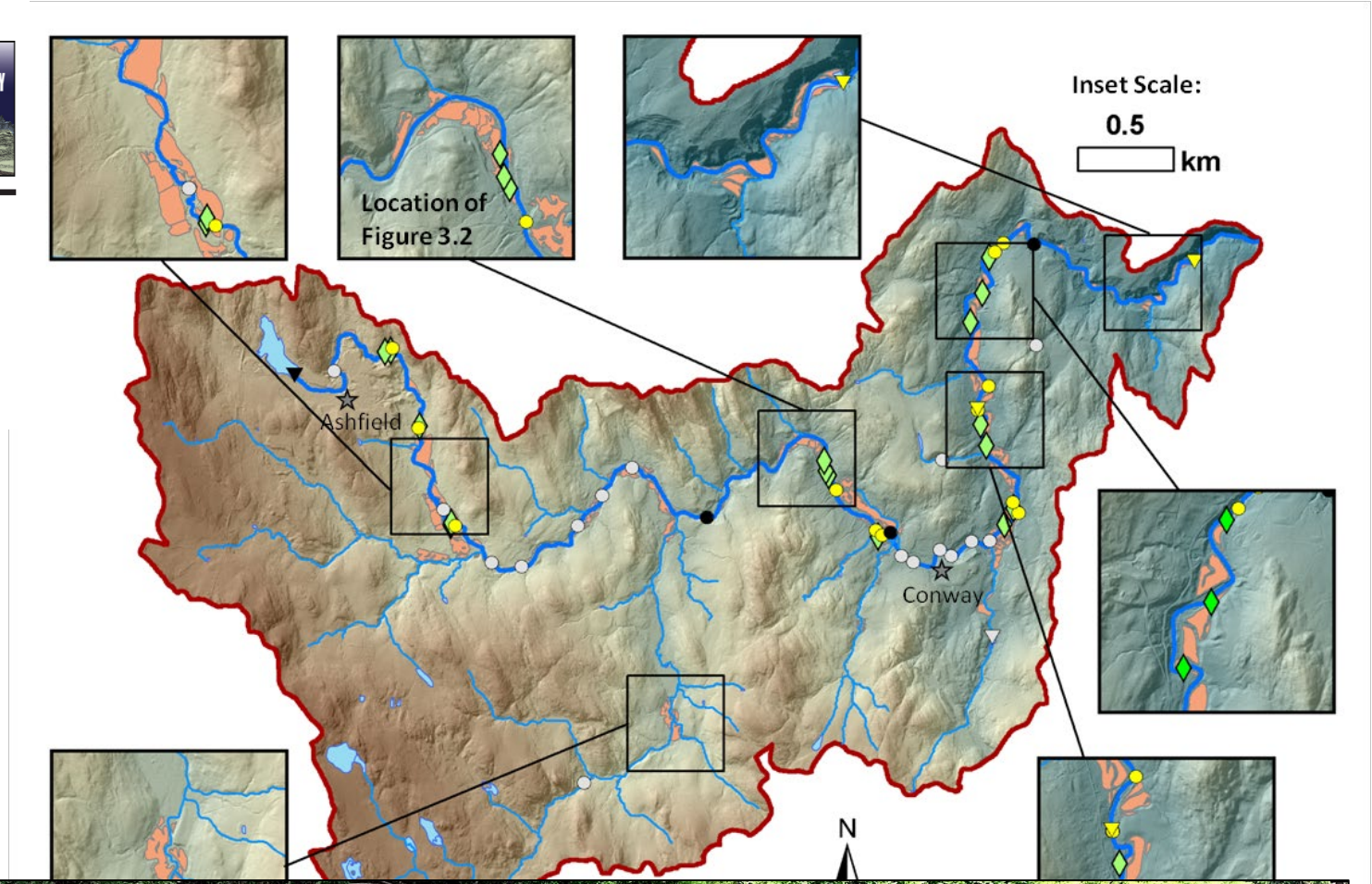
South River watershed, Massachusetts:

- 5 intact dams and 32 breached dams
- 0.49 dams/km^2
- 17 dams have been field checked for legacy sediment
- 14 dams show evidence for legacy sediment storage, up to 2.2 m thick (1.1 m average)
- ~2.5 x 10^6 m^3 of legacy sediment storage = ~4 cm of soil erosion



Dam removal, sediment, and river corridor management in New England

- Many dams do not store sediment
  - Too small to influence hydraulics
  - Too little supply upstream
- Where supply exists, sediment gets stored in the reservoir and adjacent surfaces
  - The adjacent surfaces become legacy deposits, which persist, largely unchanged, for decades to centuries
  - How important is this change in valley-bottom morphology?
- Generally supply-limited state of NE rivers means that sediment management after dam removal is less of an issue than other places
  - As long as stored sediment is uncontaminated

Cut logs eroding out of the left bank, upstream of Head Tide Dam, Sheepscot River, Maine (July 2016)