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Research

Today: The Science and Politics of Dam Removal

Glines Canyon Dam, Elwha River, WA

Acknowledgements

Amy East, U.S. Geol. Survey

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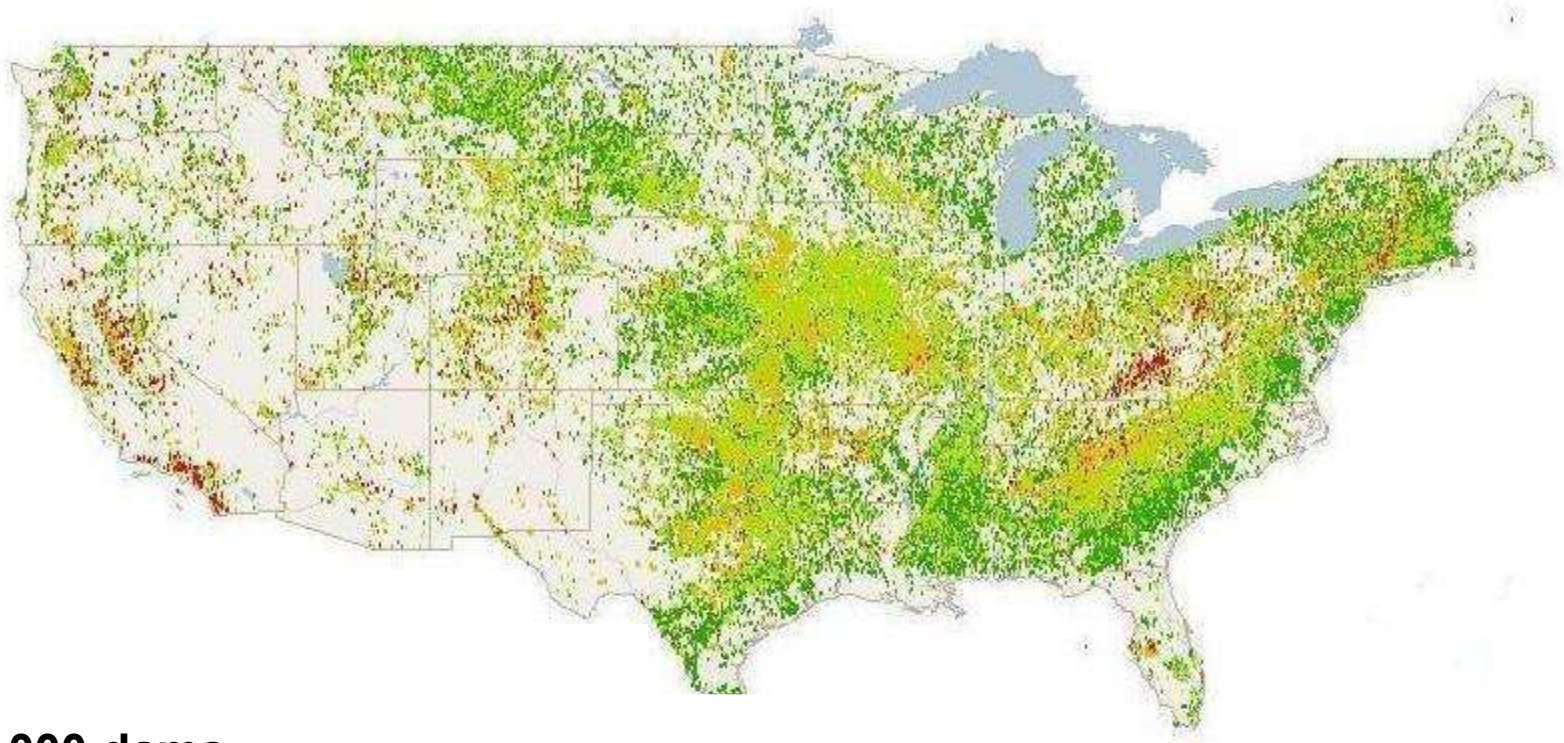
Alain Recking, IRSTEA, Grenoble

Steve Ringman/Seattle Times

https://www.youtube.com/watch?v=R8mz1o8aq1s

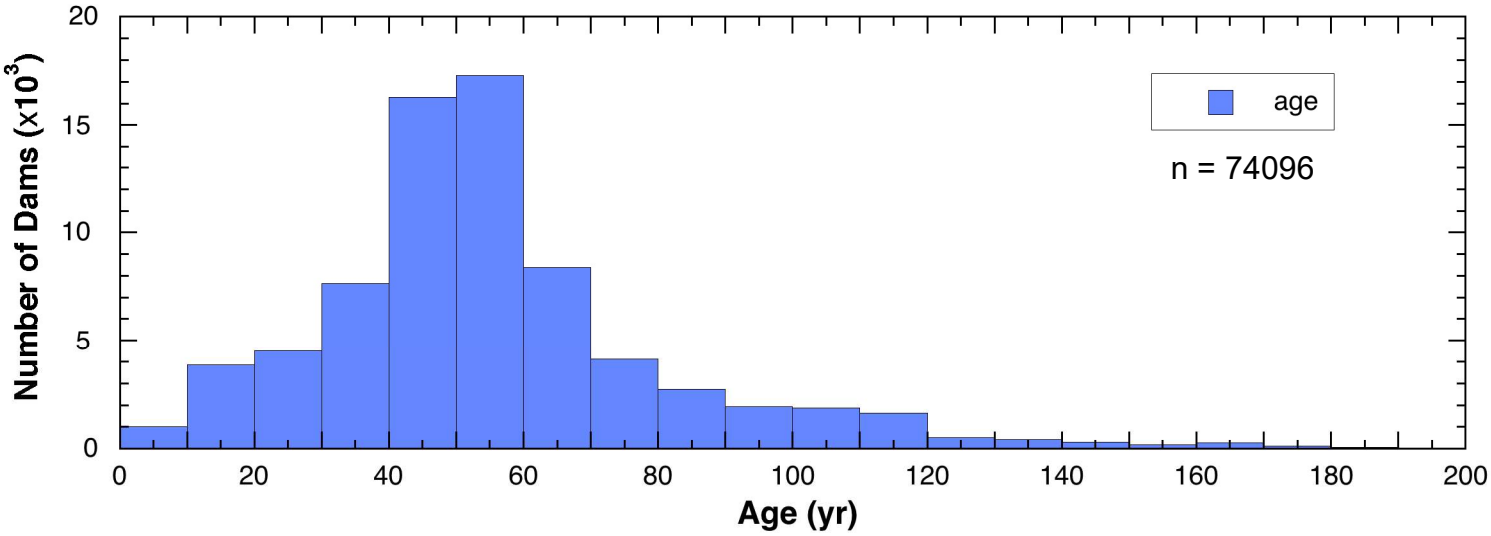
Animation courtesy of James Syvitski and Albert Kettner, CU Boulder

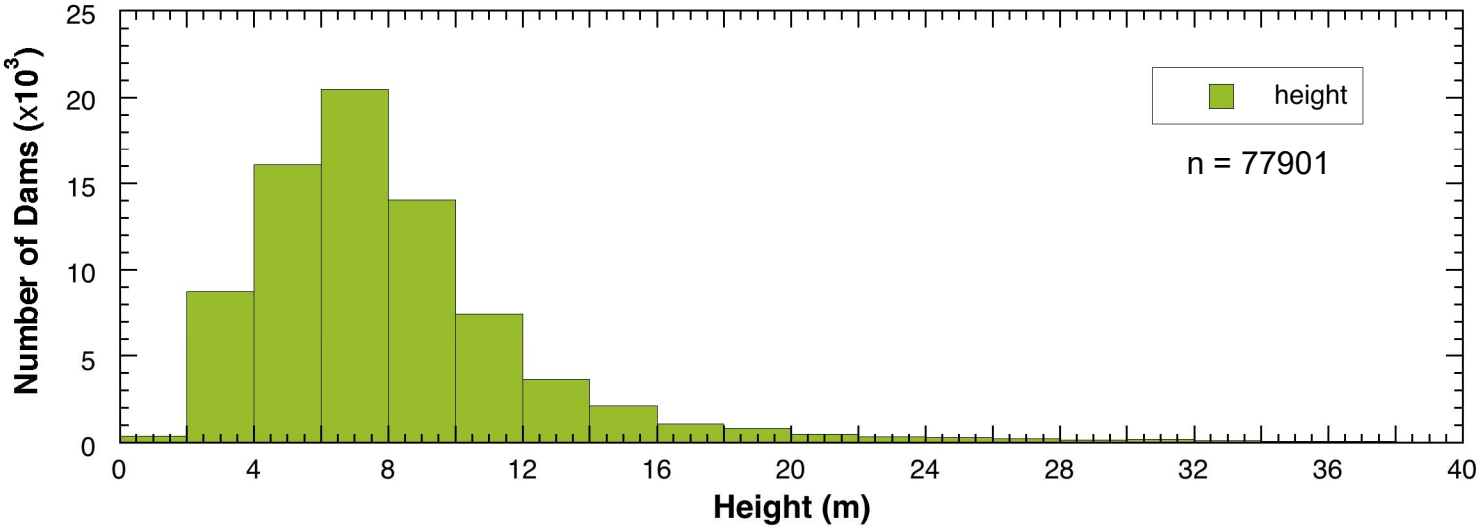
National Inventory of Dams (USACOE)



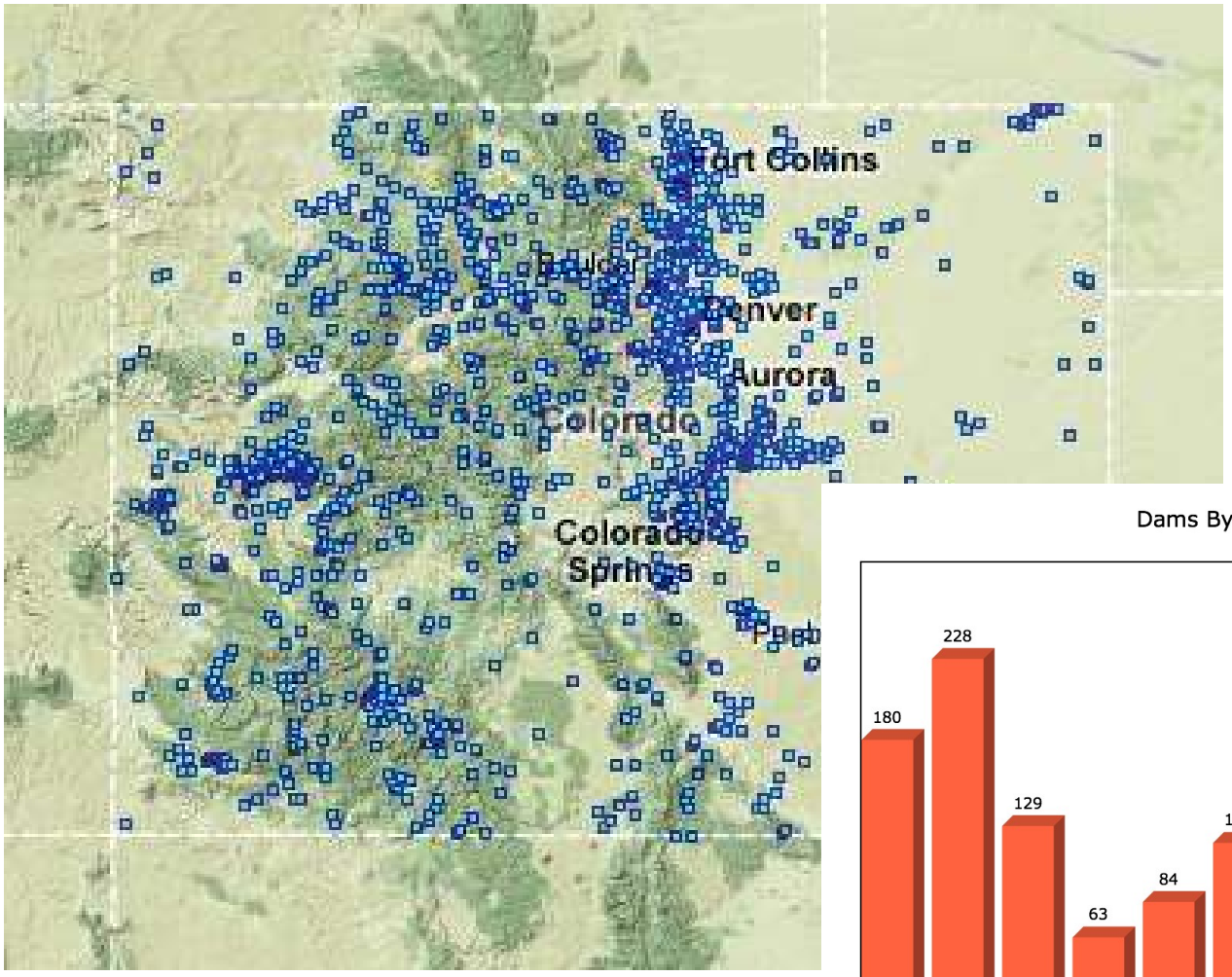
87,000 dams

- > 6 ft in height and ≥ 50 ac-ft in storage
- ≥ 25 ft in height and >15 ac-ft in storage
- High or significant hazard


Number of Dams (x10^3)
20
15
10
5
0
0
20
40
60
80
100
120
140
160
180
200
Age (yr)
age
n = 74096


Number of Dams (x10^3)
25
20
15
10
5
0
0
4
8
12
16
20
24
28
32
36
40
Height (m)
height
n = 77901

Colorado

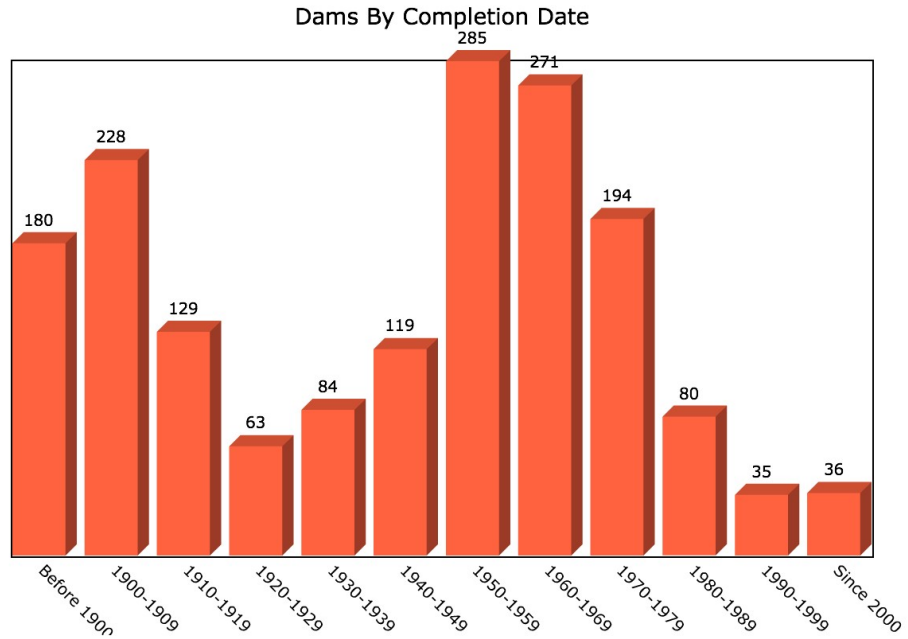


280,000 km^2

(~ size of Italy)

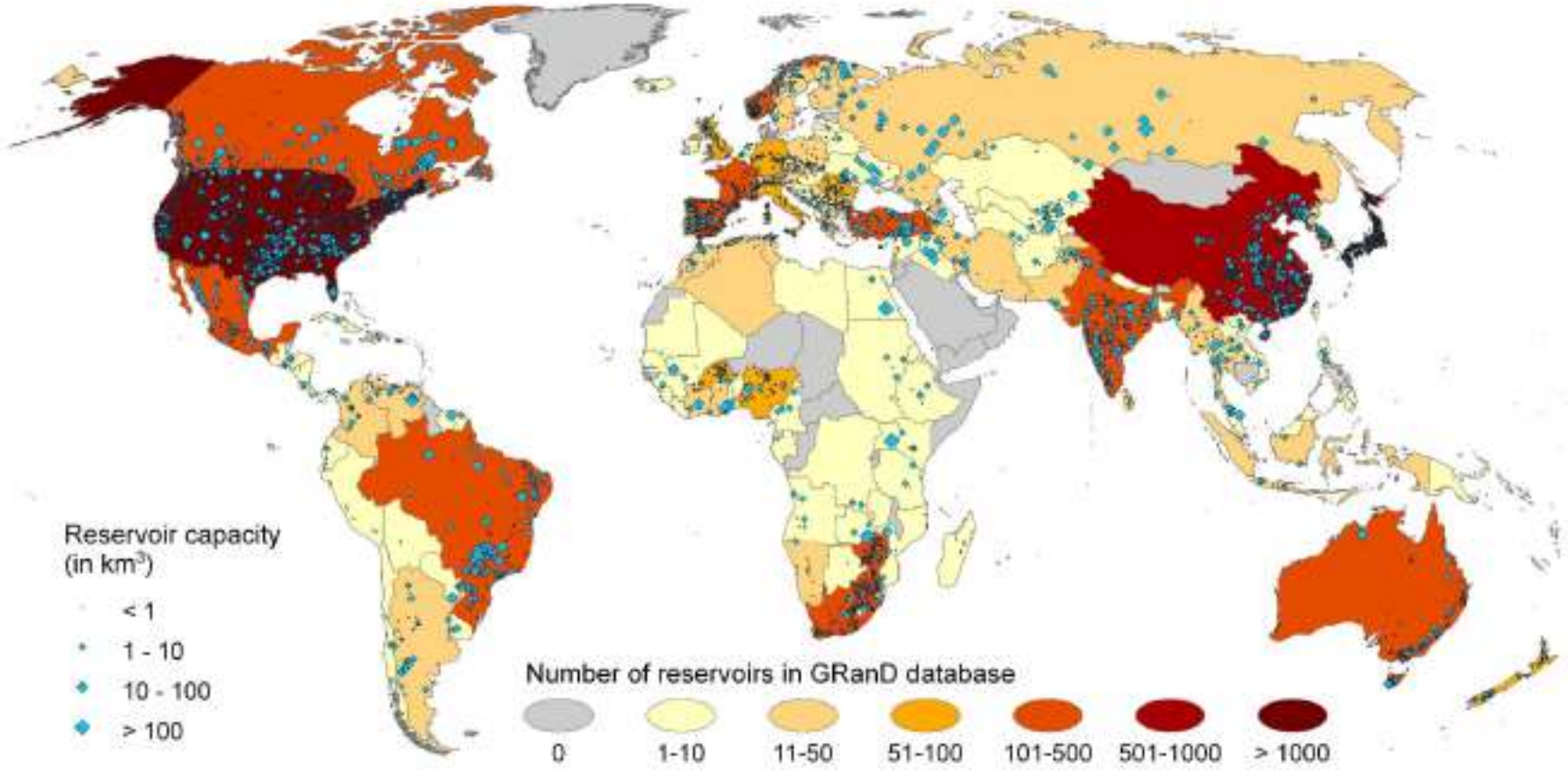
1737 dams

80% < 50 ft high

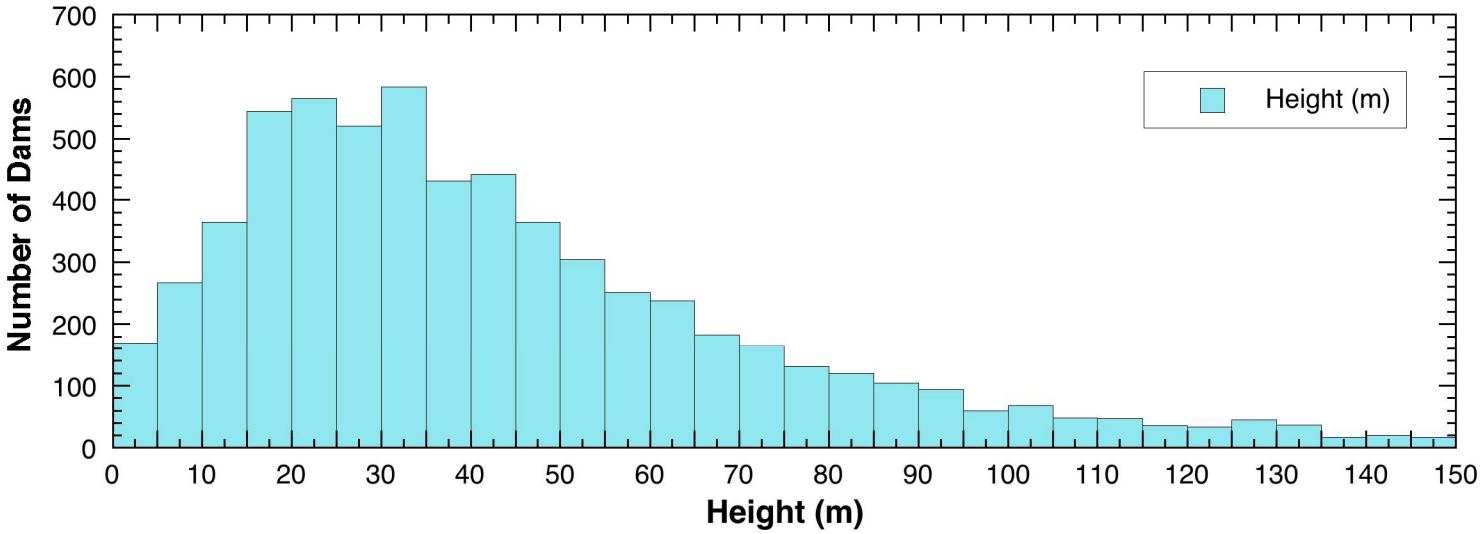


Global Reservoir and Dam (GRanD) Database

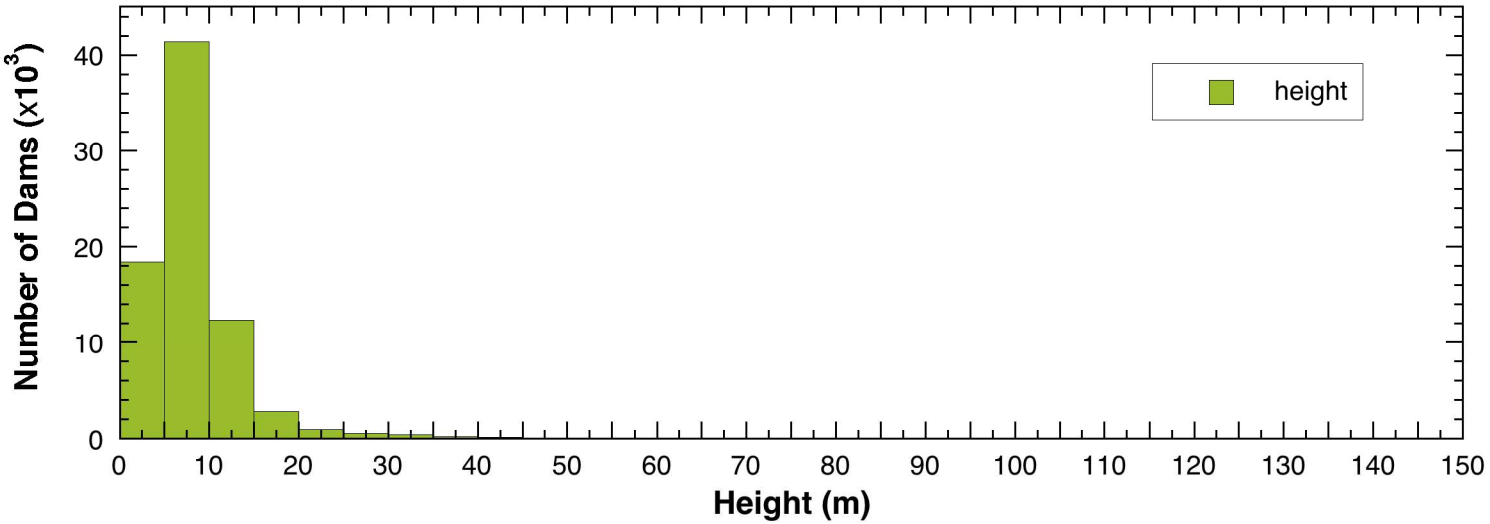
6862 reservoirs with a storage capacity >0.1 km³



GRanD database

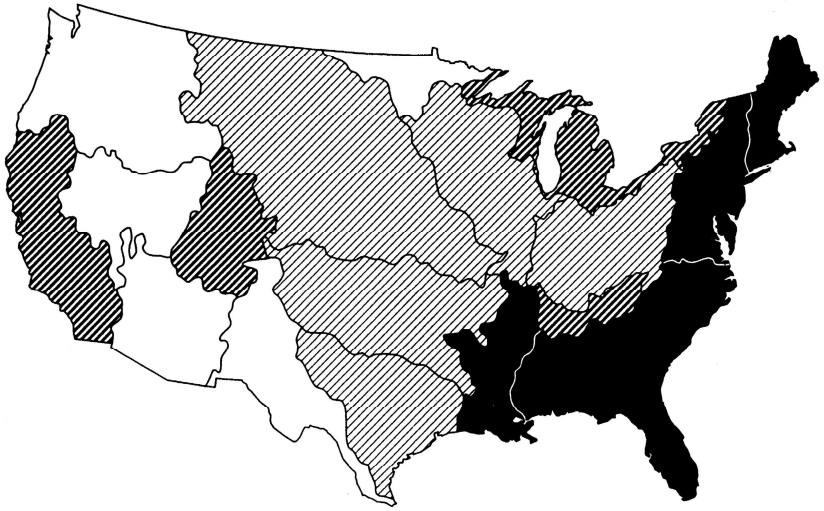


US database



Eastern USA: Greatest number of dams

Dams per Area (Graf, 1999)

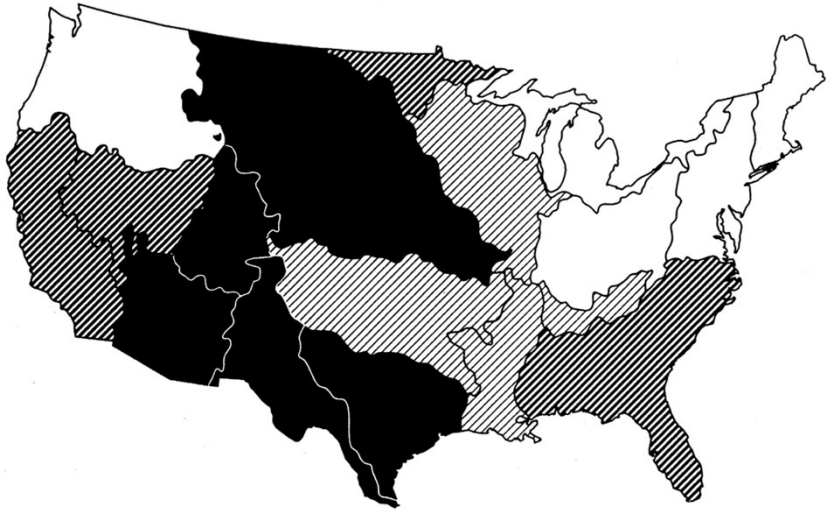


Huron River

- built to power small mills
- run-of-the-river dams… do not alter flow significantly

Western USA: Largest dams and reservoirs

Storage / Runoff Ratio (Graf, 1999)



- built for flood control, storage, hydro-electricity
- alter flow significantly
- major barriers to fish

Key Legislative Actions in US

Federal Power Act of 1920

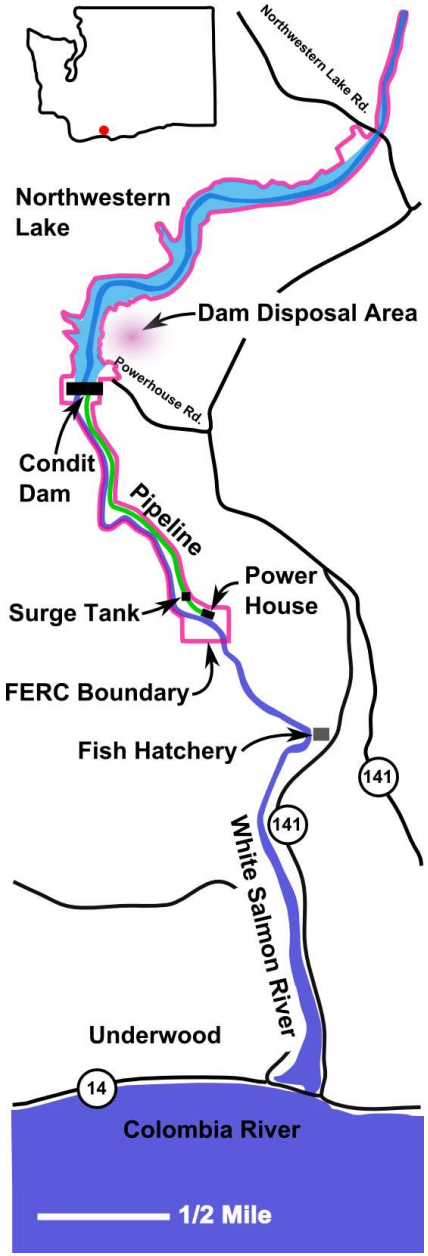
- Gives the **Federal Energy Regulatory Commission** authority to issue licenses for hydro-power projects for a defined term of years, and to direct the relicensing process.

National Environmental Policy Act of 1969

- Requires federal agencies to prepare environmental impact statements (EIS) ensuring that environmental factors are weighed equally in decisions made by federal agencies.

Endangered Species Act of 1973

- Provides for the conservation of threatened or endangered species throughout all or much of their range, and the conservation of the ecosystems on which they depend.



An Example: Condit Dam

1996: US government ordered PacifiCorp to alter the dam to add fish ladders to meet environmental codes. PacifiCorp deemed the modifications too expensive and asked to decommission the dam instead.

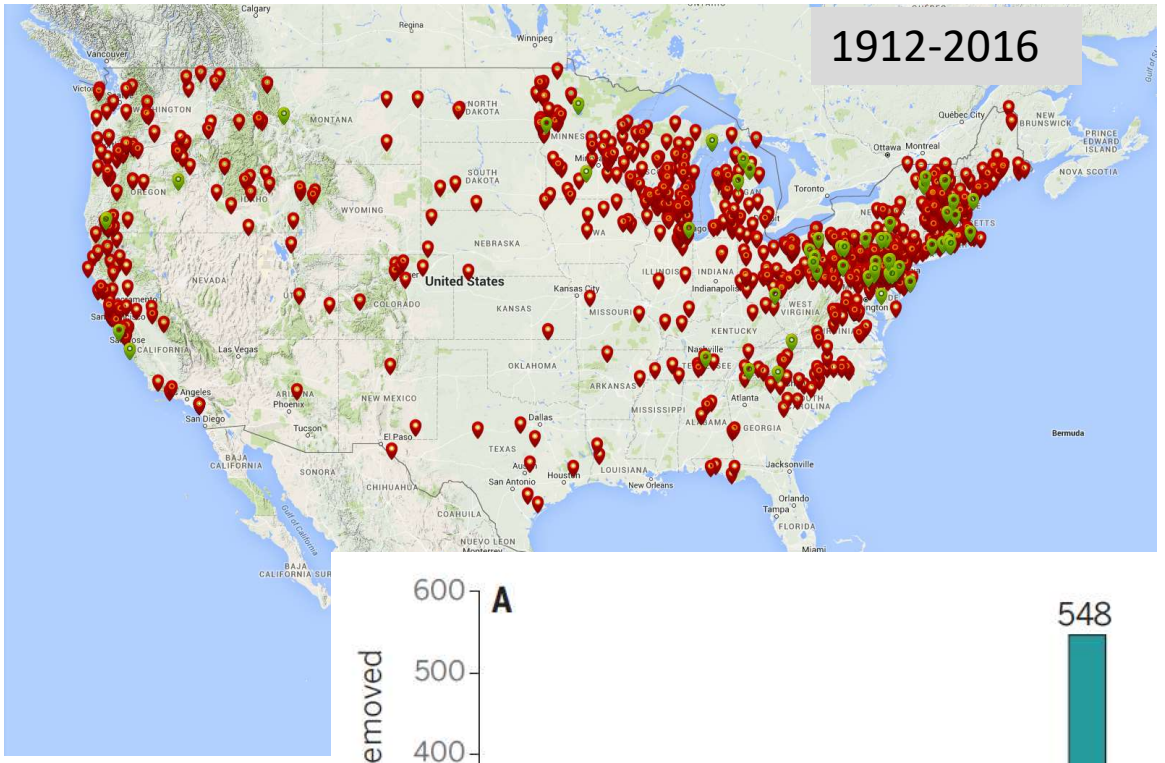
https://vimeo.com/31305629

Condit Dam, Washington

90 minutes after breach (rottura)

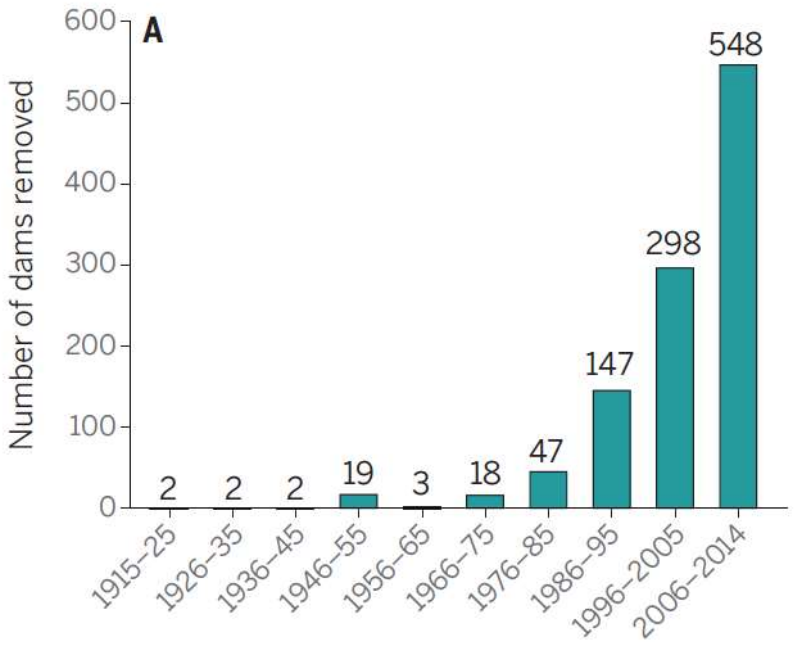
Dam removal in the US

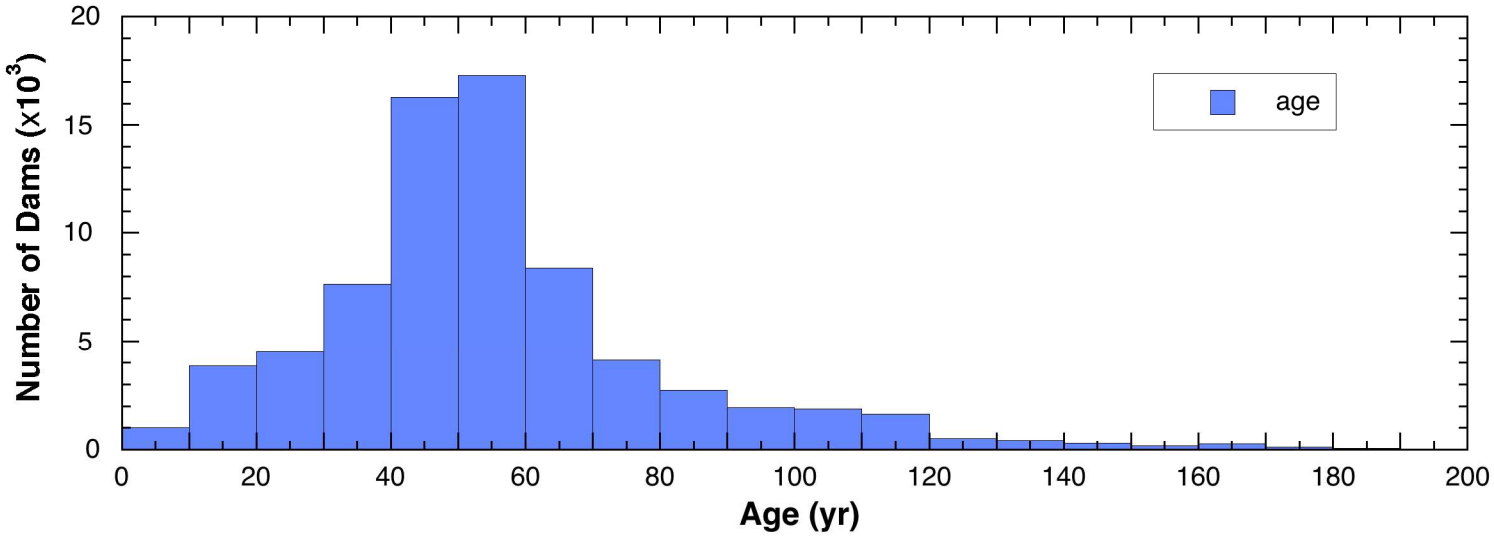
- ~1400 total
- 72 in 2016

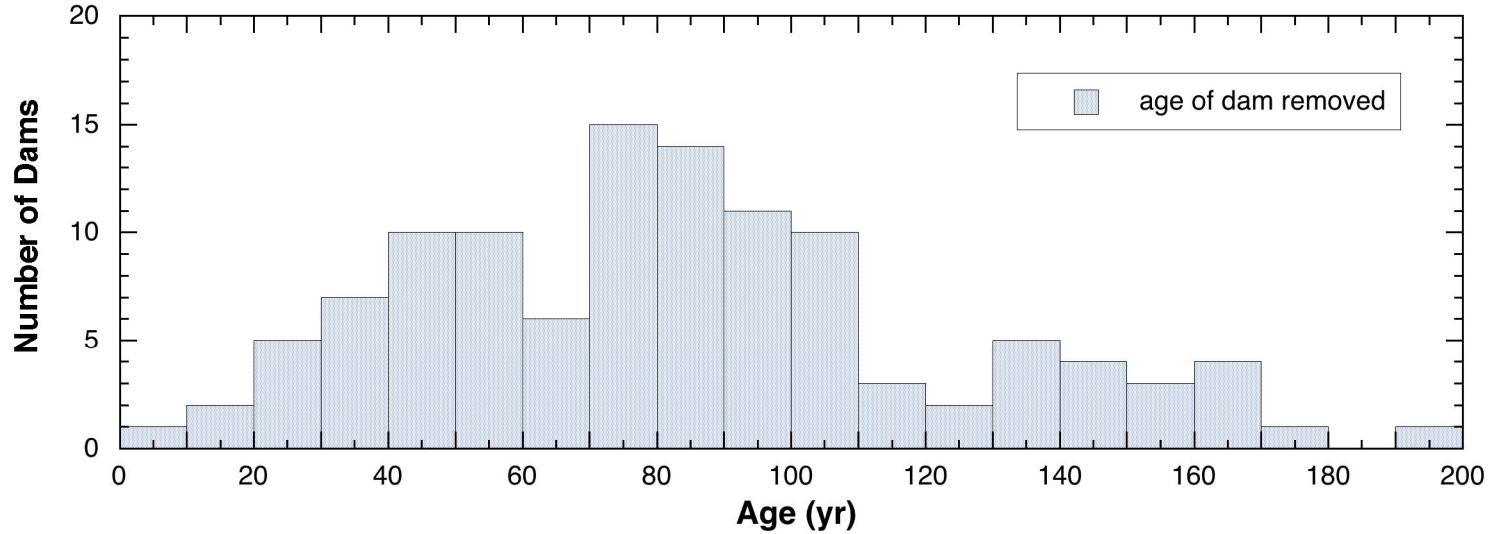


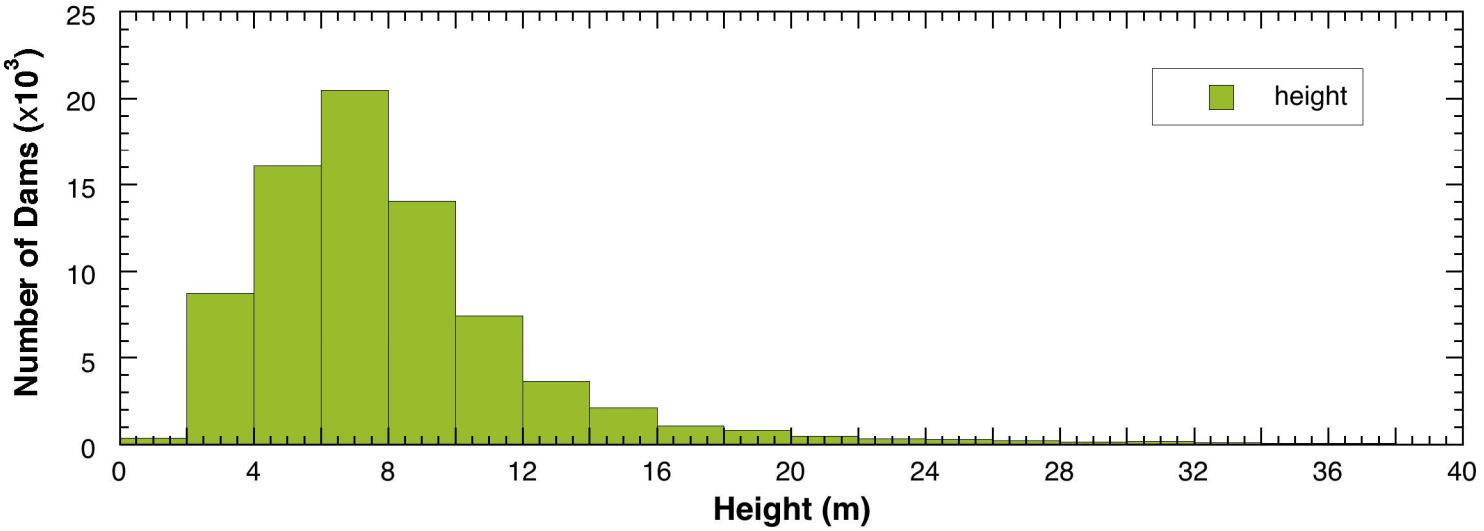
The pace of dam removal is increasing

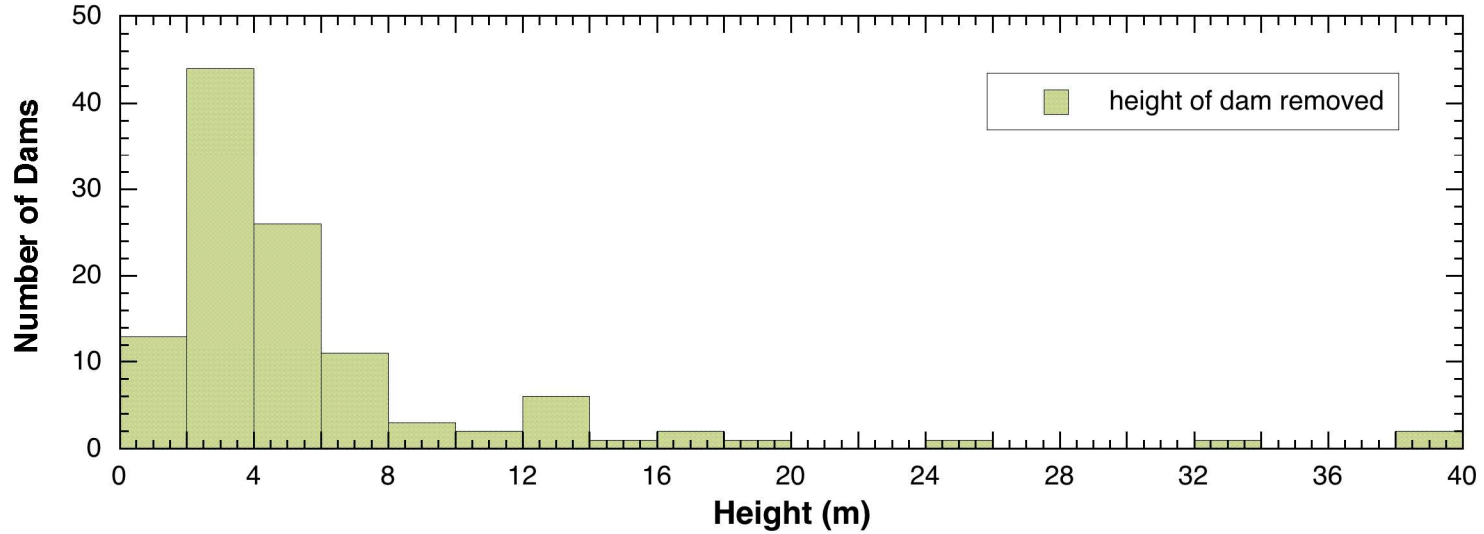
(O'Connor et al., 2015)




Number of Dams (x10^3)
20
15
10
5
0
0
20
40
60
80
100
120
140
160
180
200
Age (yr)
age


Number of Dams
20
15
10
5
0
0
20
40
60
80
100
120
140
160
180
200
Age (yr)
age of dam removed


Number of Dams (x10^3)
25
20
15
10
5
0
0
4
8
12
16
20
24
28
32
36
40
Height (m)
height


Number of Dams
50
40
30
20
10
0
0
4
8
12
16
20
24
28
32
36
40
Height (m)
height of dam removed

Effects of dam removal scale with…

- Dam height, age
- Volume and size of sediment stored
- Hydrology, sediment supply and channel gradient

Elwha River Basin, WA

- Two dams constructed in early 1900s to provide electricity to Port Angeles, WA

(Warrick et al., 2015)

Glines Canyon Dam

64 m

Elwha Dam (downstream)

Elwha River Restoration Project

Why were these dams removed?

The owners requests to relicense the dams were strongly and repeatedly opposed by

- Native American tribes
- Environmental conservation groups

1992: US Congress approves Elwha River Ecosystem and Fisheries Restoration Act

~ 20 yrs

2011: project began

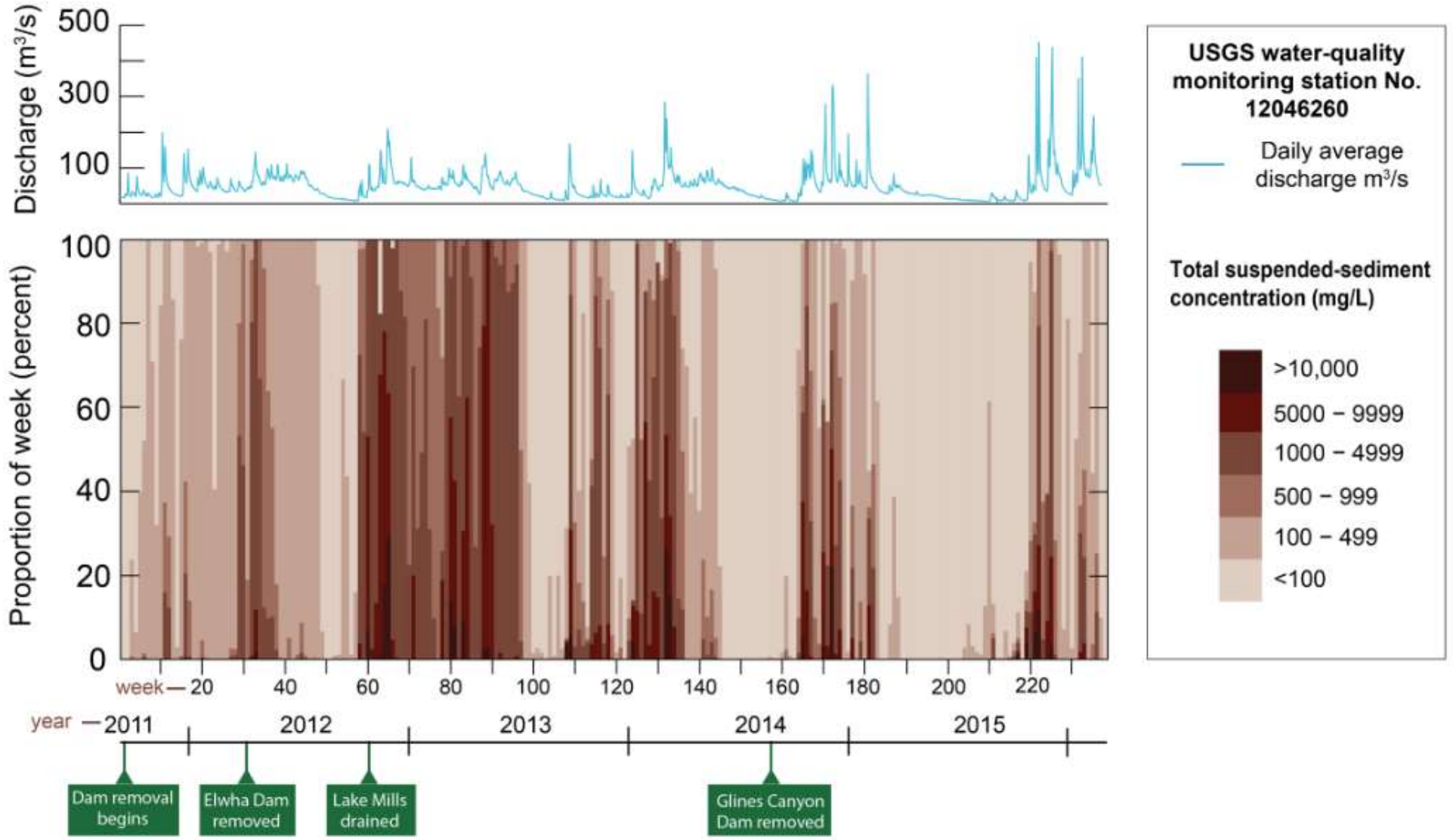
2014: project completed


Lake Mills, 2010
prior to dam removal

(Warrick et al., 2015)

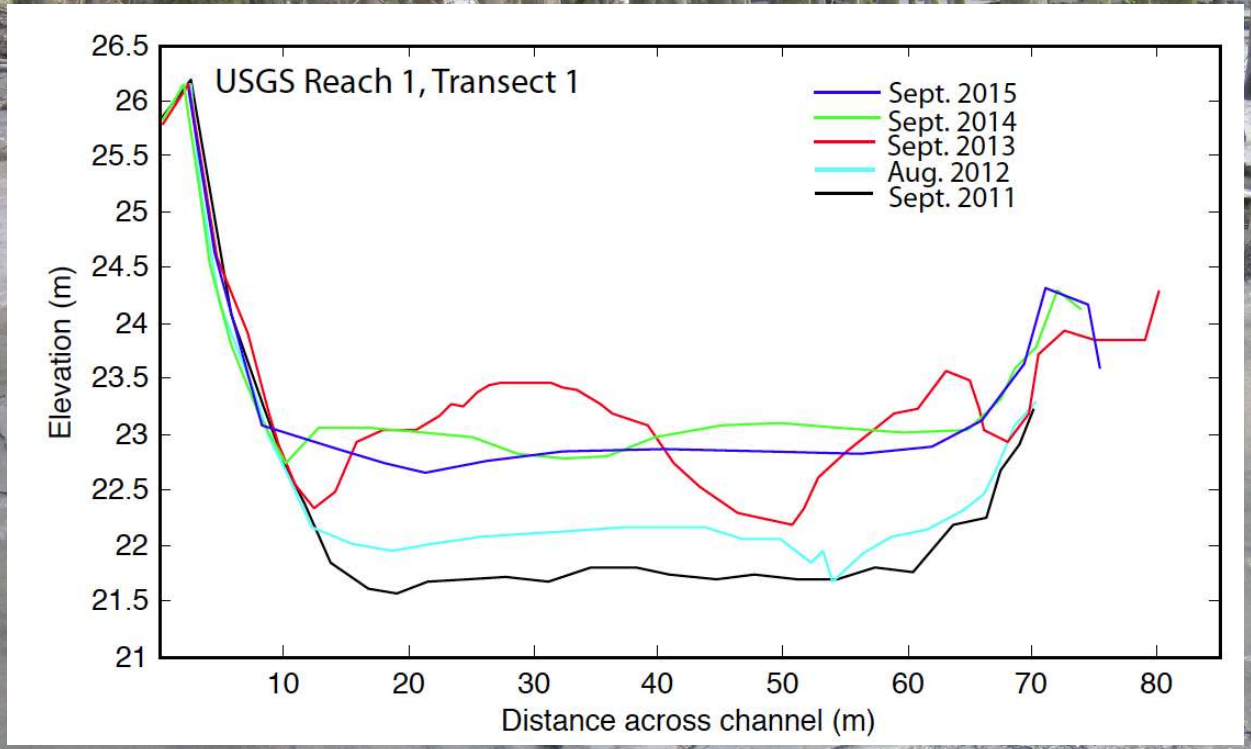

Biggest concern:
• 16 x 10^6 m^3 of sediment
• 50% sand and gravel
Dam (almost gone)
(Elaine Thompson, June 2014

Trends in suspended sediment transport



(source: Amy East, 2016)

channel aggradation ⟶ overbank deposition



Below dam site, 5.5 km above mouth

(source: Amy East, 2016)

(Elaine Thompson/Associated Press)

Common conditions / responses

- dams were located on steep rivers:

  slopes = 0.008 - 0.010

- sediment released was fine-grained:

  50-95% silt and clay

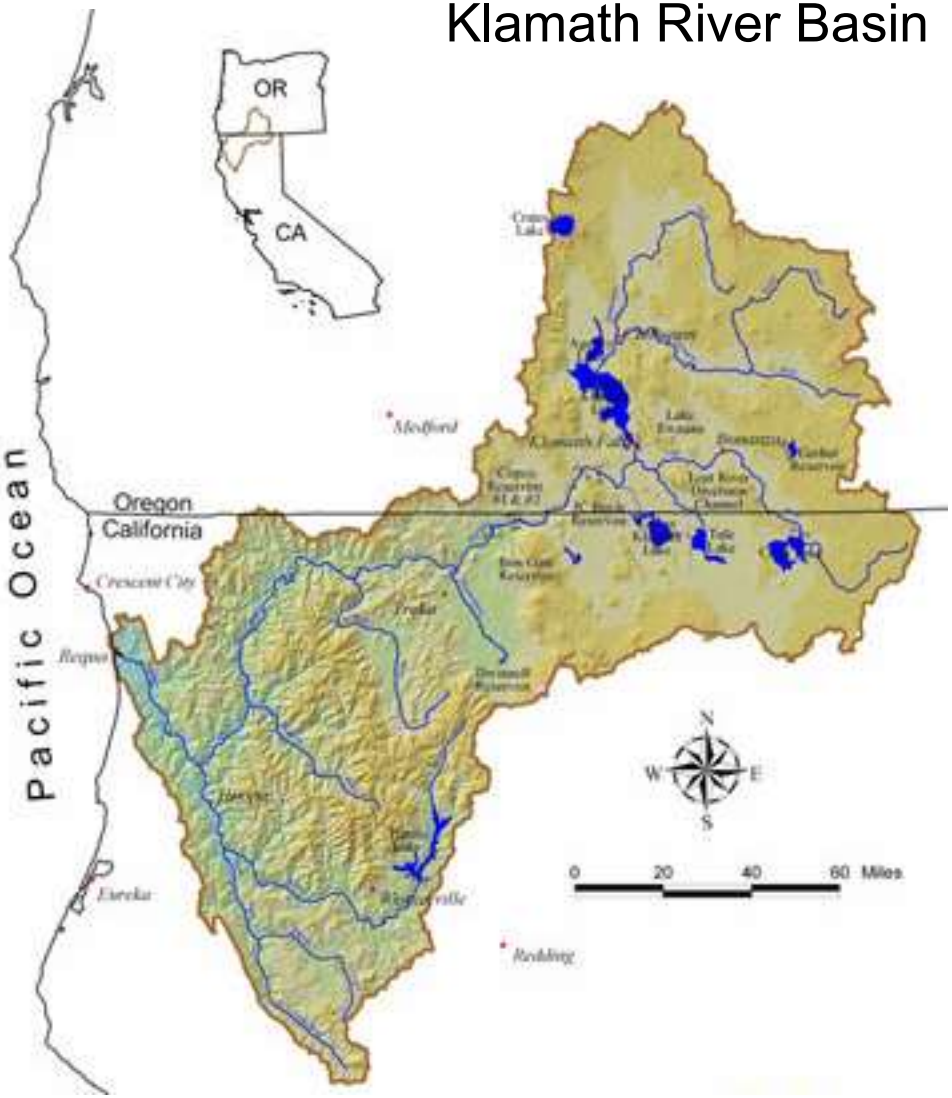
- distances to river mouths were short:

  5 - 50 km

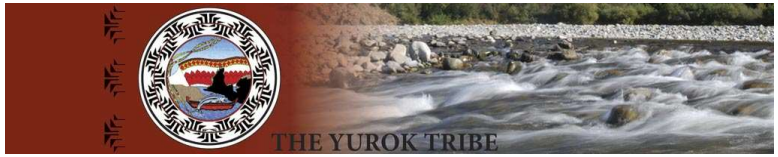
Dam removal projects in the US have generally been successful


Can success be sustained?

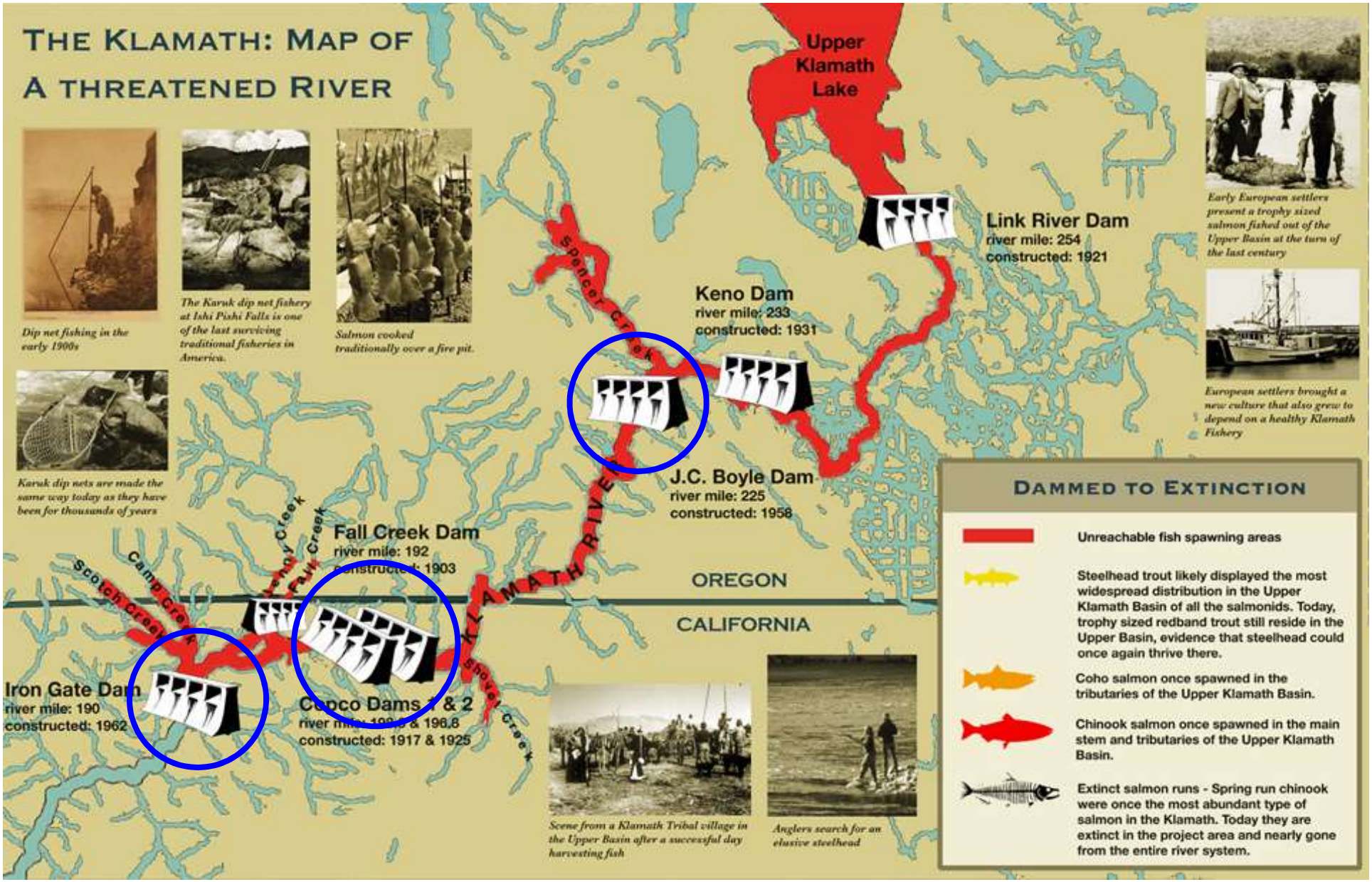
Klamath River Basin



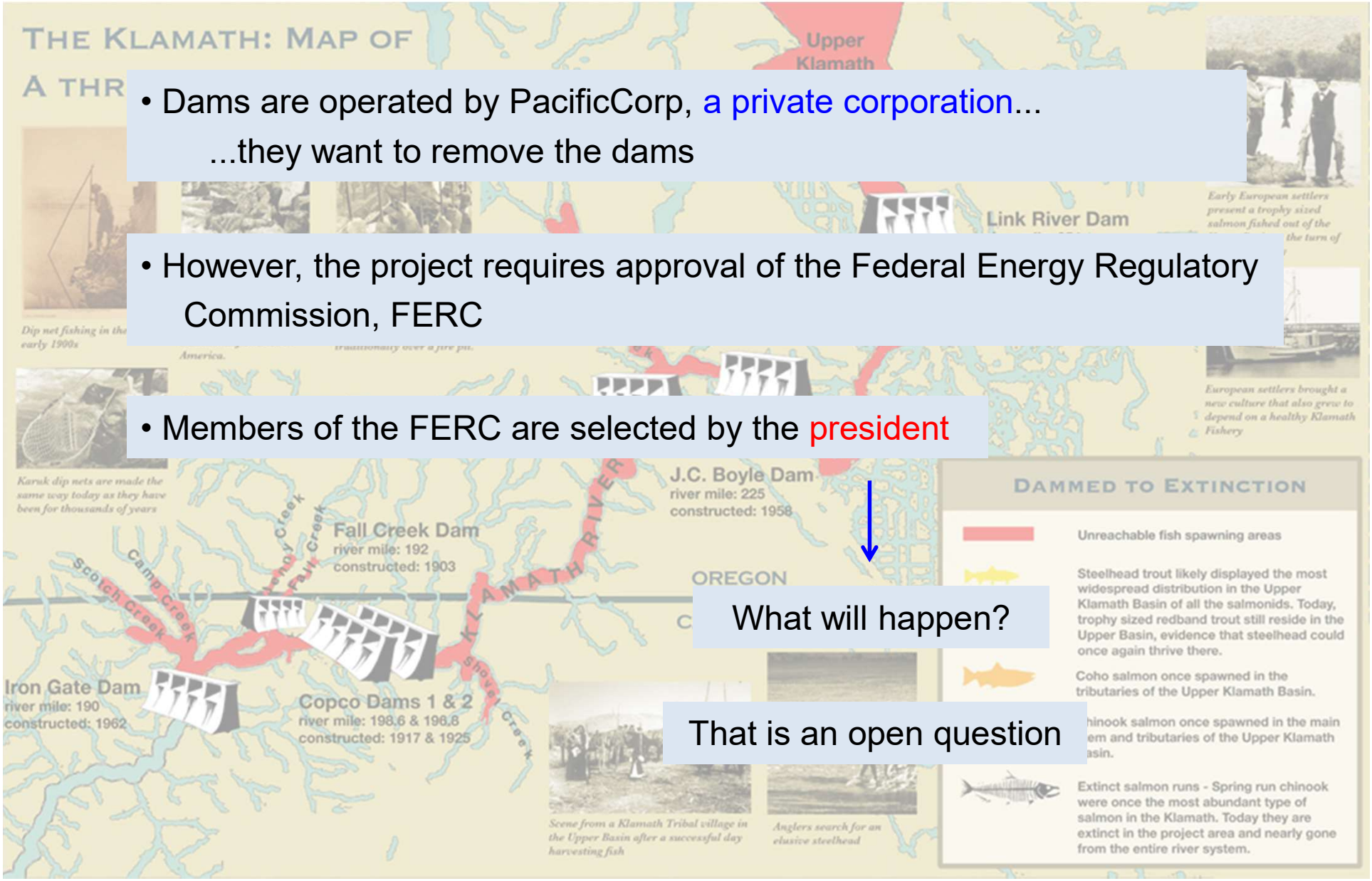
stakeholders



Plan: Remove four dams in the Klamath River basin



Plan: Remove four dams in the Klamath River basin



- Dams are operated by PacificCorp, a private corporation...
  ...they want to remove the dams
- However, the project requires approval of the Federal Energy Regulatory Commission, FERC
- Members of the FERC are selected by the president

What will happen?

That is an open question

Conclusions

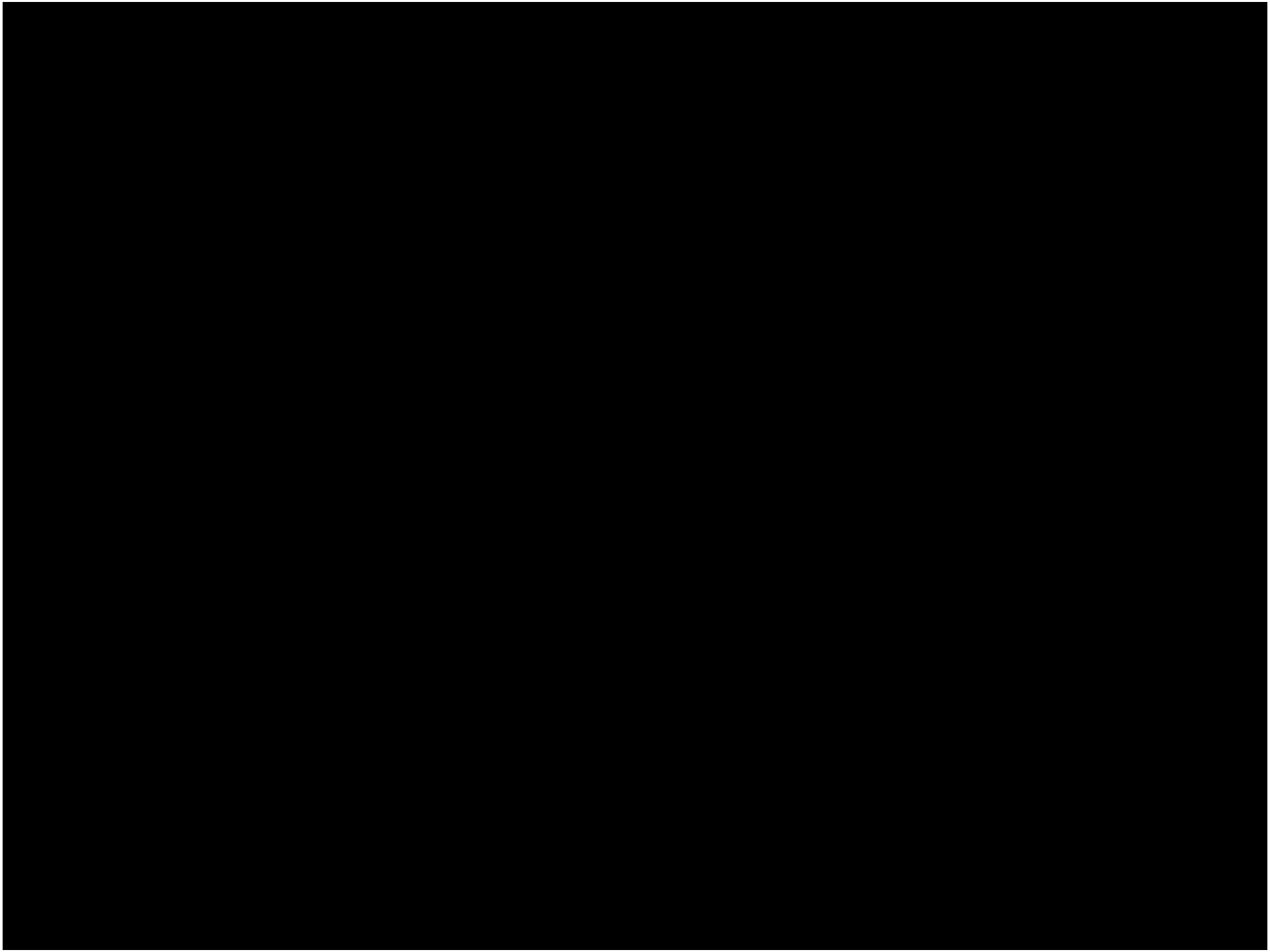
In the US, dam removal is motivated by environmental / economic concerns

- The costs of retro-fitting old dams to comply with modern environmental standards are generally much greater than the costs of removal

- In the future, the focus will mainly be on small dams (< 10 m in height)

- Proposals for removing large dams are controversial; process is driven more by ideology and politics than science.

Grazie! Sono felice di fare domande!

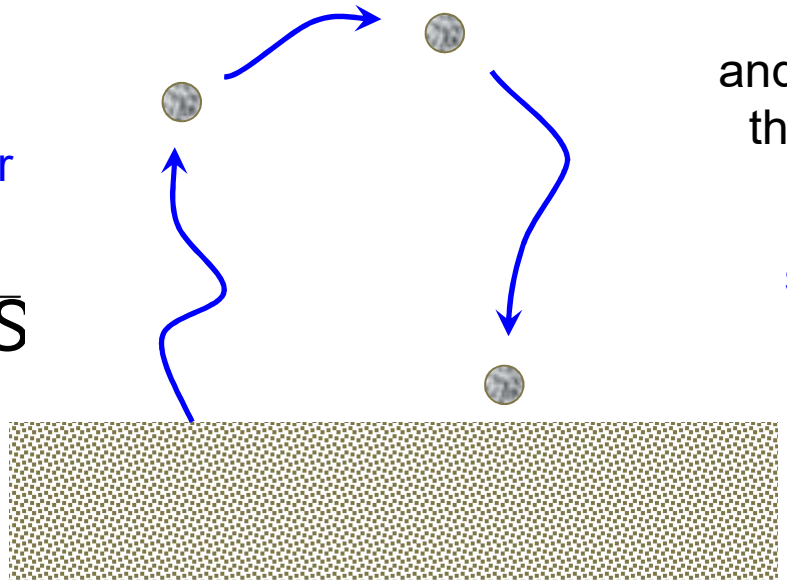


Suspended Sediment Transport

particles are put into suspension by turbulence

scales with shear velocity:

$$u_* = \sqrt{gHS}$$



and they fall back to the bed under their own weight

scales with fall velocity:

$$w_s = f(D, \upsilon)$$

a particle size D is likely to move in suspension if

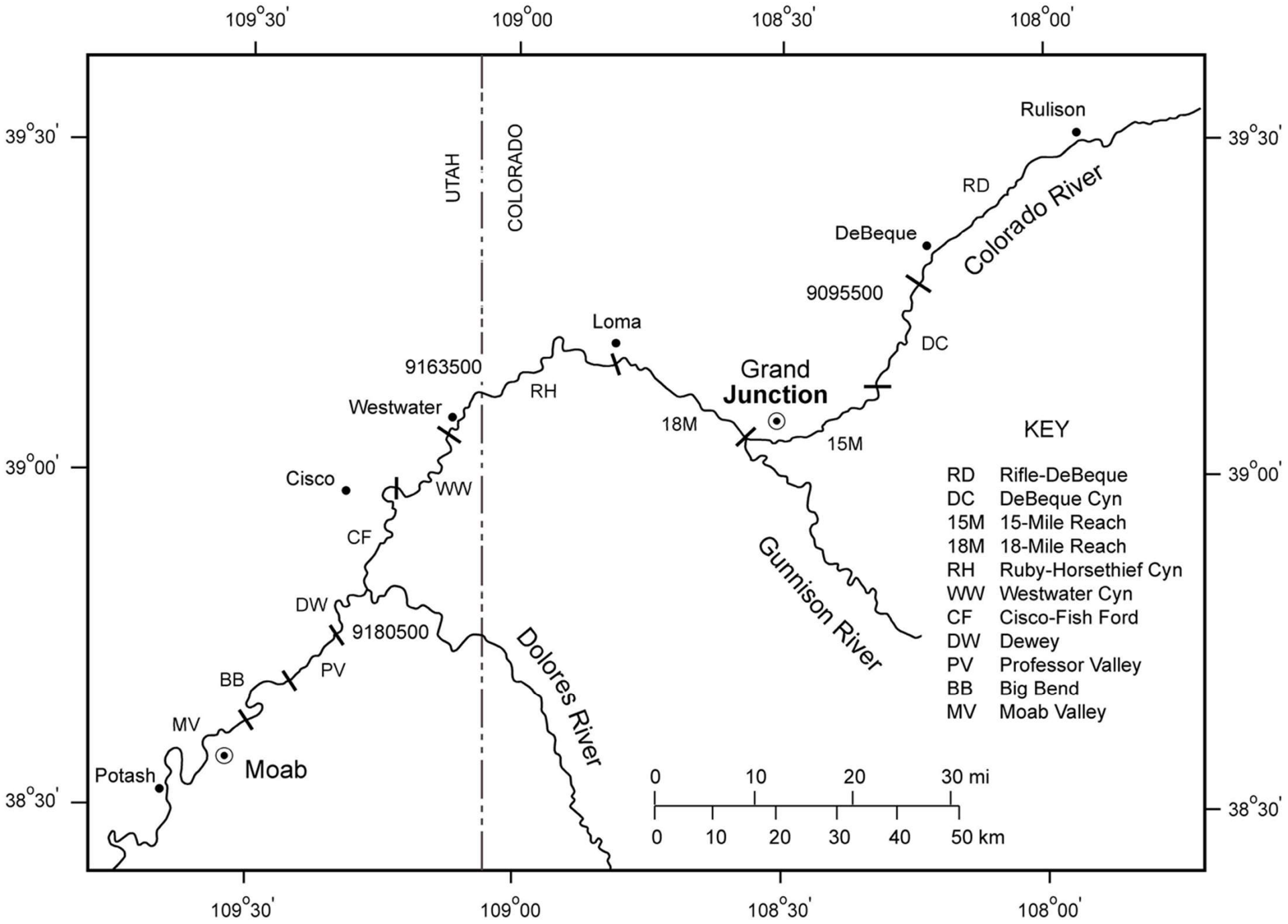
$$u_* > w_s$$

Colorado River

western Colorado – eastern Utah

Colorado Pikeminnow

Razorback Sucker


109°30'
109°00
108°30'
108°00'
39°30'
39°00'
38°30'
UTAH
COLORADO
Rulison
RD
Colorado River
DeBeque
9095500
DC
Loma
9163500
RH
Grand
Junction
18M
15M
Westwater
Cisco
WW
CF
DW
9180500
PV
BB
MV
Moab
Potash
Dolores River
Gunnison River
KEY
RD Rifle-DeBeque
DC DeBeque Cyn
15M 15-Mile Reach
18M 18-Mile Reach
RH Ruby-Horsethief Cyn
WW Westwater Cyn
CF Cisco-Fish Ford
DW Dewey
PV Professor Valley
BB Big Bend
MV Moab Valley
0 10 20 30 mi
0 10 20 30 40 50 km

Study area:

total length ~ 250 km

X-sect every 1.6 km

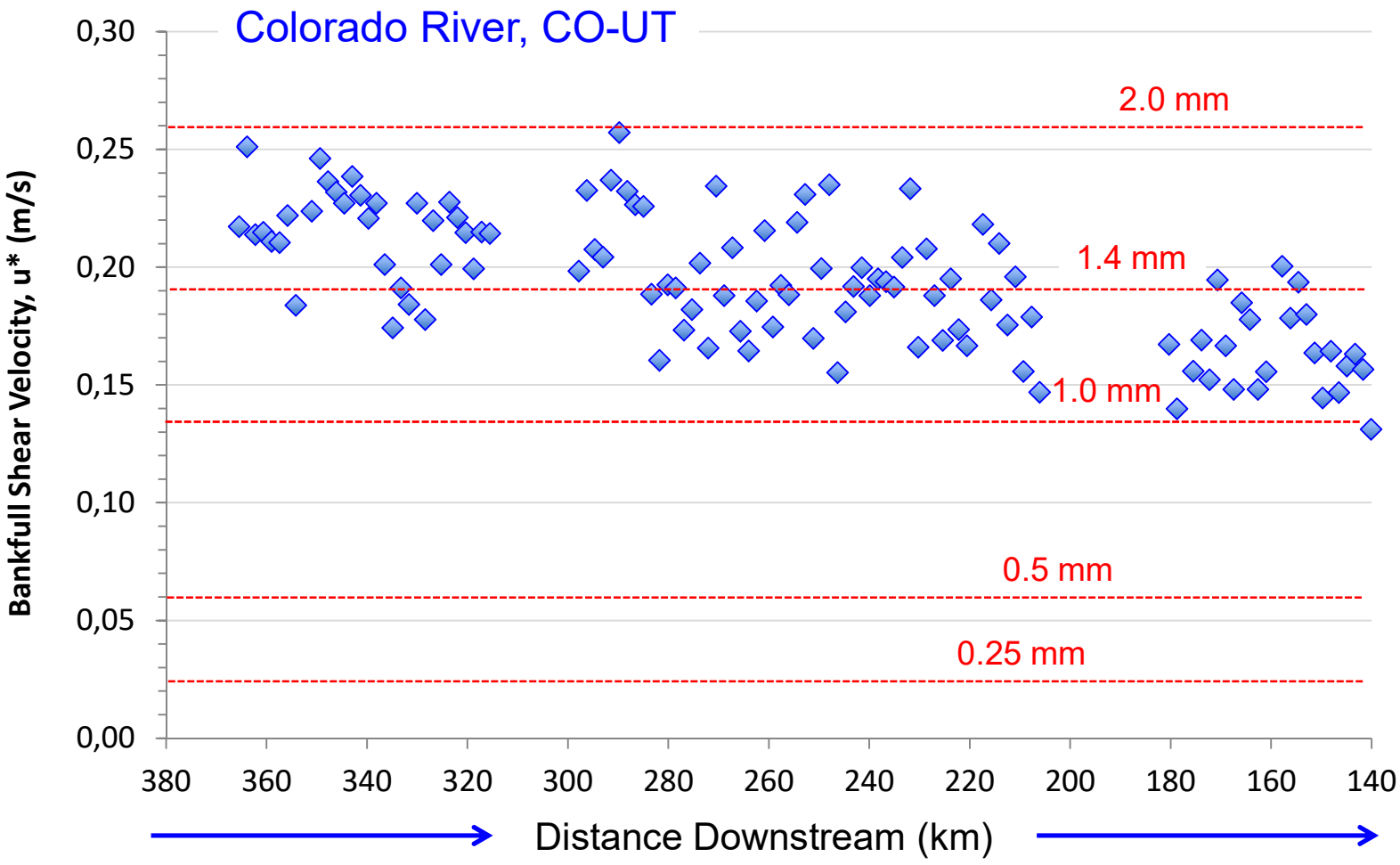
↓

- bankfull *H*
- local slope, *S*

↓

$$u_* = \sqrt{gHS}$$

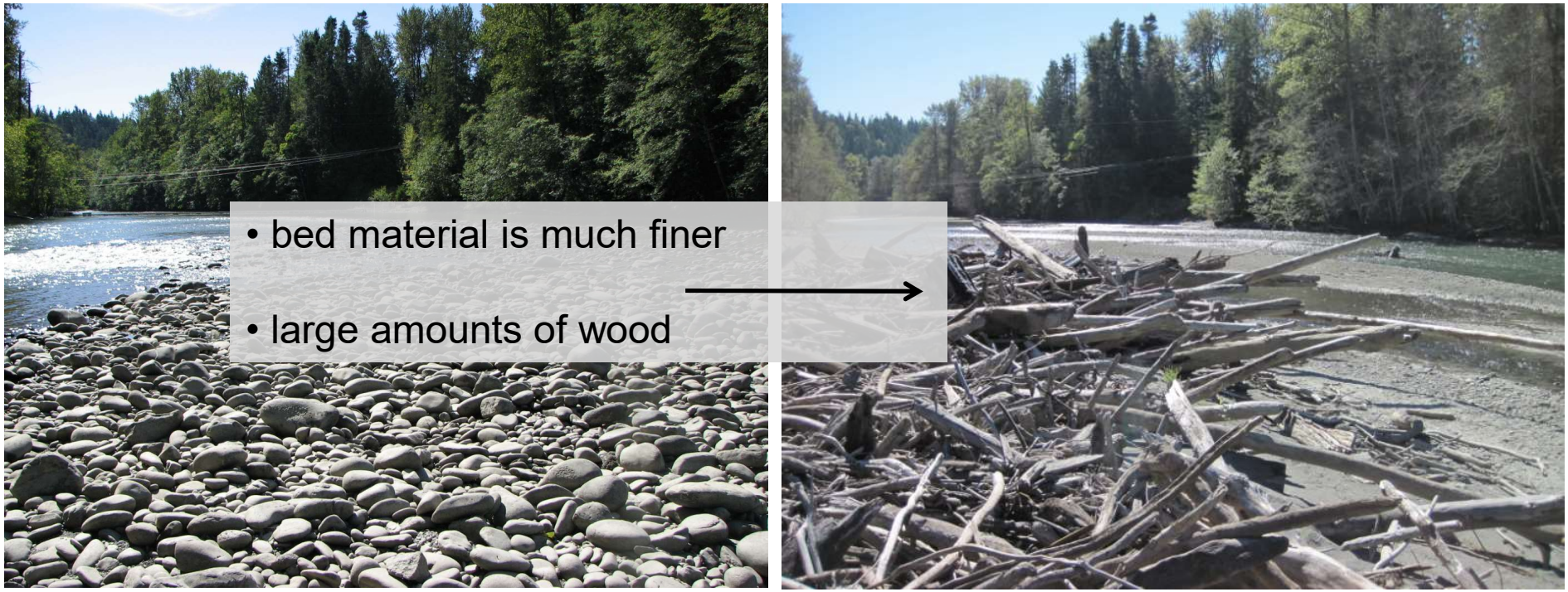
What sizes are likely to be in suspension at bankfull discharge?



Elwha main channel, downstream of upper dam

September 2011

September 2014



5.5 km upstream from Elwha River mouth

(source: Amy East, 2016)

Study area:

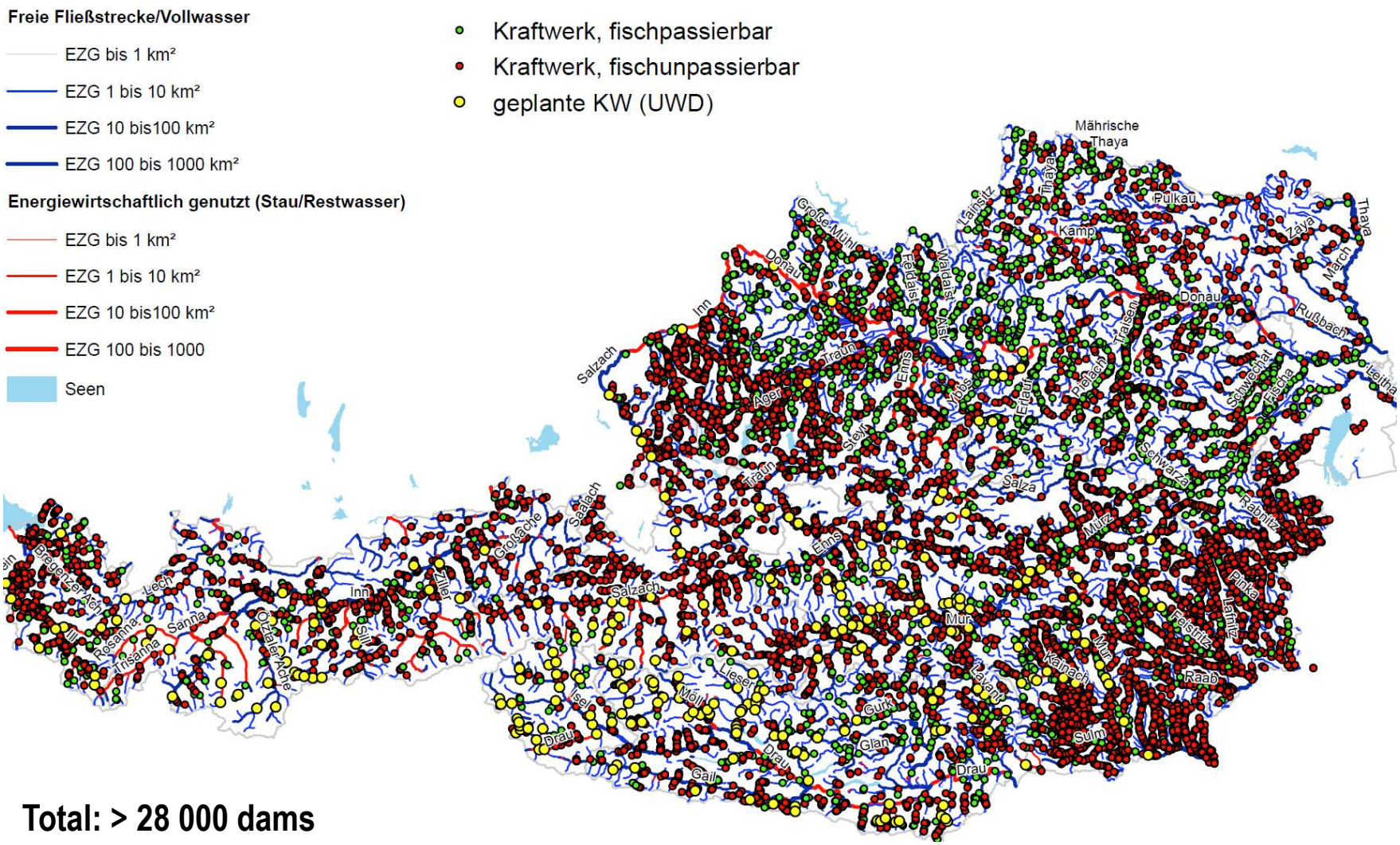
total length ~ 250 km

X-sect every 1.6 km

- bankfull H
- local slope, S

$\rightarrow$ $u_* = \sqrt{gHS}$

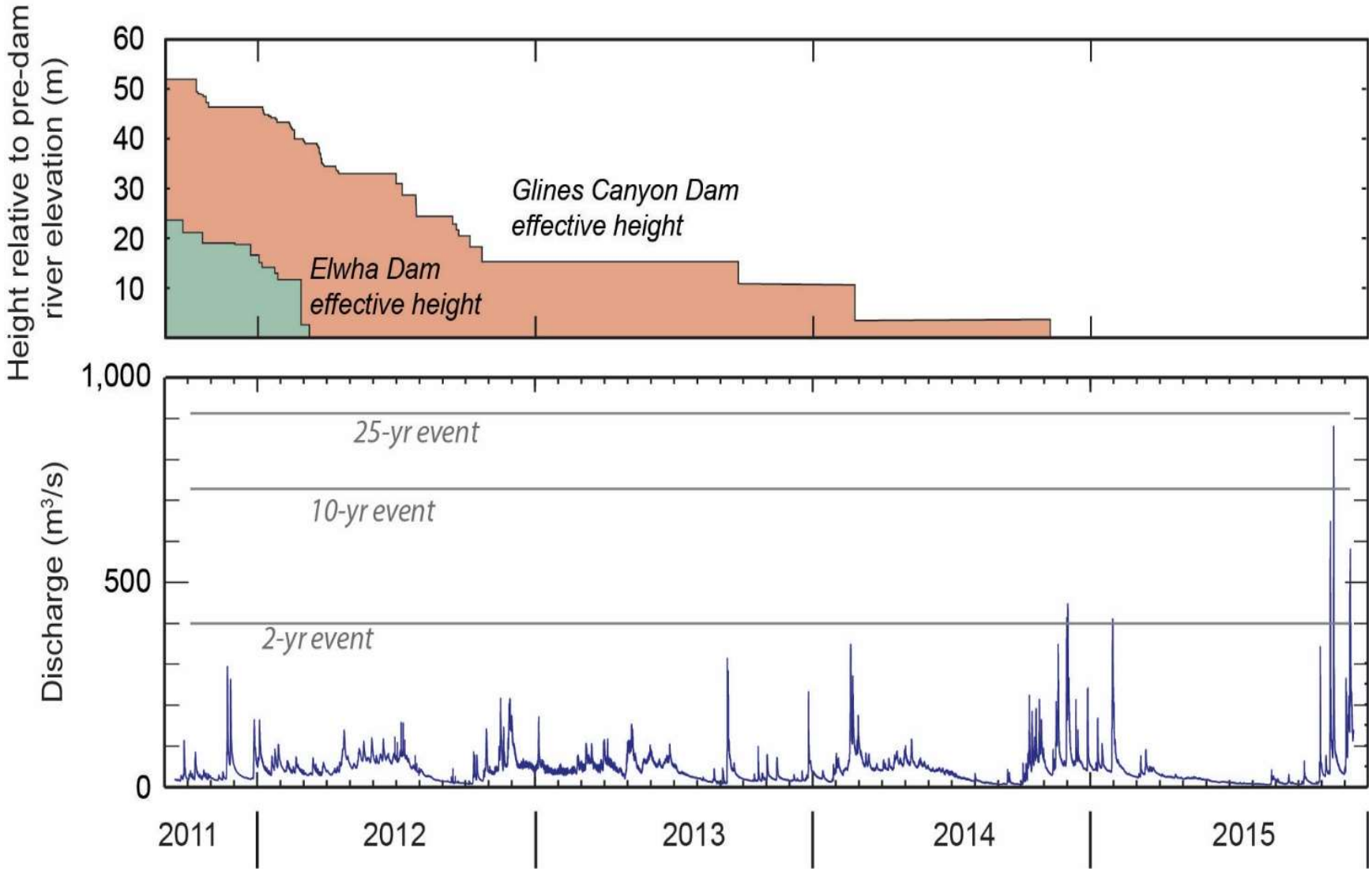
Dams in Austria



Total: > 28 000 dams

Austrian Ministry of Agriculture, Water Management and Environment

Sequence of events



(source: Amy East, 2016)

KLAMATH RESTORATION AGREEMENTS

Restoring a River and Revitalizing Communities

- Dam removal could mobilize one-third to two-thirds of the 13.1 x 10^6 yd^3 of sediment trapped behind the dams and transport it to the Pacific Ocean.

- The majority of the material behind the dams is fine grained and would not be deposited in the river channel or estuary, it would float out to sea.

but! ... it's190 miles (300 km) to the Pacific Ocean!

http://www.klamathrestoration.org/index.php/issues/sediment-behind-the-dams