Reservoir Sediment Management Options For Long-term Sustainability

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River Engineering and Restoration Section

August 2017

US Army Corps of Engineers

BUILDING STRONG®

Sediment Management Options

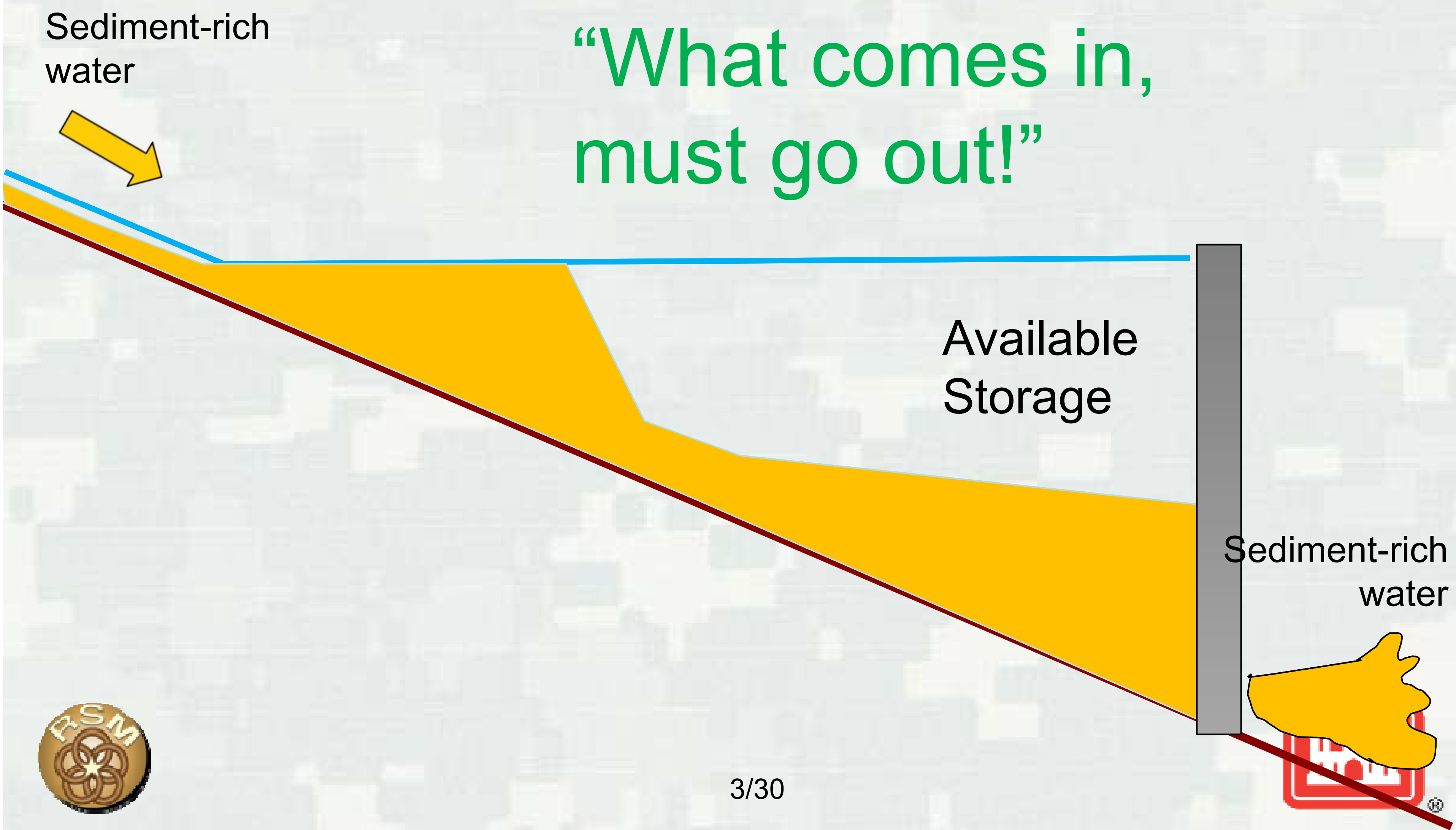
Minimize sediment inflow

React to sediment accumulation

Sustainable Management

Reservoir Sediment Sustainability

“What comes in, must go out!”



Lake Dredging Costs

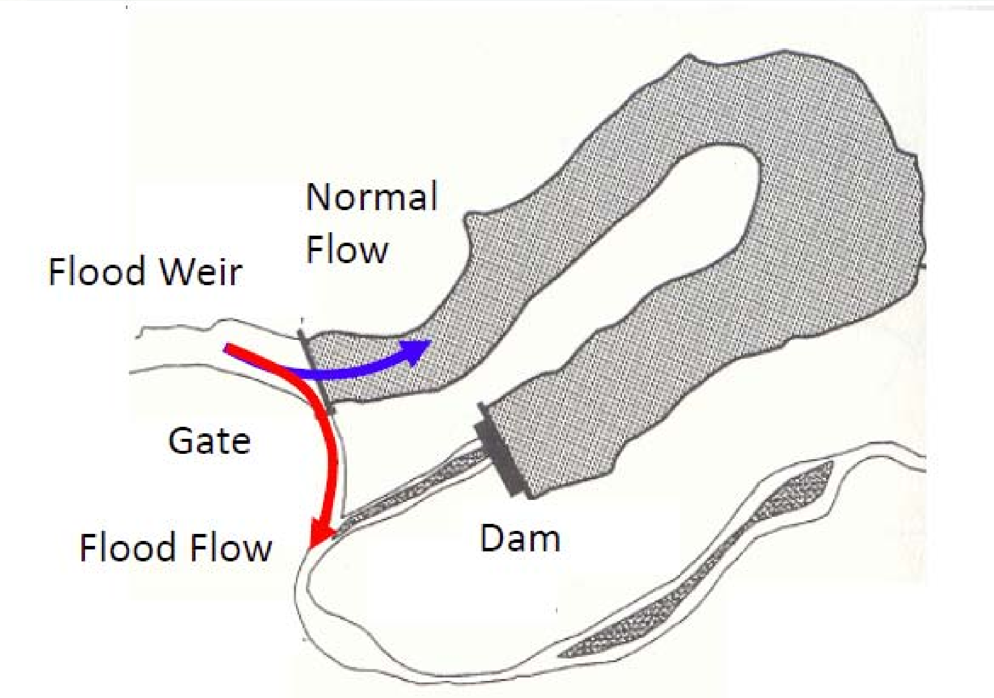
- John Redmond: $6.5/cu yd
- Mission Lake: $6.5/ cu yd
- Lake Seminole: $27/ cu yd
- Kanopolis: $229 / cu yd

Dredging in Perspective

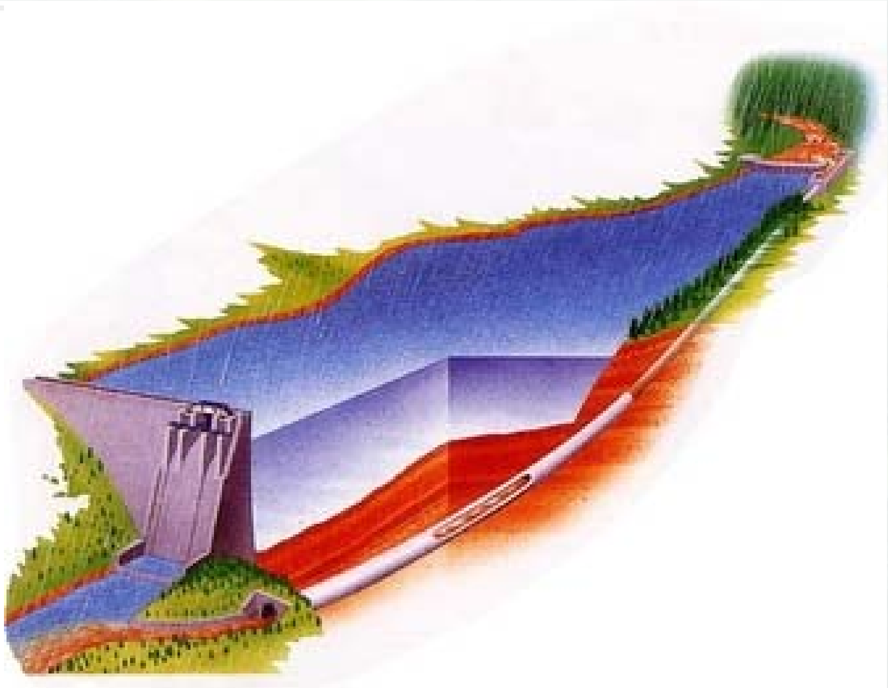
- Cost for dredging all 8 federal reservoirs in the Kansas River Basin:
  - ► At $6.5/yd^3$
  - ► $105+++ million/year
  - ► $151/person each year

Health and Environment- Enviornment	$	4,440,934
Department of Agriculture	$	9,894,366
Kansas Water Office	$	1,154,576
Department of Wildlife, Parks, and Tourism	$	5,151,993
	$	20,641,869

Sediment Bypass



Sediment bypass at Nagle Dam, South Africa
(Figure from Annandale 2013)

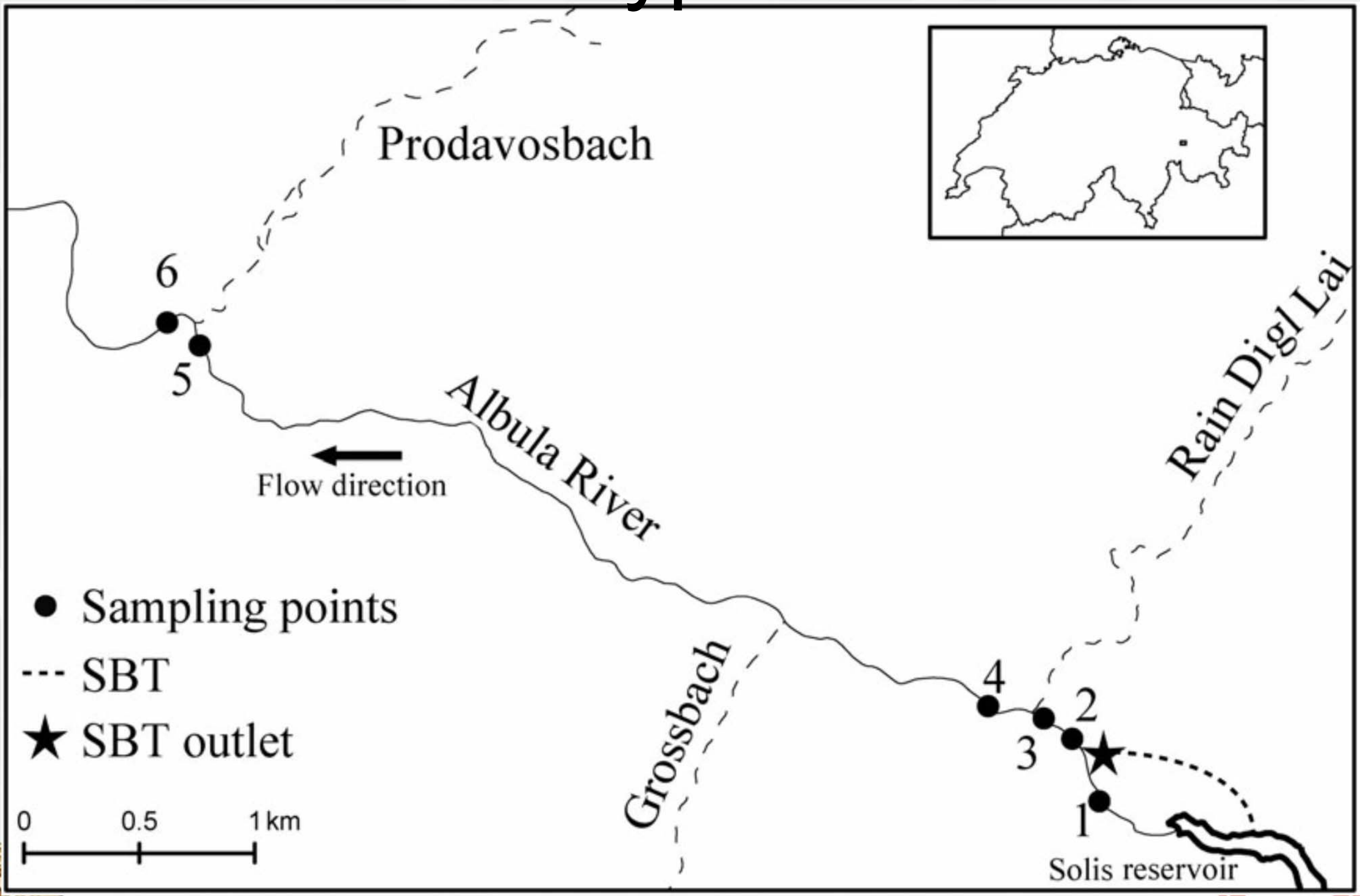


Sediment bypass tunnel at Miwa Dam, Japan
(Figure from Annandale 2011)

Sediment Bypass

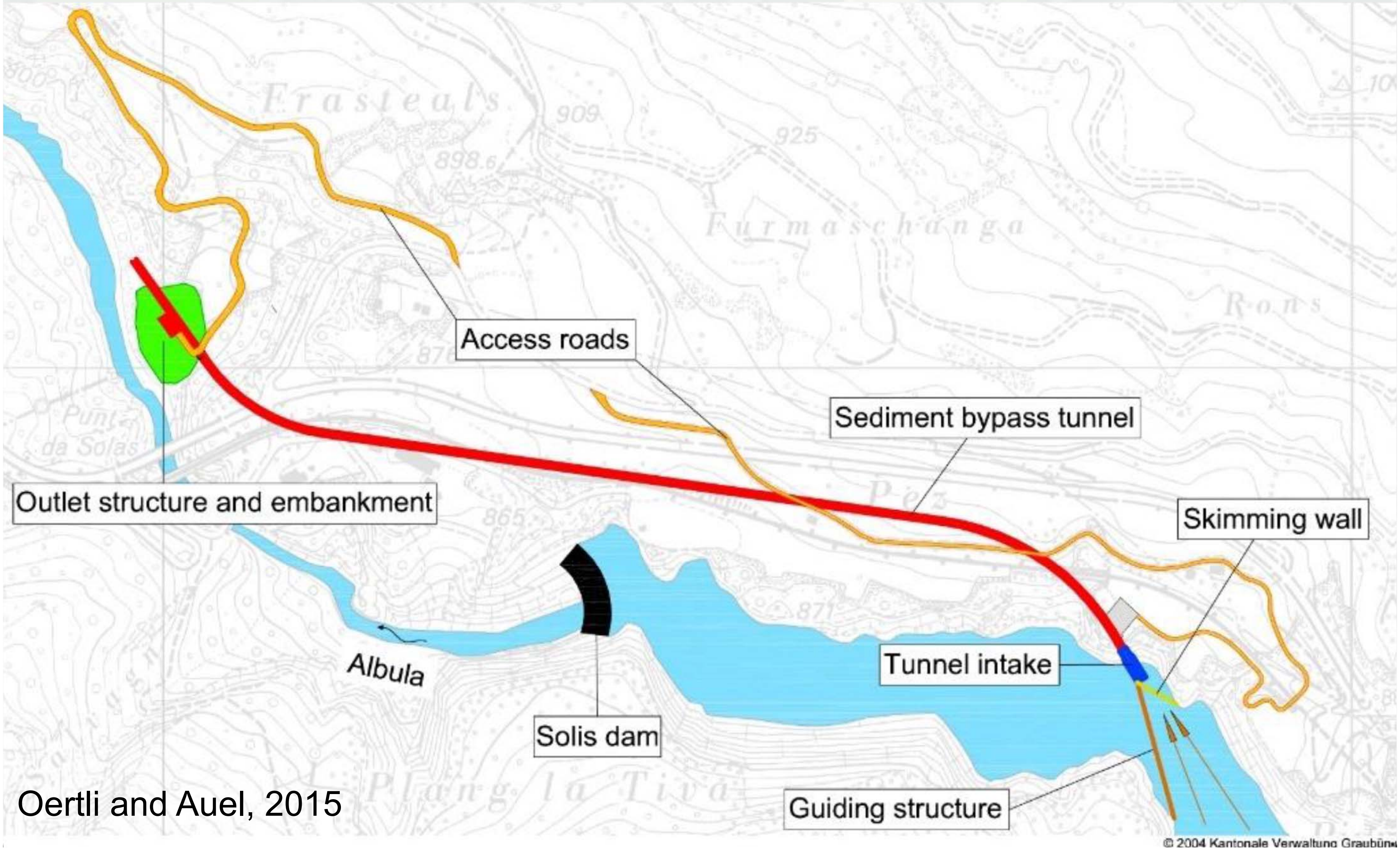
- PRO
  - ► Passes sediment during high flows (more natural)
- CON
  - ► Very expensive retrofit for existing facilities
  - ► Doesn't pass 100% of sediment

Sediment Bypass Tunnel

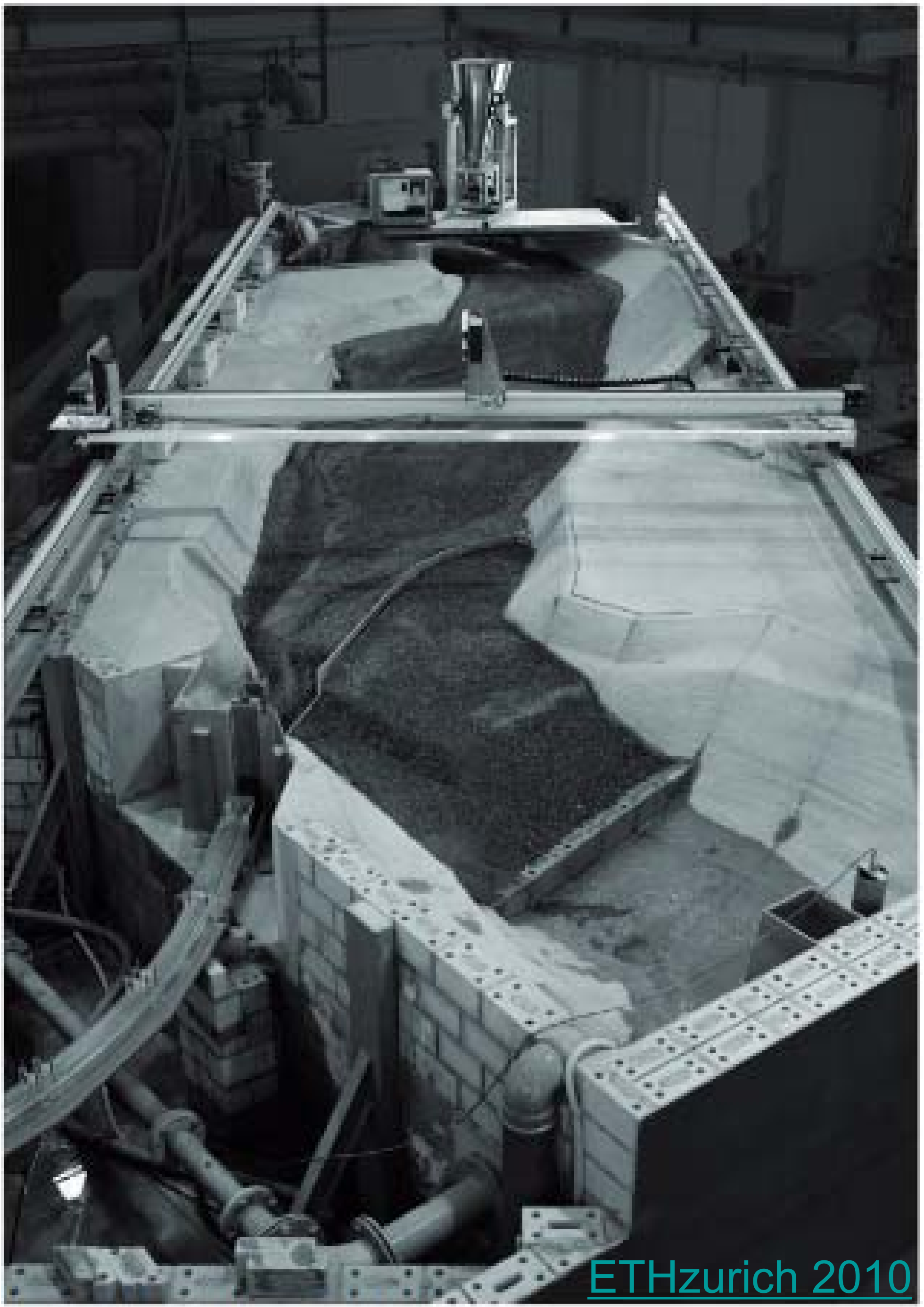


 Martin, Doering, and Robinson, 2017

Solis Reservoir, Switzerland

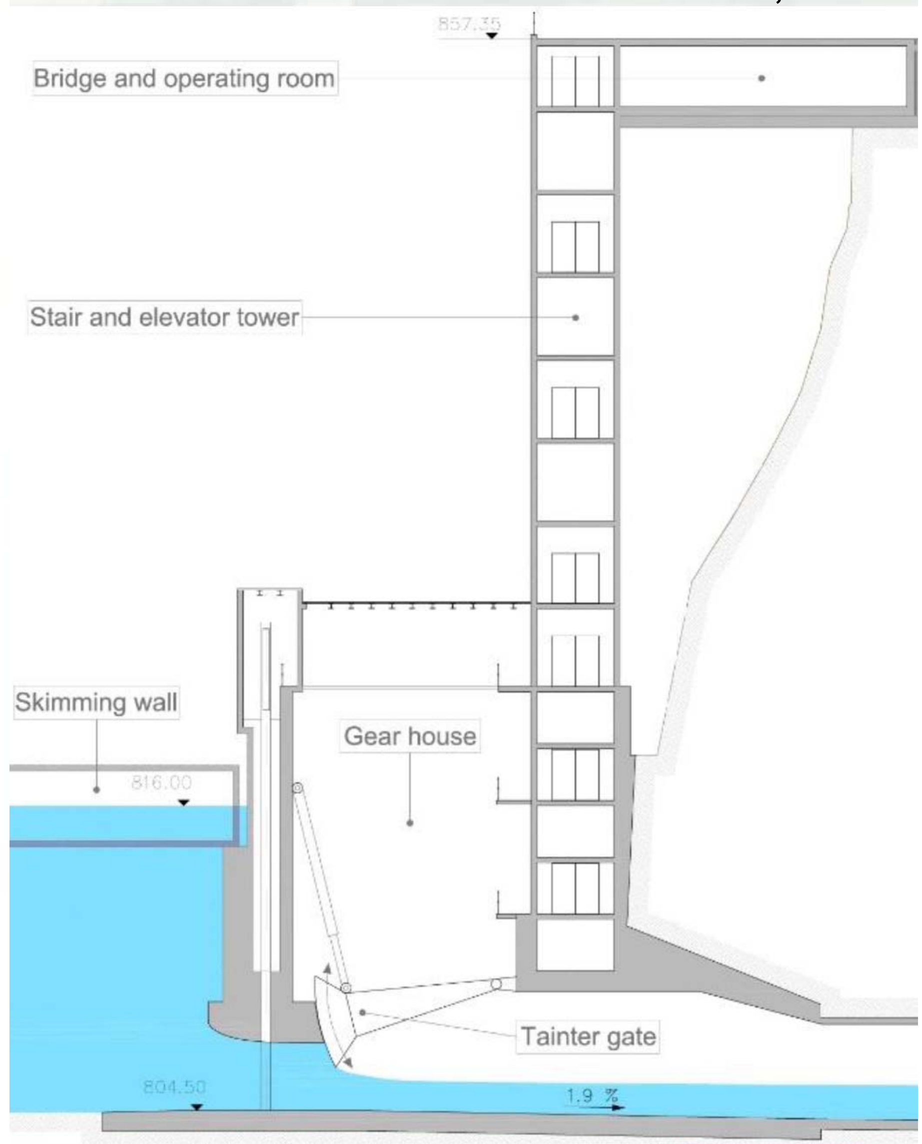


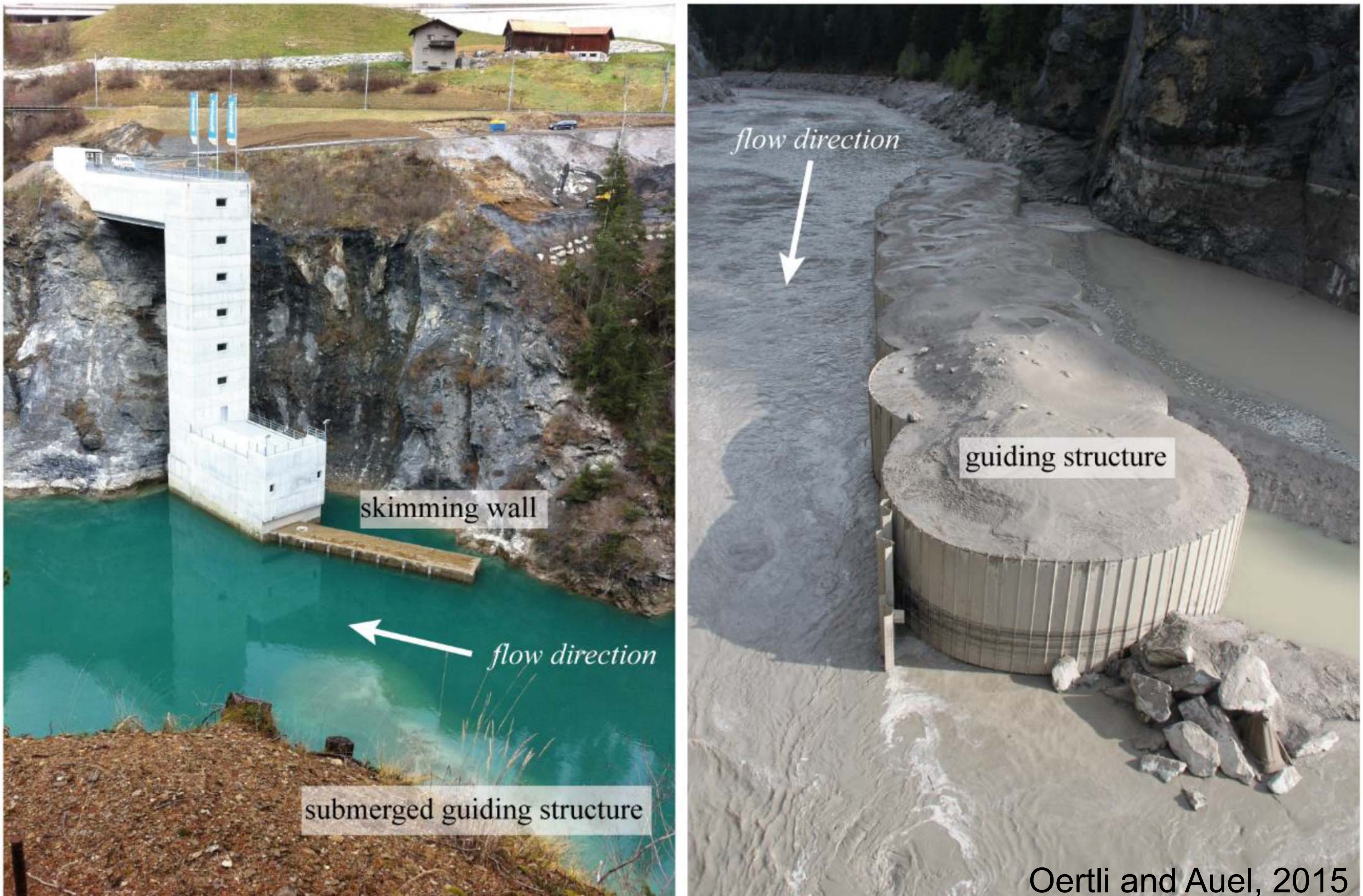
Oertli and Auel, 2015



hydraulic model overview

Oertli and Auel, 2015





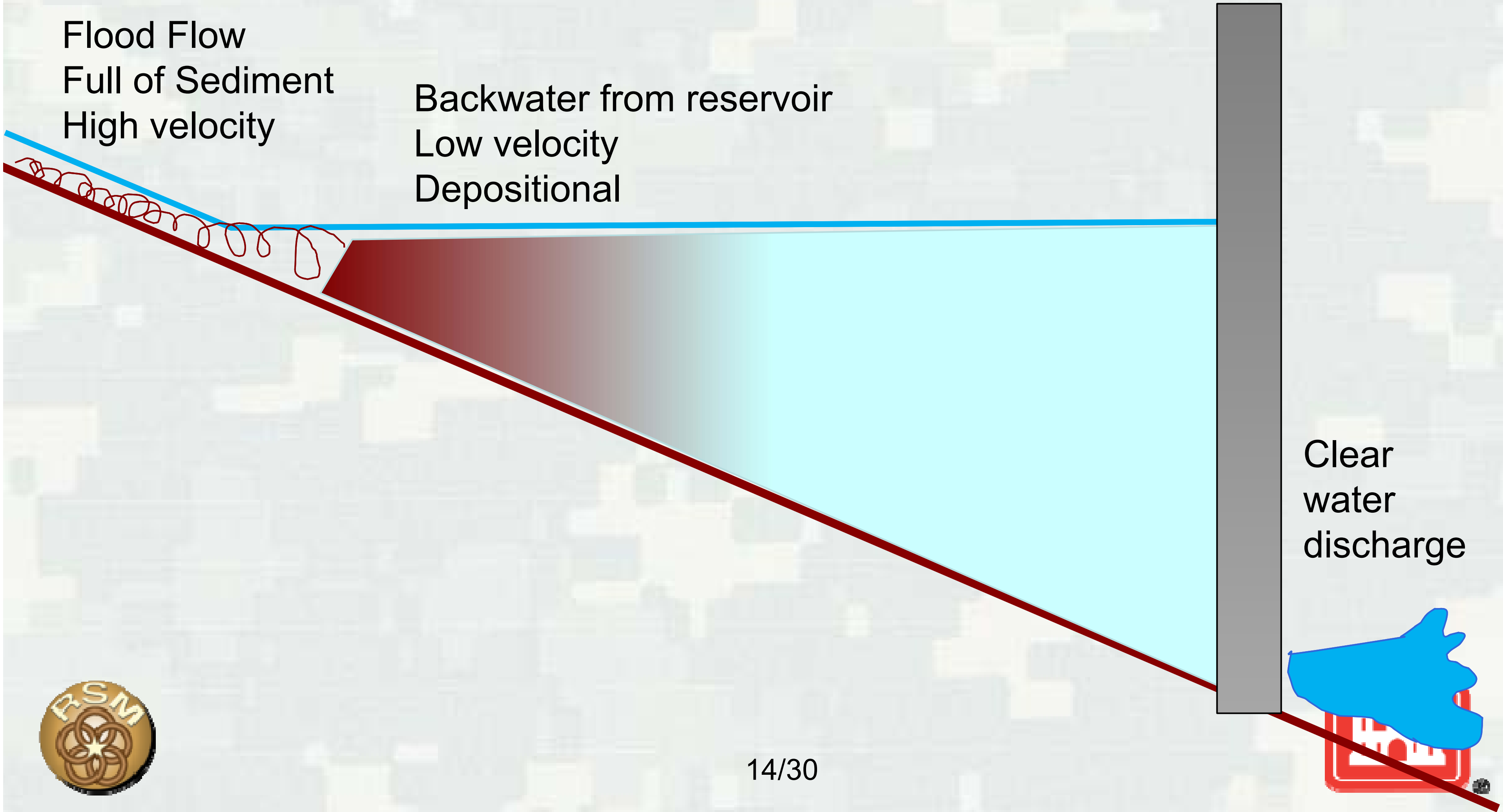
Oertli and Auel, 2015

Downstream Discharge

Effectiveness

1987 Flood (No SBT)	2014 Flood (with SBT)
▪ 252 m^3/s	▪ 288 m^3/s
▪ 248,000 m^3 deposition	▪ 102,000 m^3 deposition

Sediment Pass-through (aka routing, aka sluicing)



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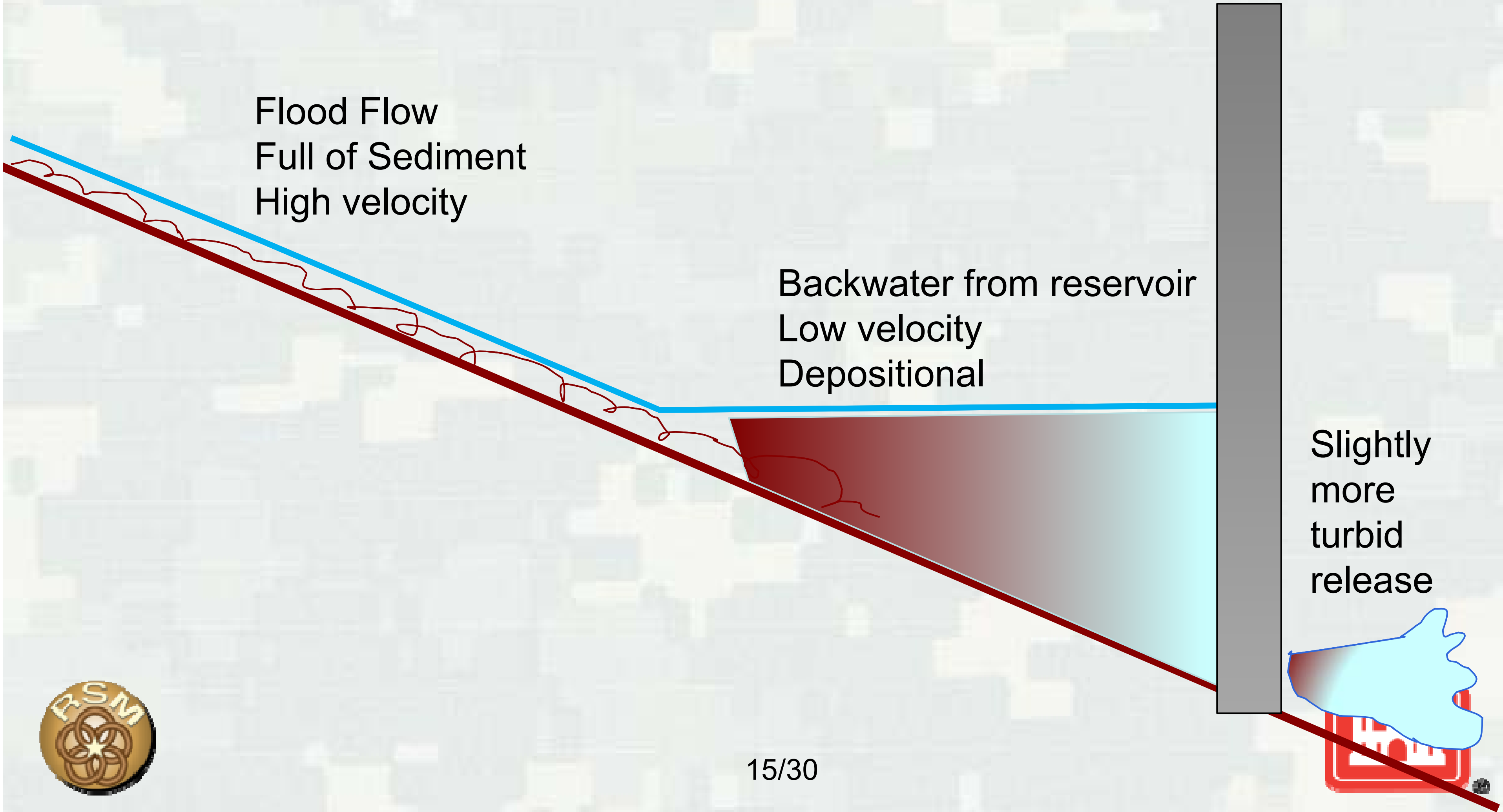

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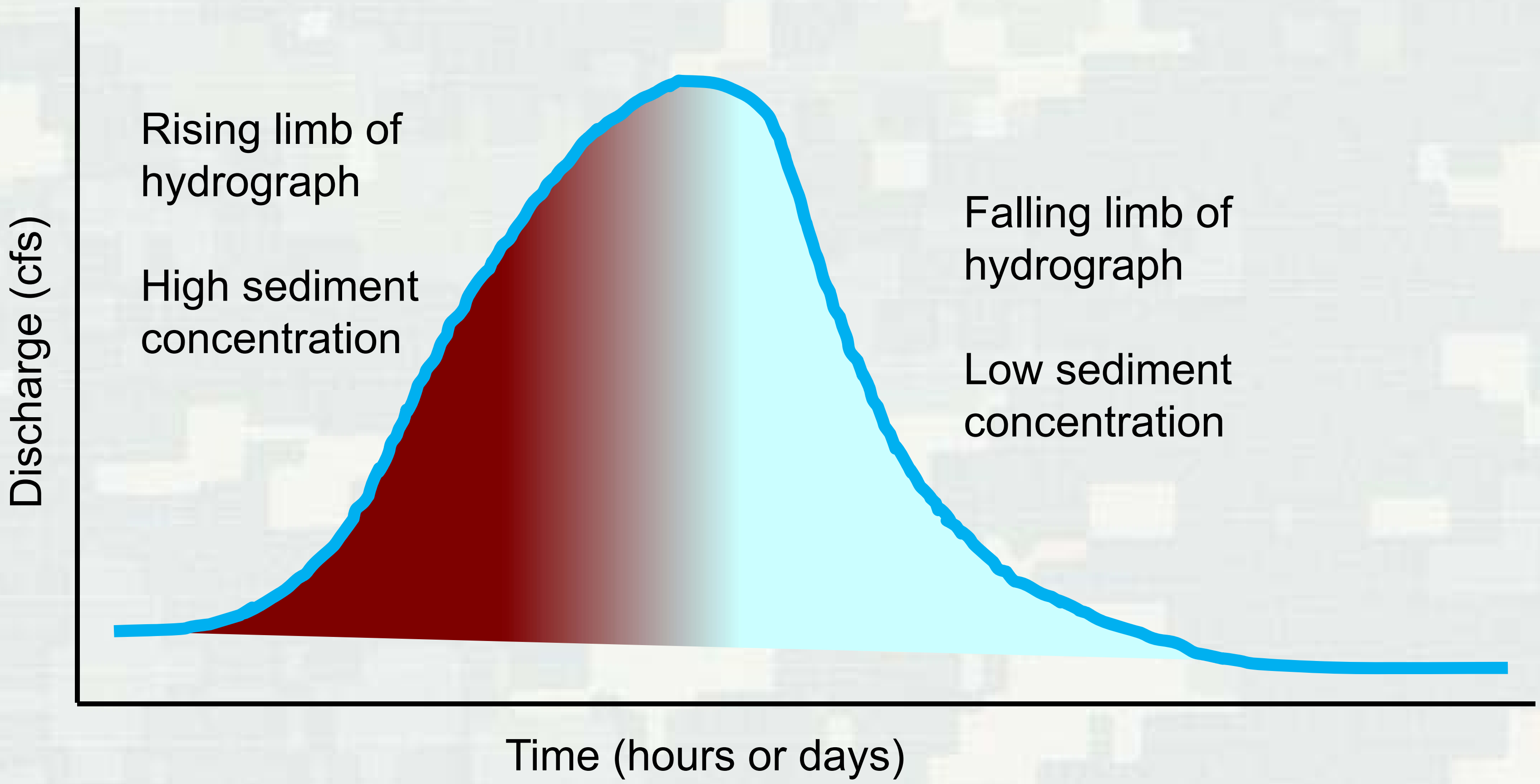

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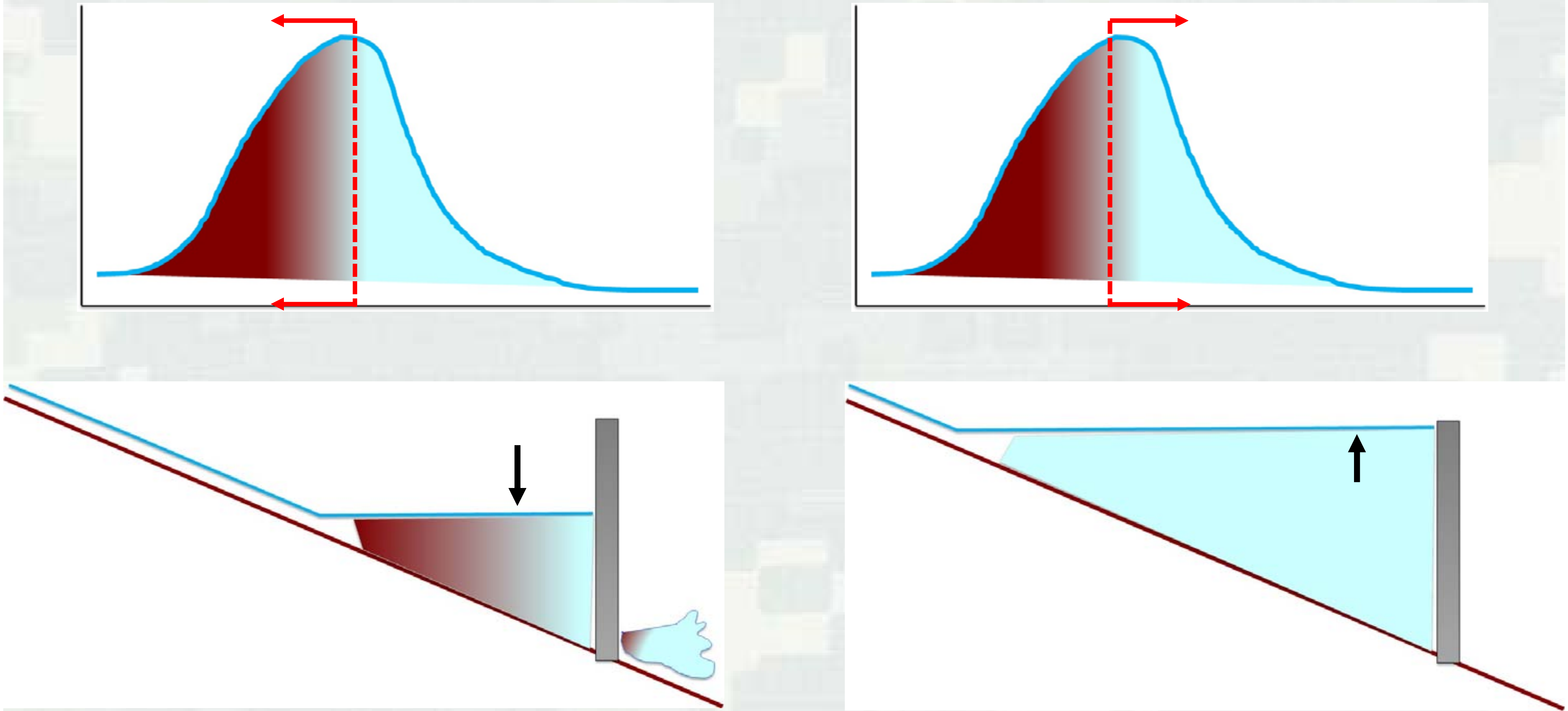
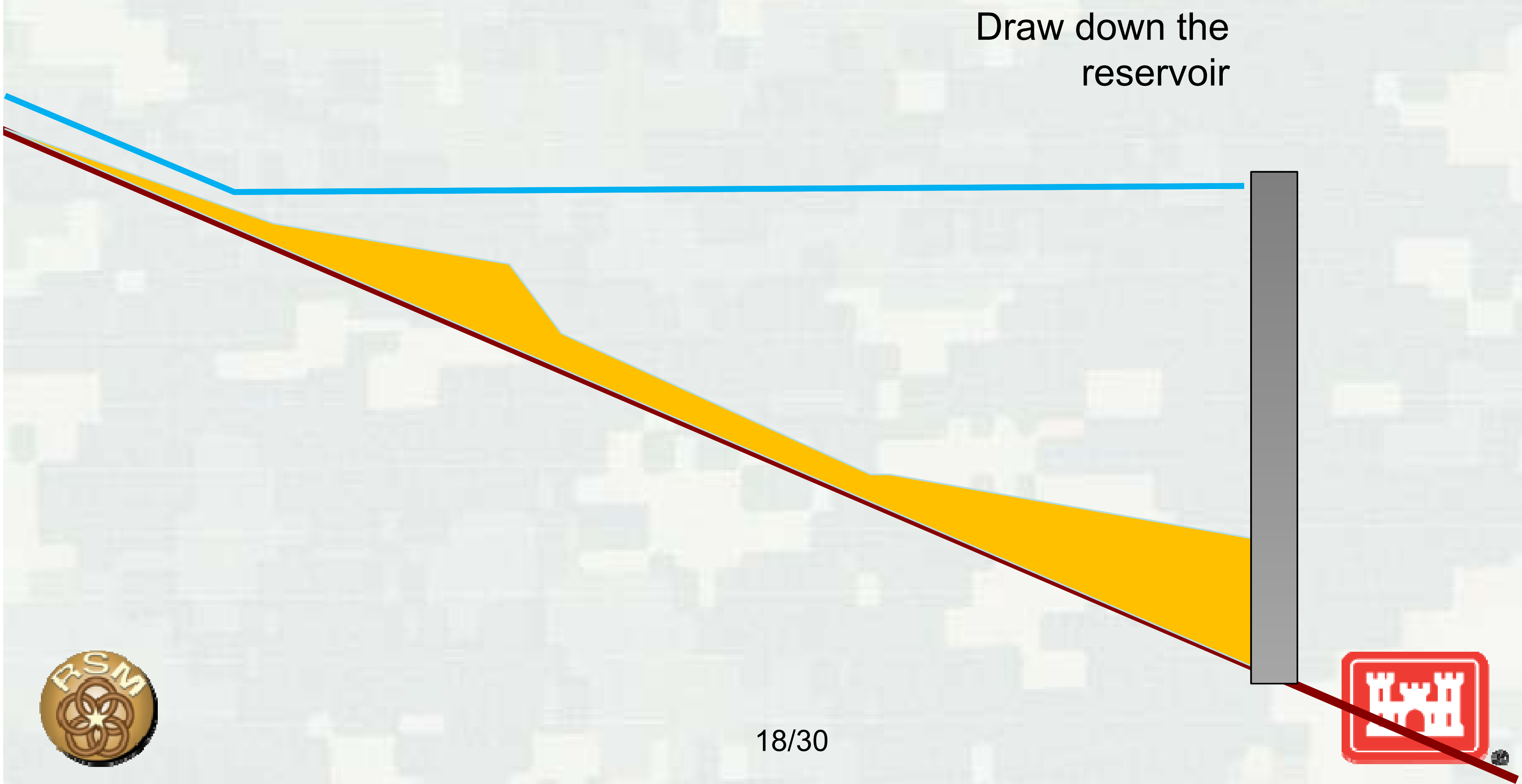


Reservoir Drawdown Flushing



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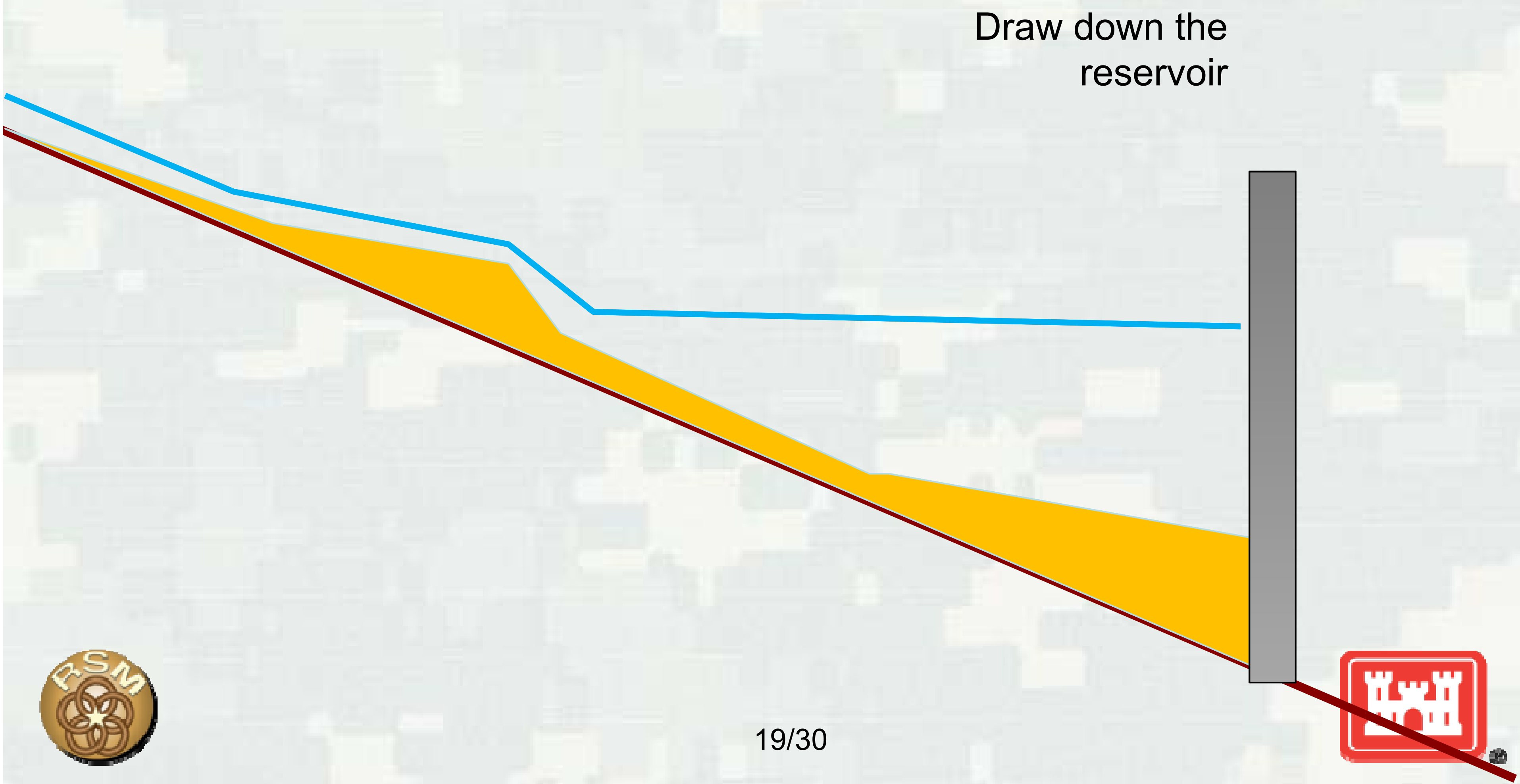

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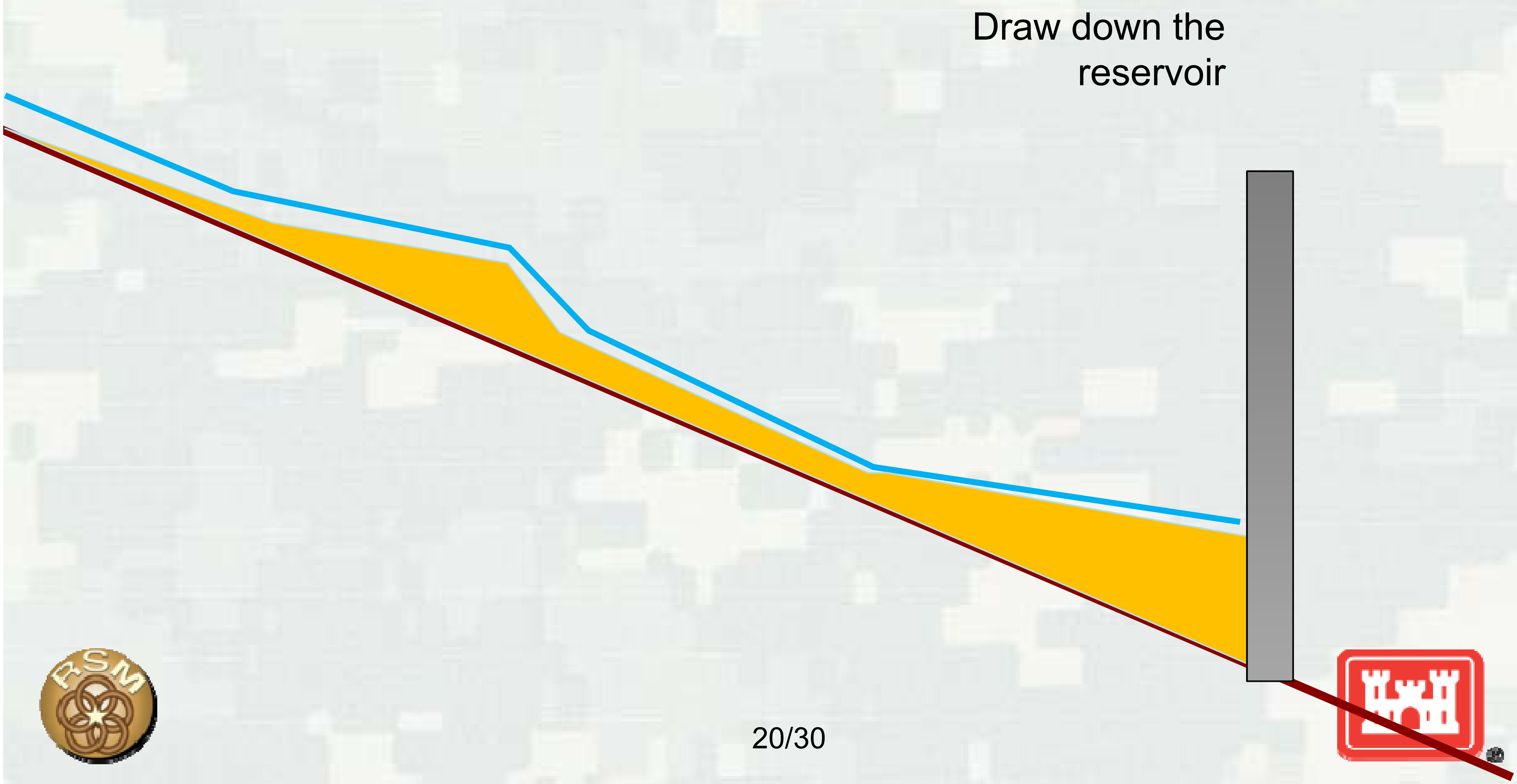

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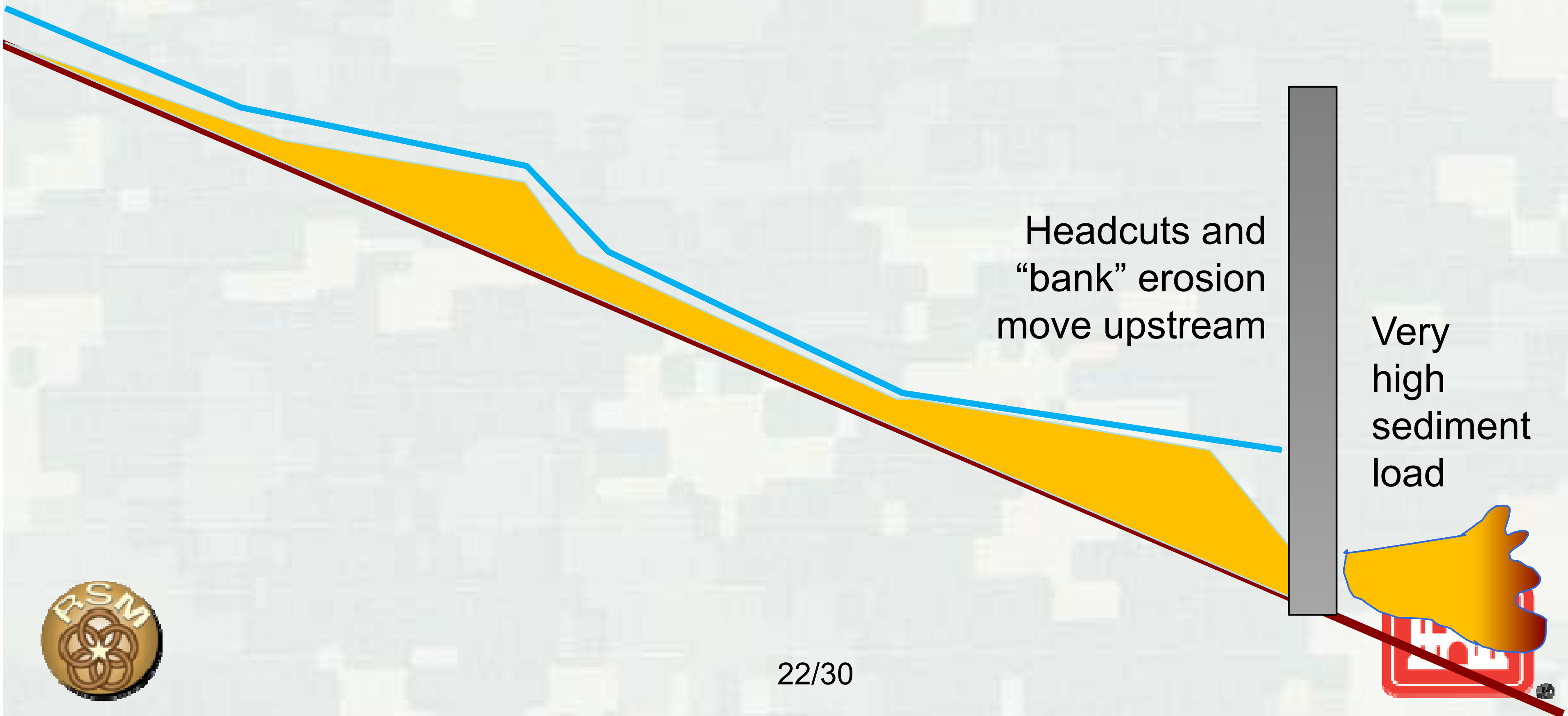

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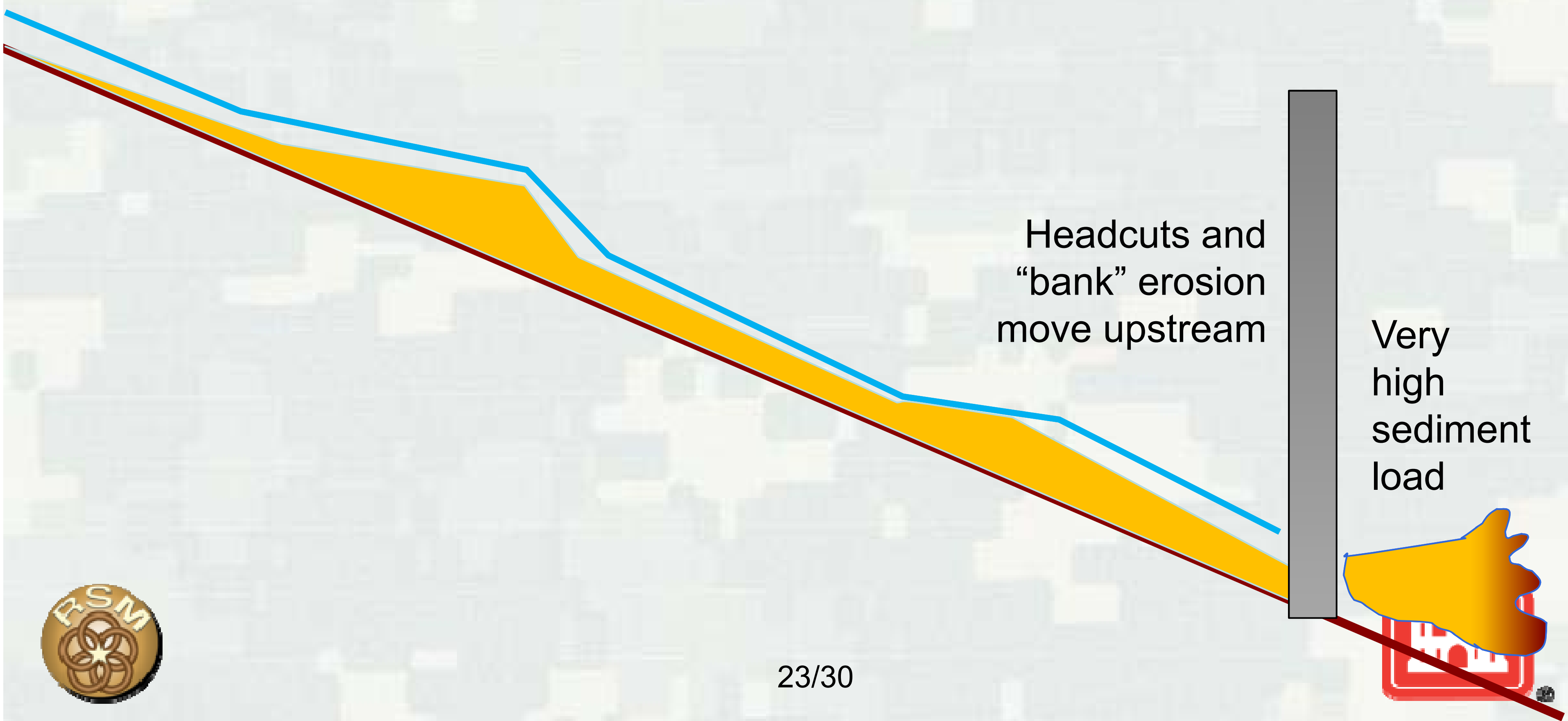
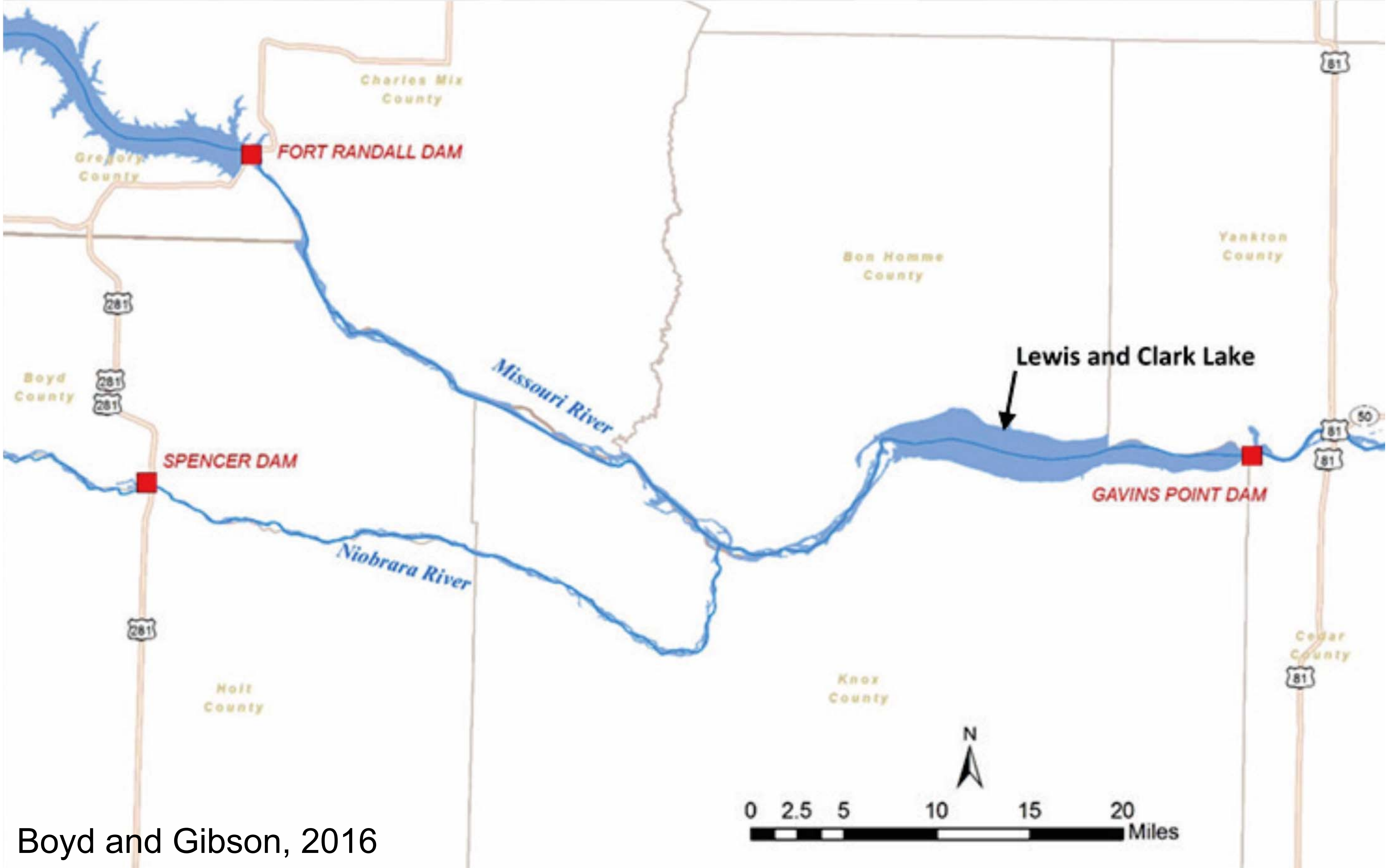


Reservoir Drawdown Flushing

Reservoir Flushing: Fall Creek

Reservoir Flushing: Spencer Dam

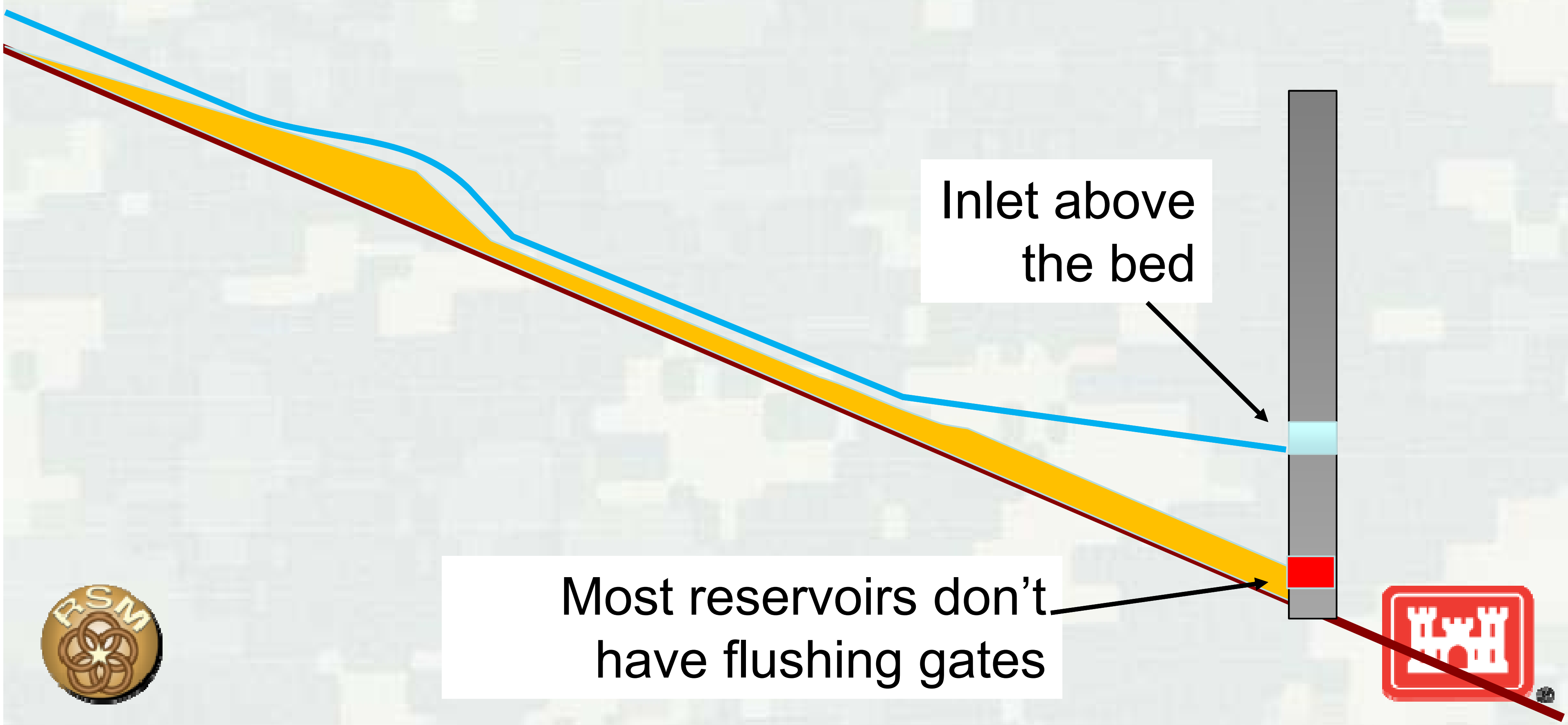


Boyd and Gibson, 2016

Reservoir Flushing: Spencer Dam

Gebidim Dam Flushing

Reservoir Flushing: Problem!



Reservoir Flushing

PROS

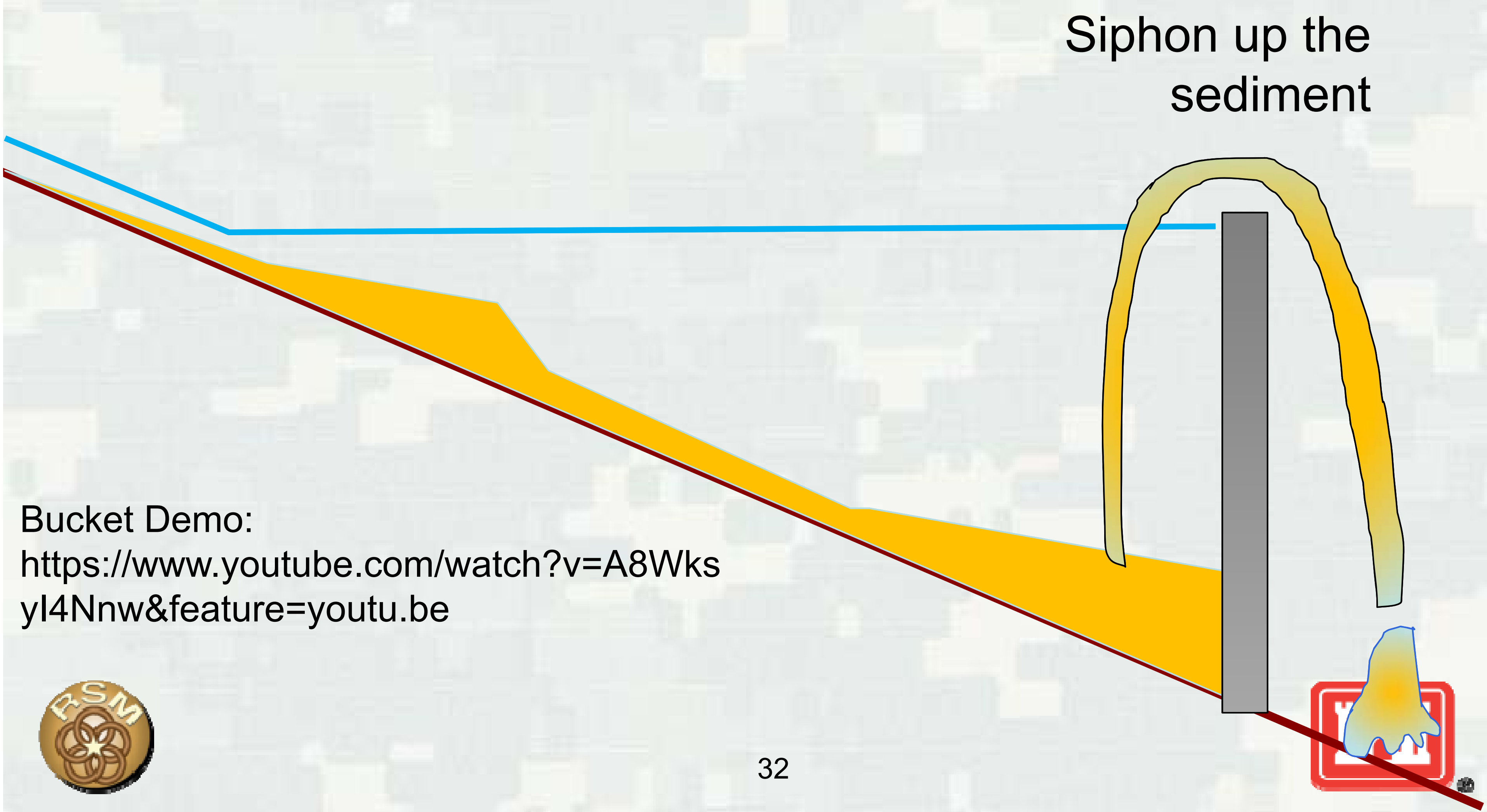
- No external power
- No land needed
- Significant sediment removal

CONS

- Uses ALL the water
- Sediment-laded effluent – high concentration short duration
- Potential downstream impacts
- Will not usually flush out the “floodplain” i.e. maintained reservoir storage may be less than the original

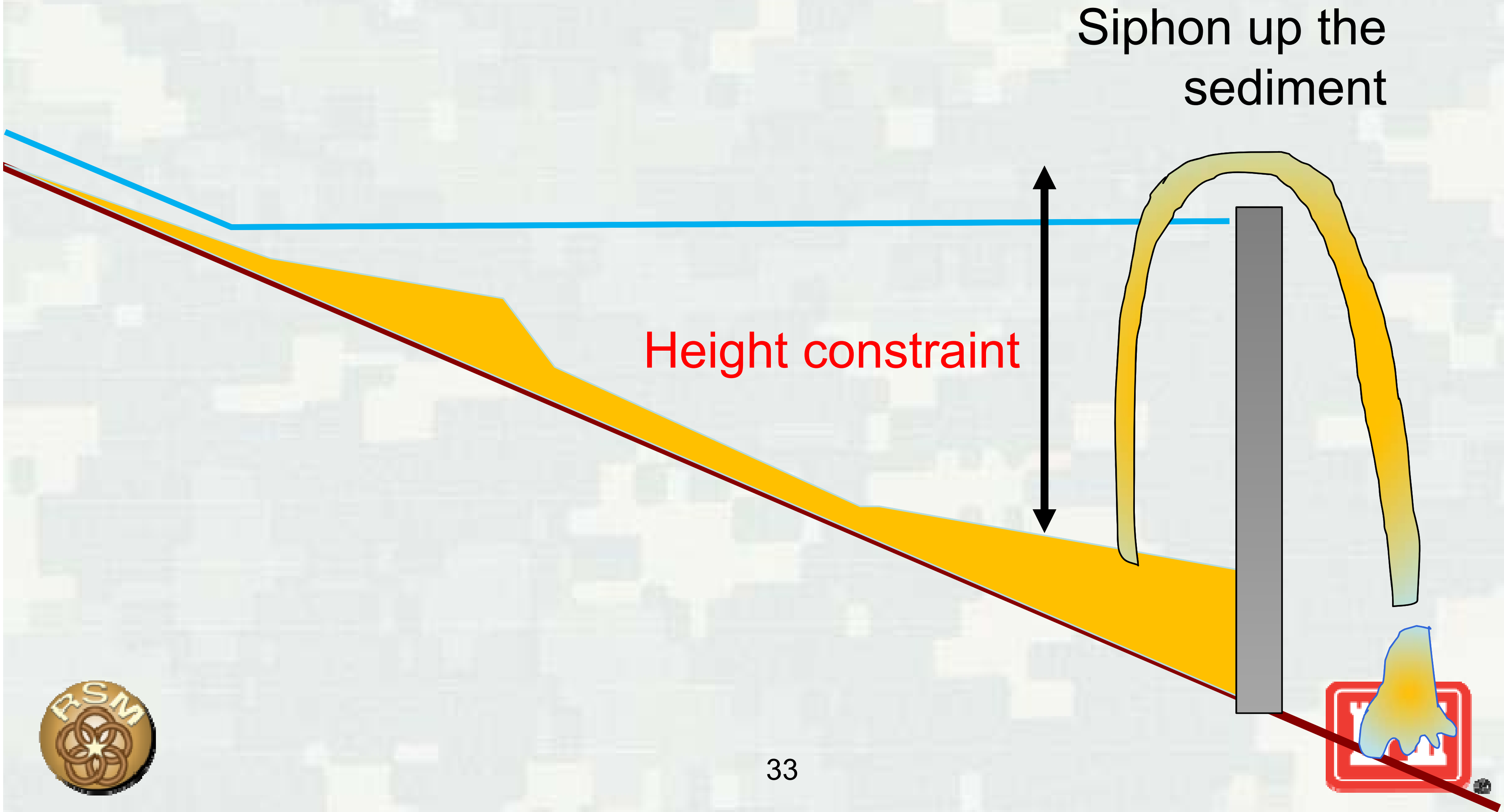
Hydrosuction

Hydrosuction

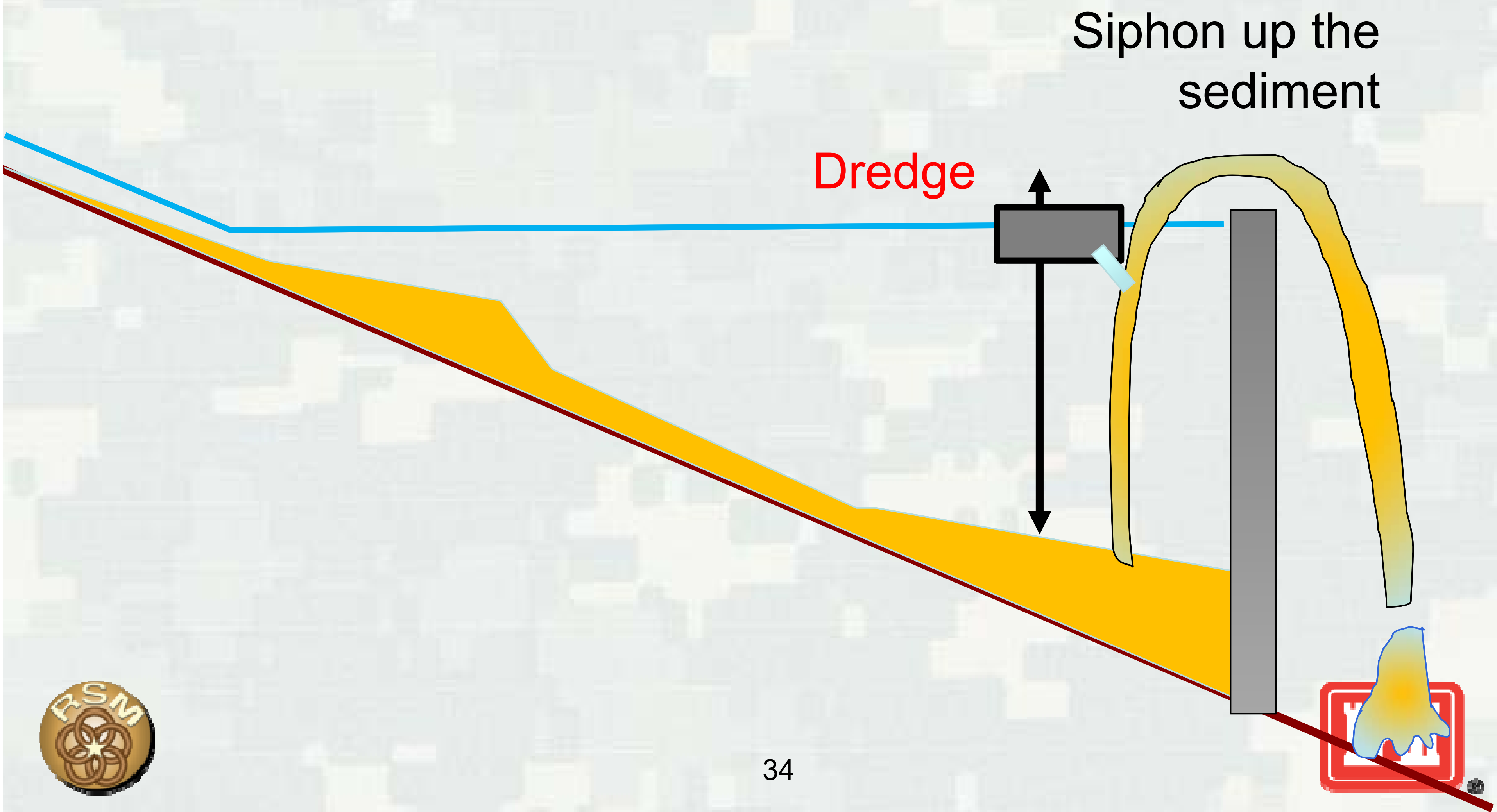


Bucket Demo:
https://www.youtube.com/watch?v=A8WksyI4Nnw&feature=youtu.be

Hydrosuction

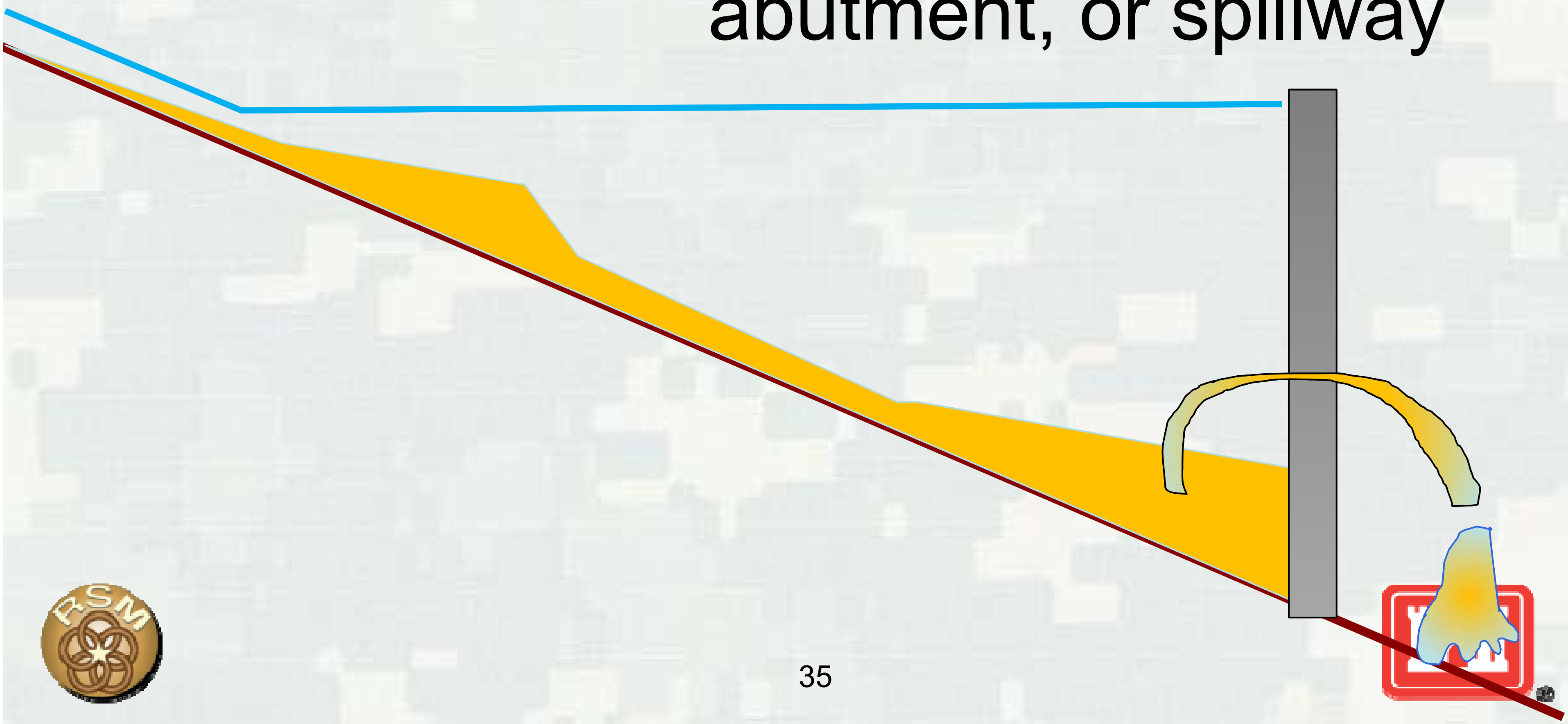


Dredging with Downstream Discharge of Sediments



Hydrosuction

Go through the dam, abutment, or spillway



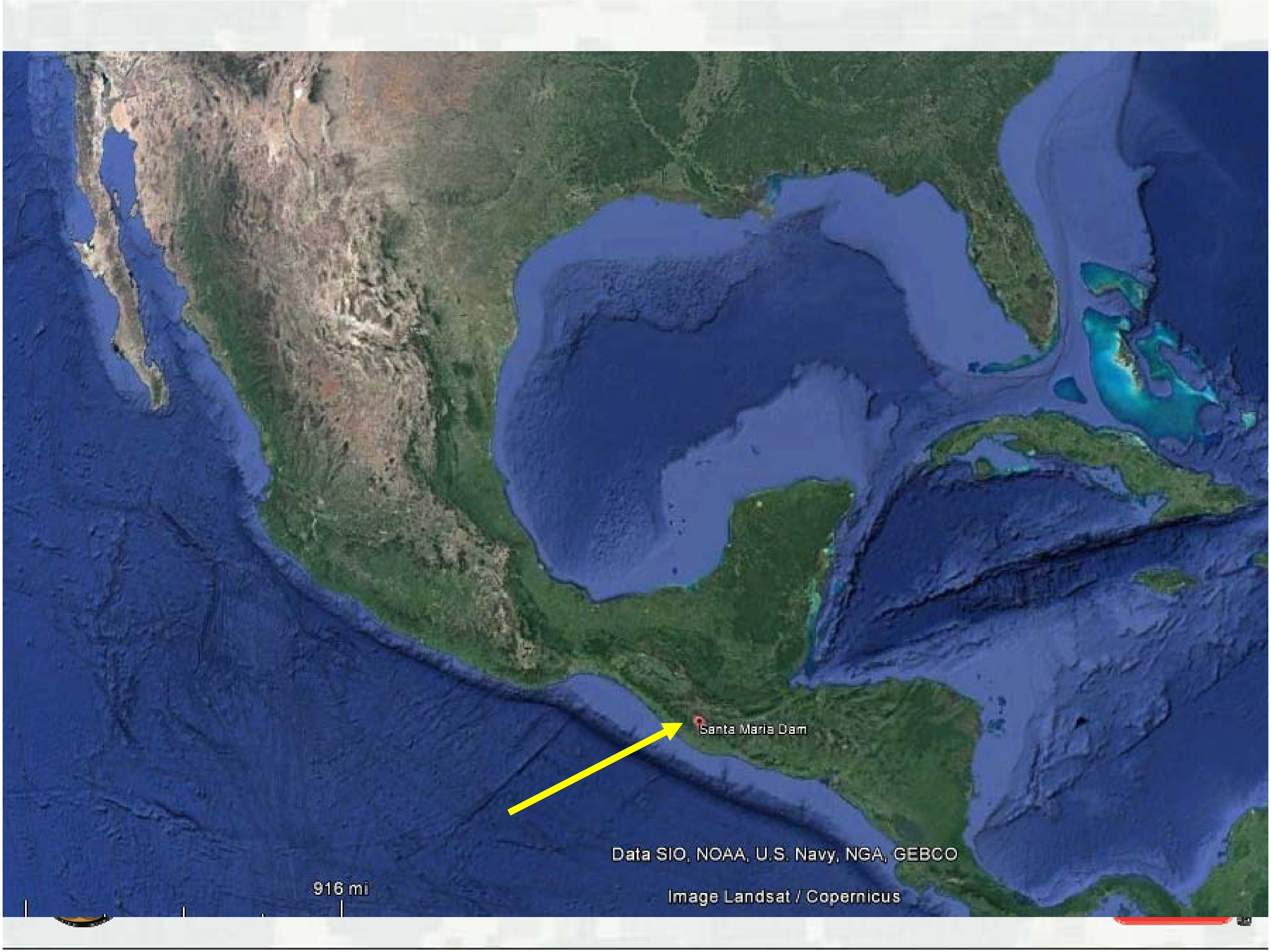
Hydrosuction in the United States

- Experimental installation on Grove Lake, NE
  - ►3,000 ft 6-inch PVC pipe
  - ►Sand balance restored for more than 5 years

Slide Source: Rollin Hotchkiss

Hydrosuction Internationally

Sedicon


Santa Maria Dam
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
916 mi
Image Landsat / Copernicus

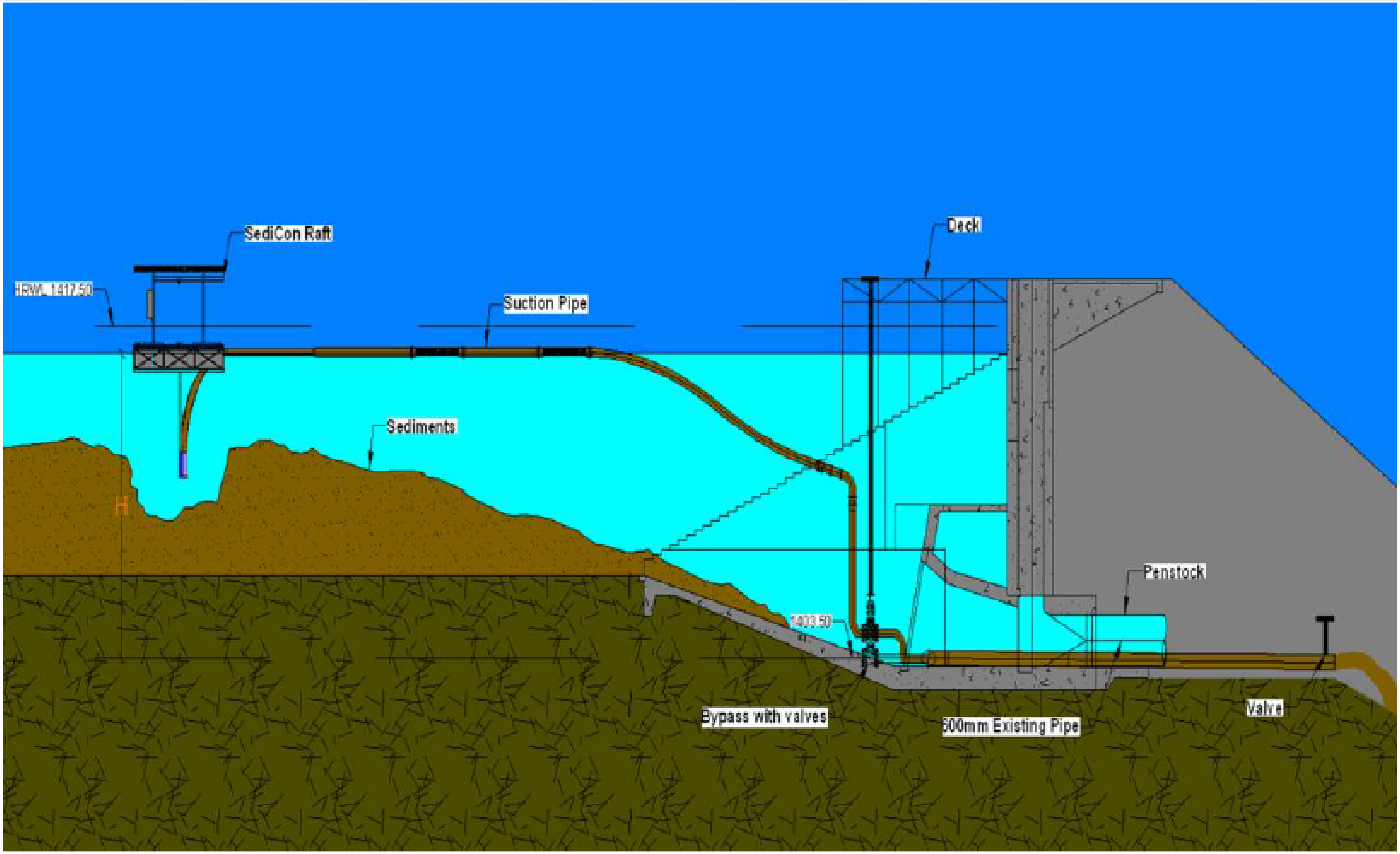
Santa Maria HPP, Guatemala

Santa Maria HPP, Guatemala

Santa Maria HPP, Guatemala

El Canada Reservoir

El Canada Hydrosuction



El Canada Hydrosuction- Connecting to Existing Conduit

Fig. 2.

Bypass connection to existing drainage pipe (a) side view (b) downstream view

El Canada Hydrosuction- Floating Barge

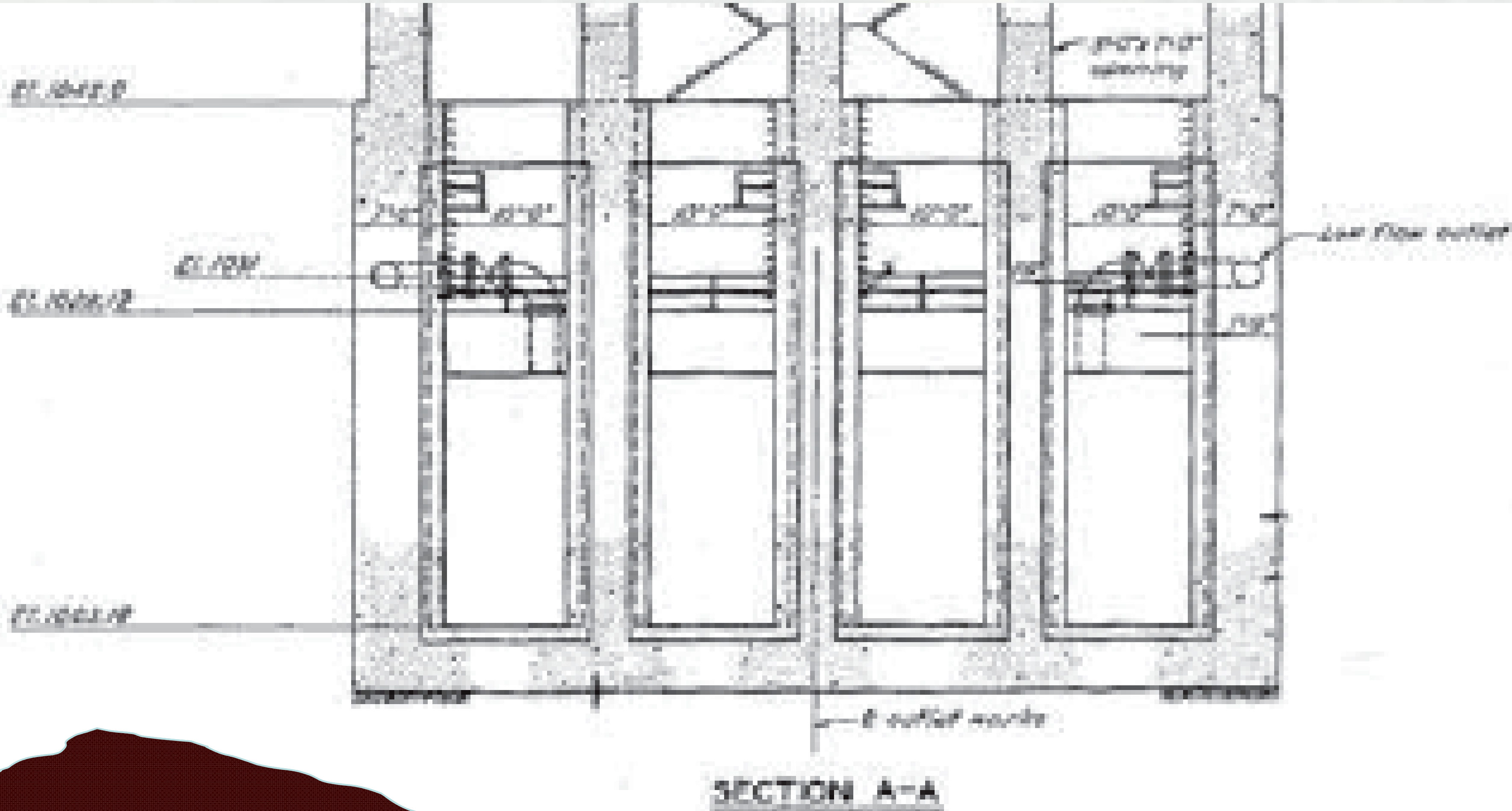
El Canada Hydrosuction-Discharge

Results

- ≈ 157,000 cy in first 6 months

Year	Concentration	Availability
2012	12%	86%
2013	9%	98%
2014	8%	98%

Inlet Extension Analysis at Tuttle Creek Lake



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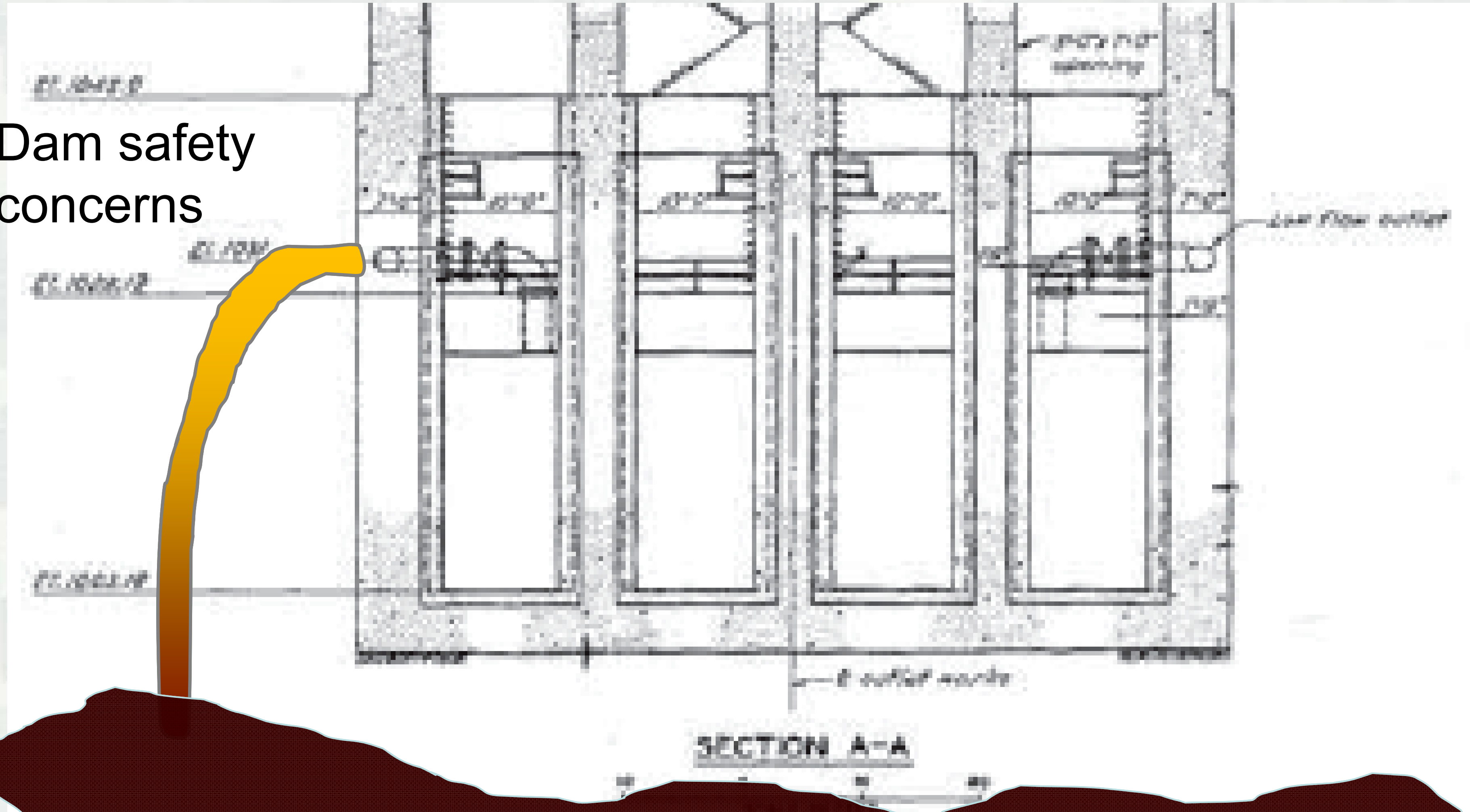
Inlet Extension Analysis at Tuttle Creek Lake

Dam safety concerns



ERDC/CHL LR-15-6
November 2015

Tuttle Creek Dam Siphon Dredging Investigation

by Dr. Brian C. McFall and Tim L. Welp

Option	Cavitation	Design Flow Velocity [ft/s]	Design Flow Rate (ft^3/s)	Estimated Production Rate [10^6 yd^3/yr] (6% solids)	Maximum Pipe Elevation Above Reservoir without Cavitation [ft]
1	Yes	N/A	N/A	N/A	28 – 29
2	Yes	N/A	N/A	N/A	28 – 29
3 (1 Pipe)	No	8.9 – 19.1	28 – 60	2.0– 4.2	N/A
3 (2 Pipes)	No	8.9 – 19.1	56 – 120	4.0 – 8.4	N/A

Table 2: Summary of results for the three (3) design options.

1 pipe: 26 to 54% of annual sediment load

2 pipes: 52 to 109 % of annual sediment load

Important: Would require drilling a hole into the side of the current inlet works.

An Option for Tall Dams: Notch The Spillway

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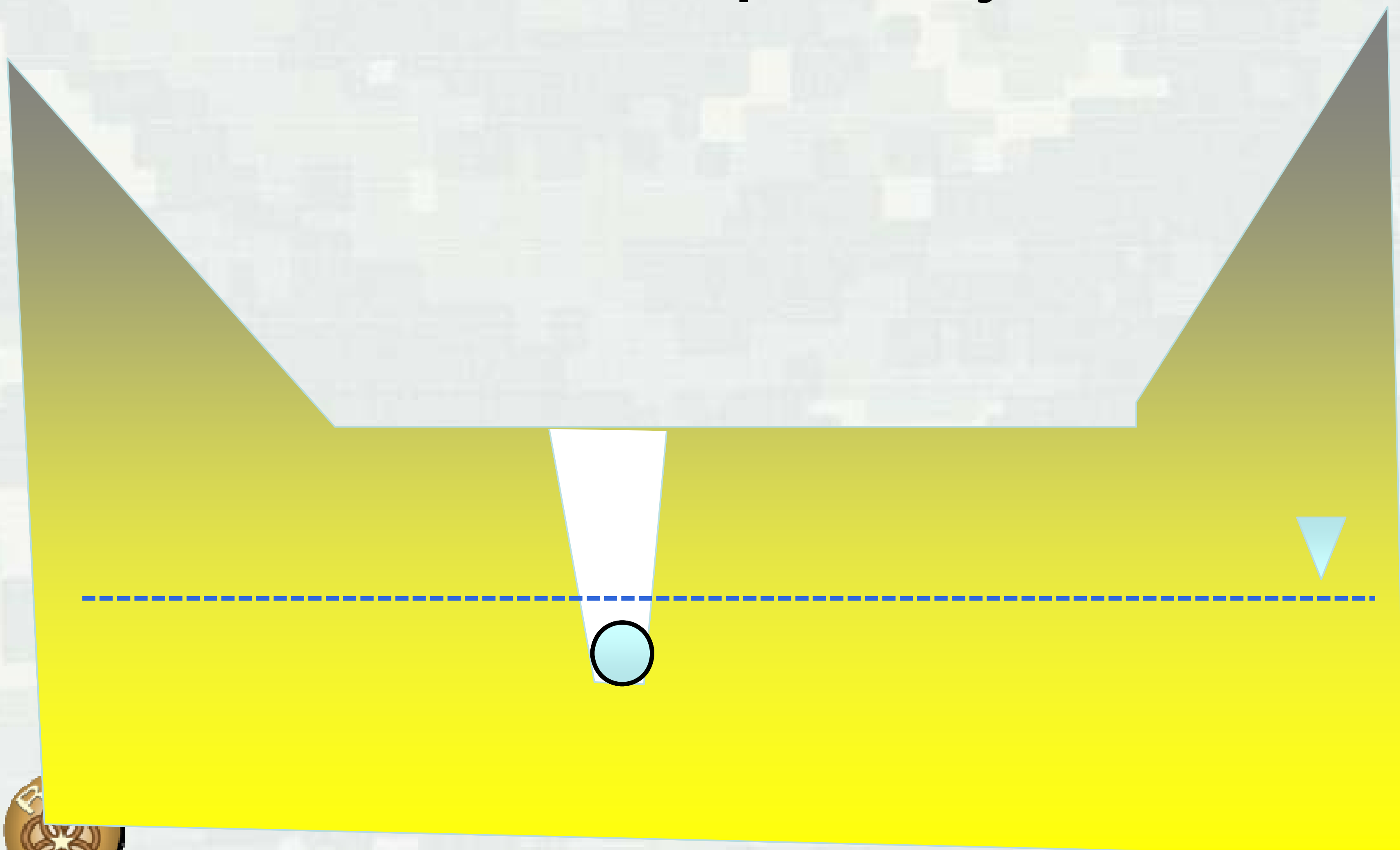

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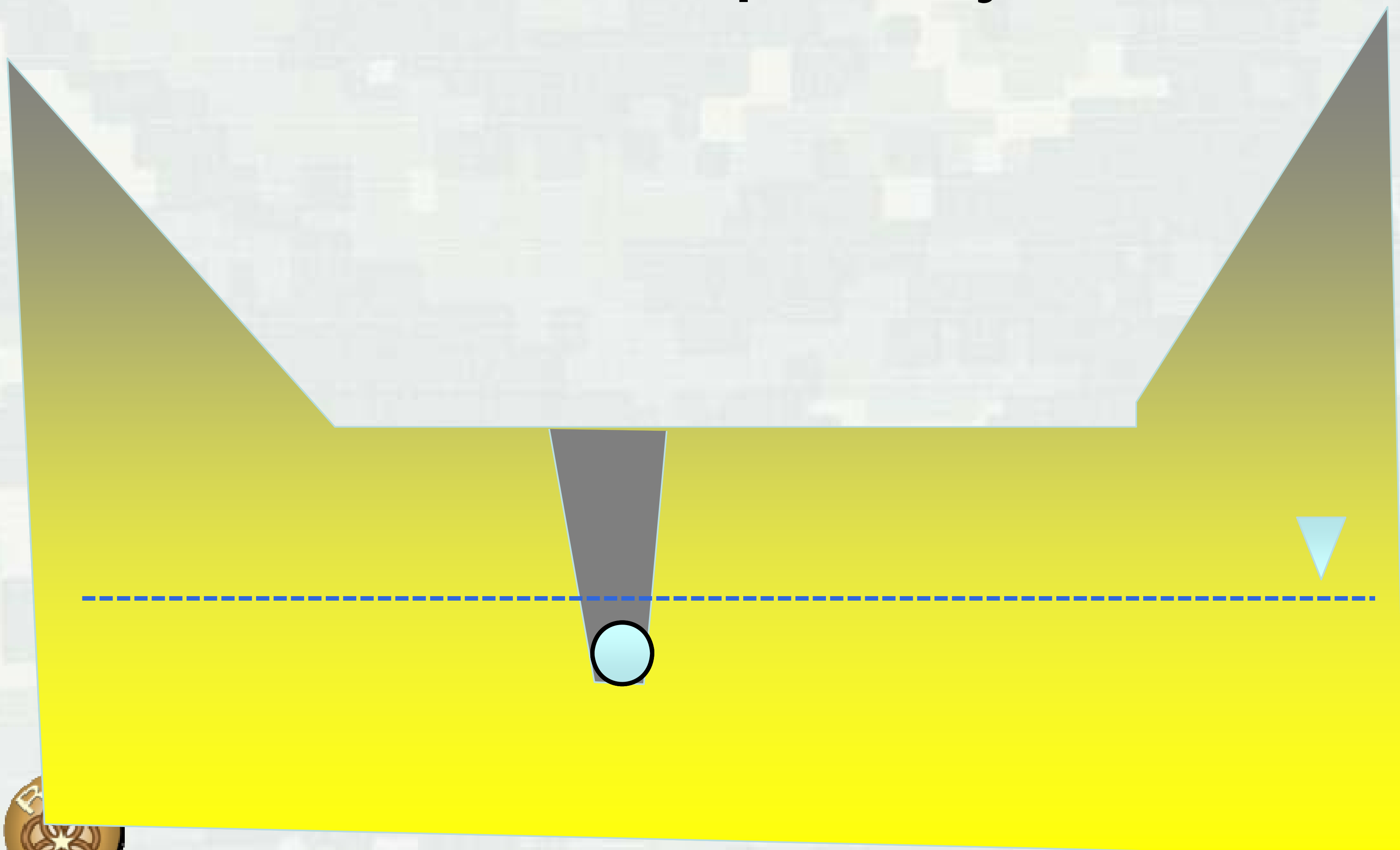

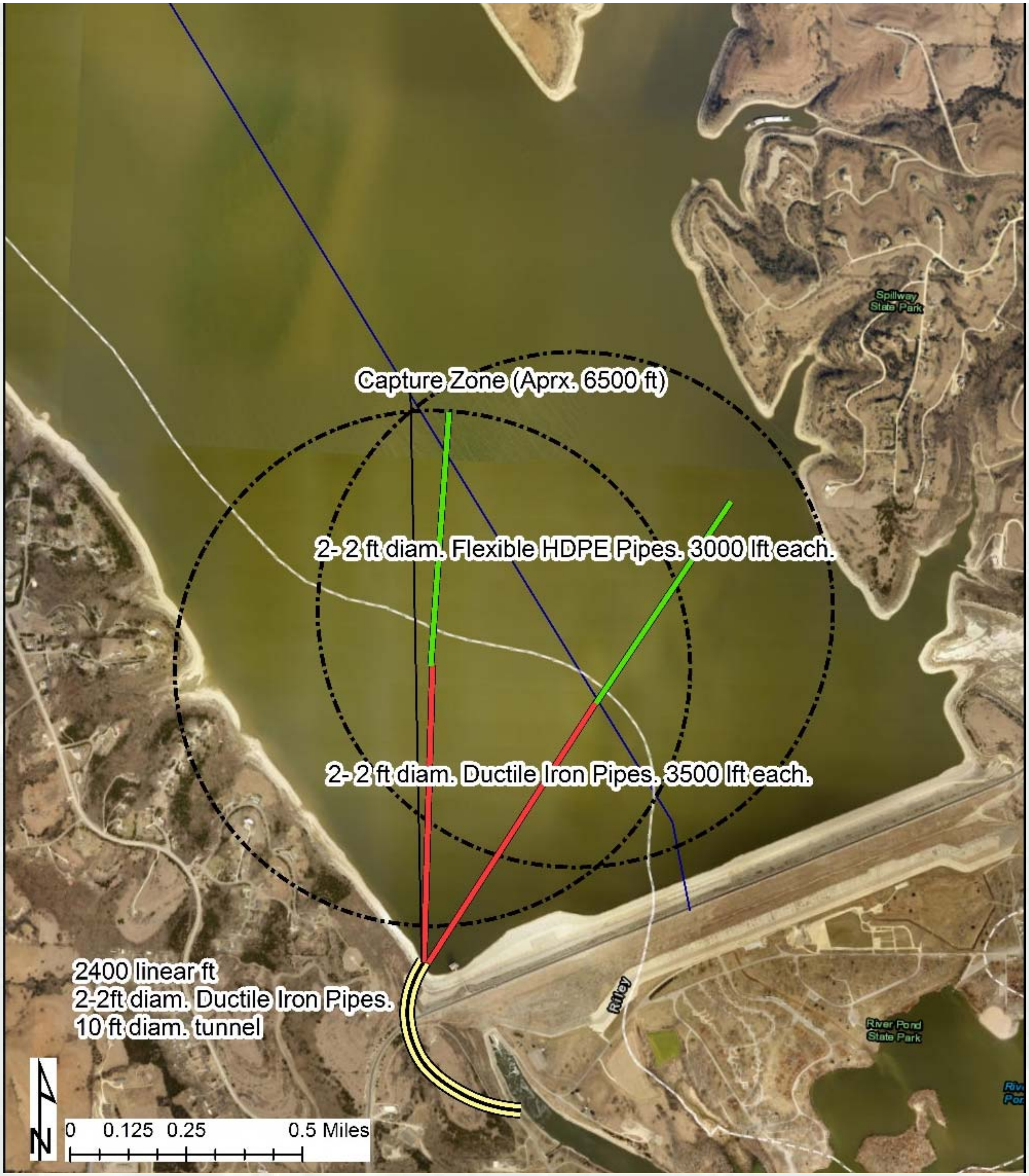

Capture Zone (Aprx. 6500 ft)
2- 2 ft diam. Flexible HDPE Pipes, 3000 lft each.
2- 2 ft diam. Ductile Iron Pipes, 3500 lft each.
2400 linear ft
2-2ft diam. Ductile Iron Pipes.
10 ft diam. tunnel
Spillway State Park
River Pond State Park
Riley
N
0 0.125 0.25 0.5 Miles

Summary

- Dredging with land disposal
- Dredging with downstream discharge
- Bypass
- Pass-through (routing, sluicing)
- Drawdown flushing
- Hydrosuction (up-and-over or through)
- Density current venting