Project A: Streamflow, Sediment, and Vegetation Dynamics; Implications for Geomorphic Change in the Colorado River and its Tributaries

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- **Project Elements and Objectives**
  - **A.1. Stream Gaging and Hydrologic Analyses**
  - **A.3. Sediment Transport and Budgeting**
- **Cooperators: USGS AZ WSC**
- **LTEMP Resource goals: Sediment**

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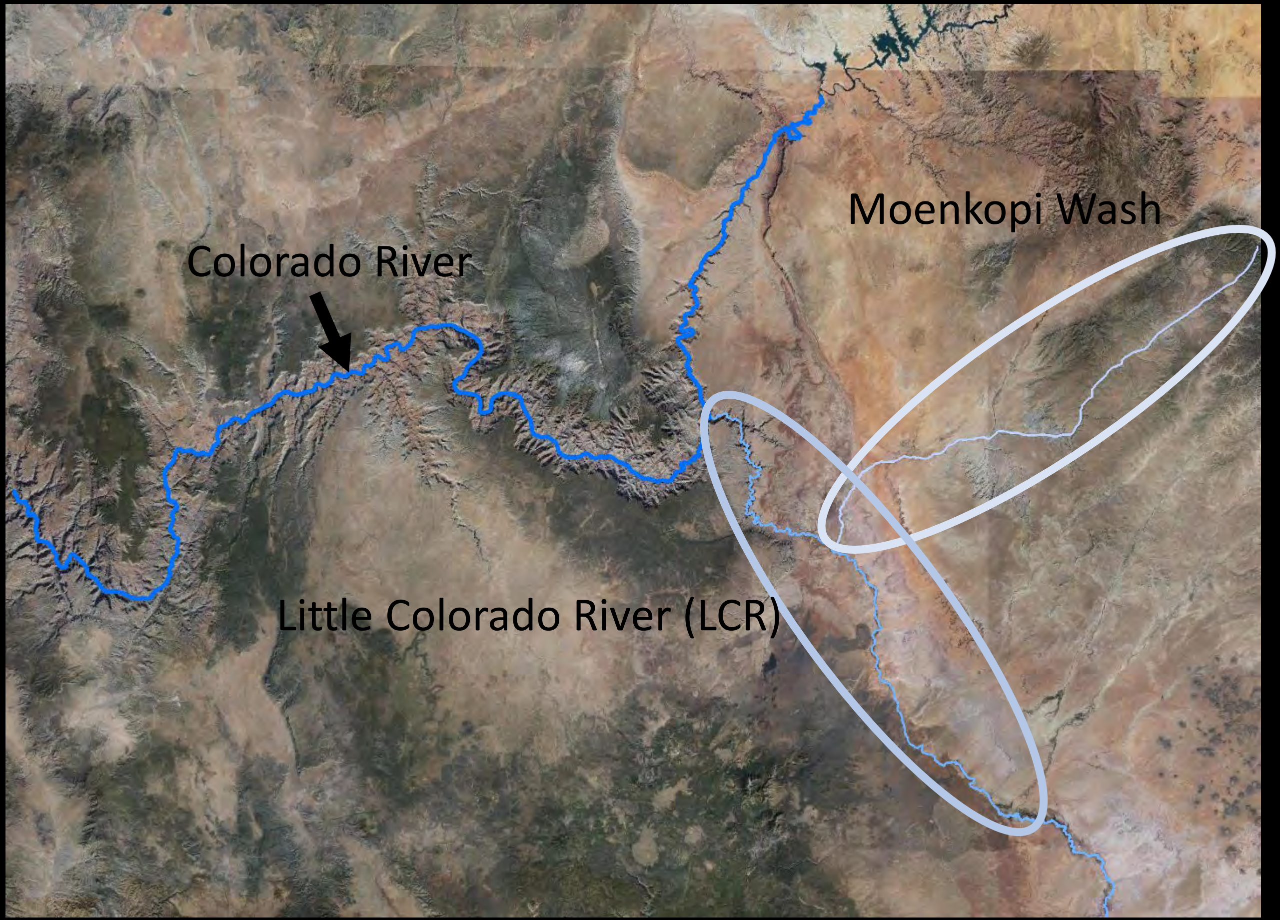
Presentation Outline

1. Brief Discussion of Drivers of Geomorphic Change in Rivers

2. Moenkopi Wash and Little Colorado River
    a. Streamflow, Sediment, and Vegetation Dynamics → Geomorphic Change

    b. Implications for Sediment Delivery to Colorado River

3. Colorado River
    a. Effects of possible low flows (SEIS) on vegetation encroachment and geomorphic change



1) General Discussion of Drivers of Geomorphic Change in Rivers

Moenkopi Wash

Moenkopi Wash, AZ,
Looking upstream from
Hwy 89 bridge
Near Cameron, AZ

Little Colorado River

How Does
This Happen?

How Does
This water and
sediment
movement
downstream?

Little Colorado River, AZ
Looking Downstream from
Highway 89 bridge
near Cameron, AZ

Dean and Topping, 2019, *GSA Bulletin*

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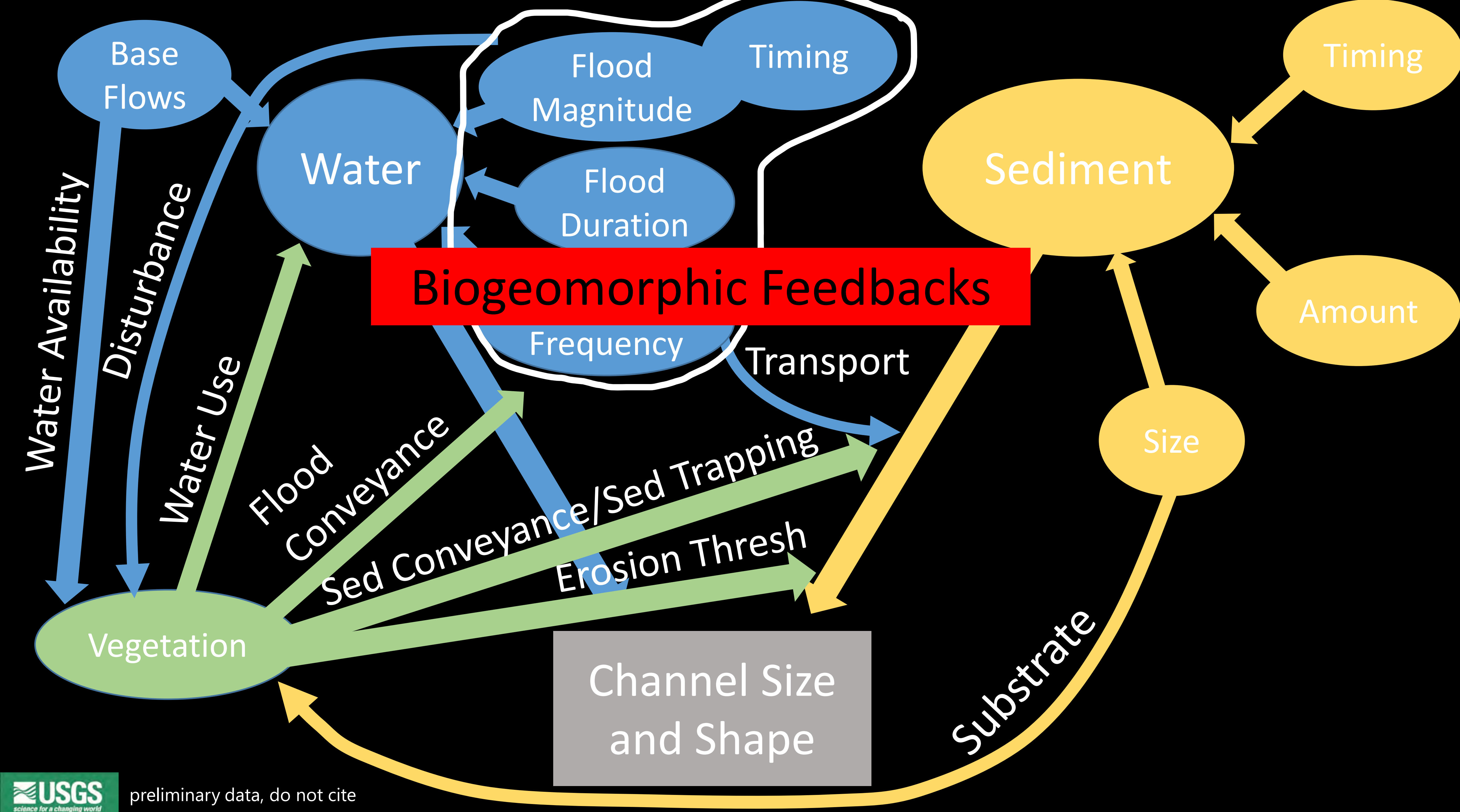
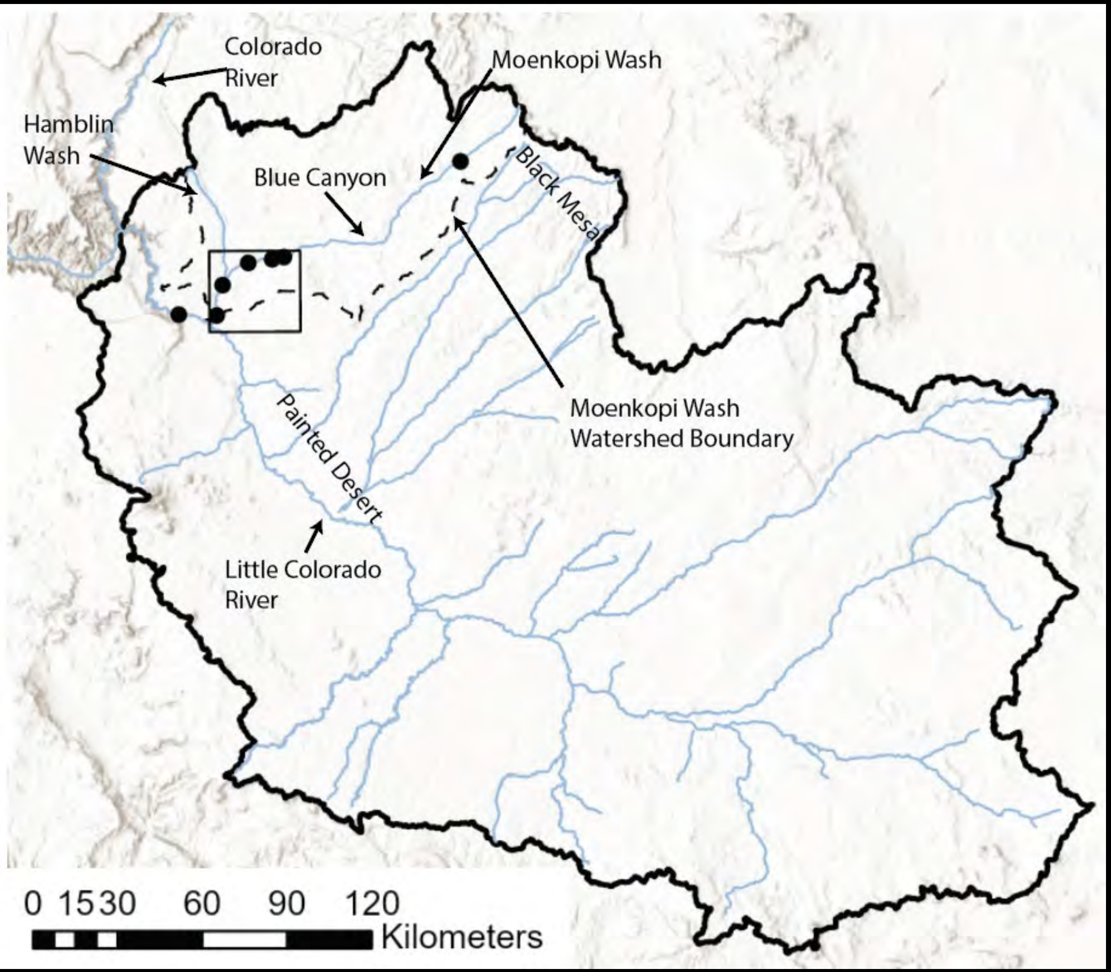
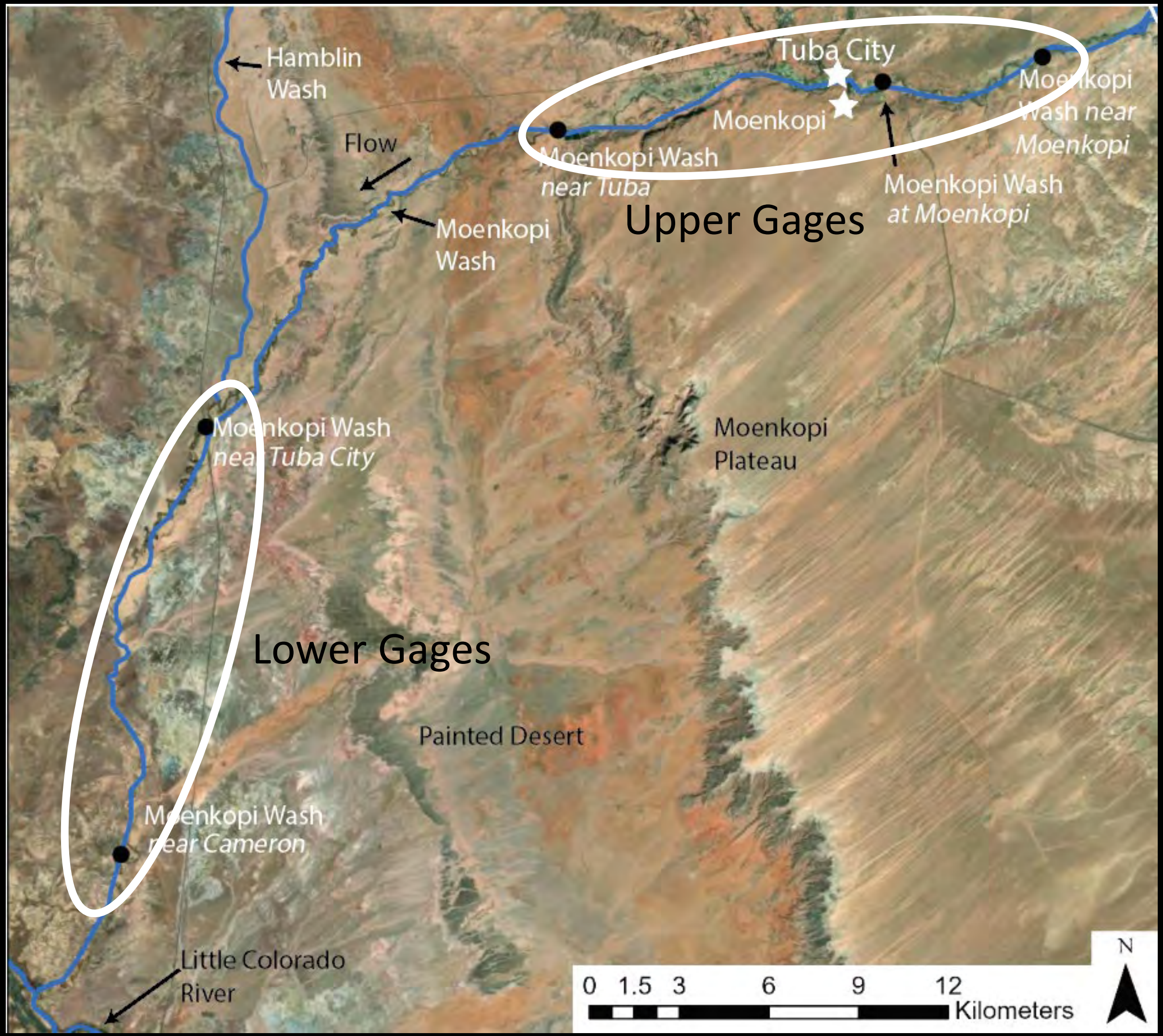
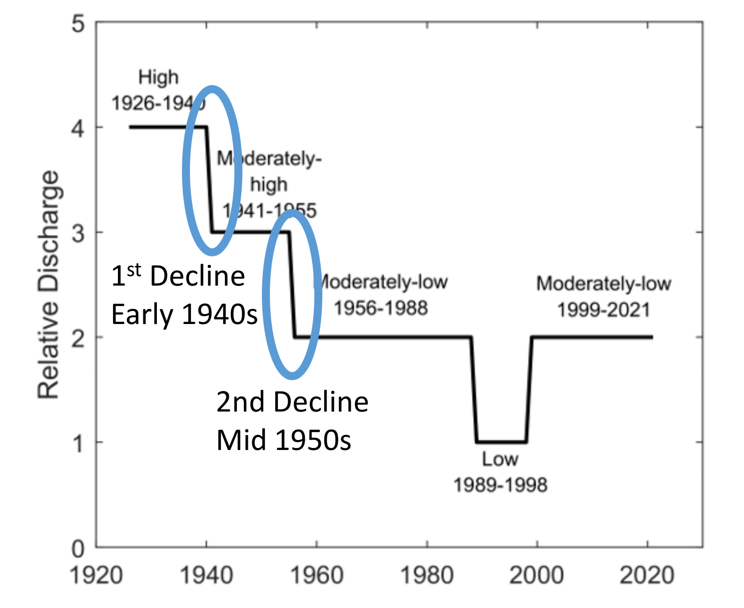

Base Flows
Water
Flood Magnitude
Timing
Flood Duration
Frequency
Biogeomorphic Feedbacks
Sediment
Timing
Amount
Size
Water Availability
Disturbance
Water Use
Flood Conveyance
Sed Conveyance/Sed Trapping
Erosion Thresh
Transport
Substrate
Vegetation
Channel Size and Shape

2) How does this apply to Moenkopi Wash and the Little Colorado River?

Moenkopi Wash

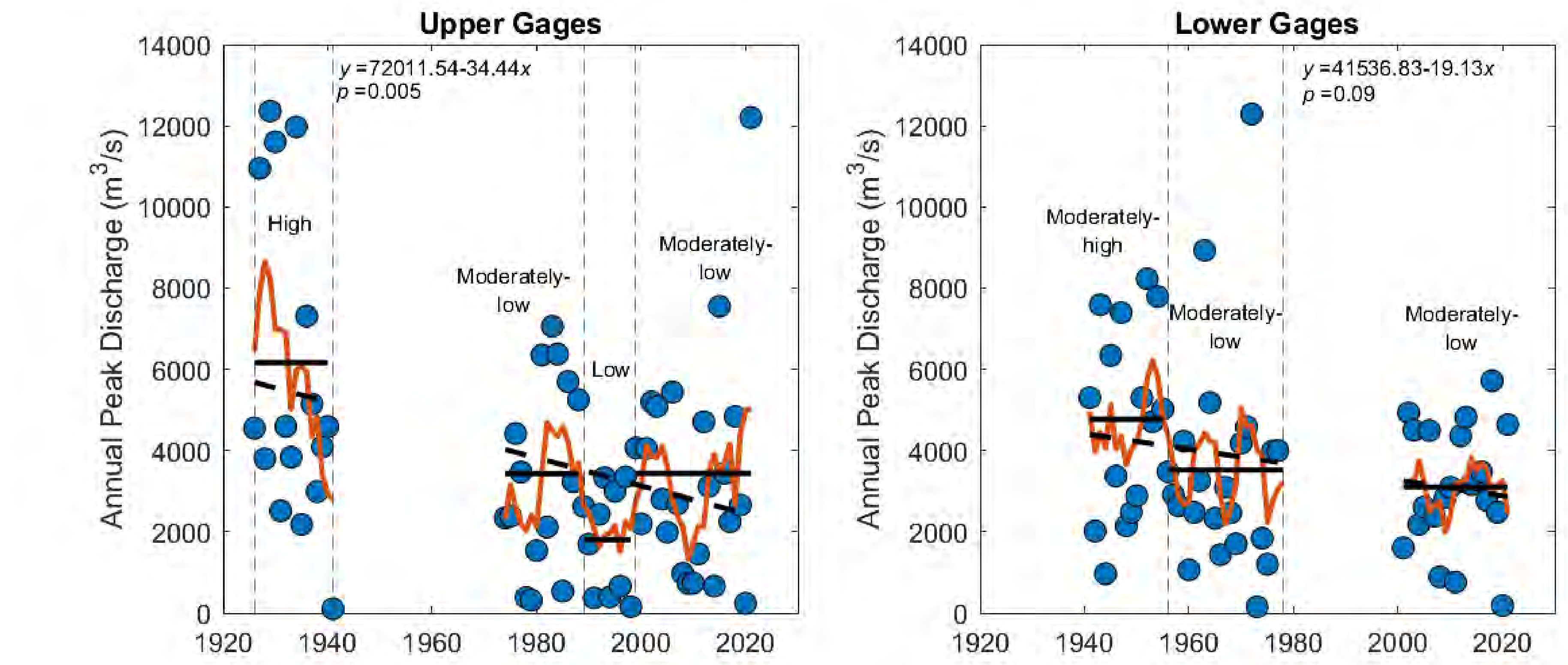






Moenkopi Wash
Hydrologic Change

Changes in Annual Peak Discharge



preliminary data, do not cite

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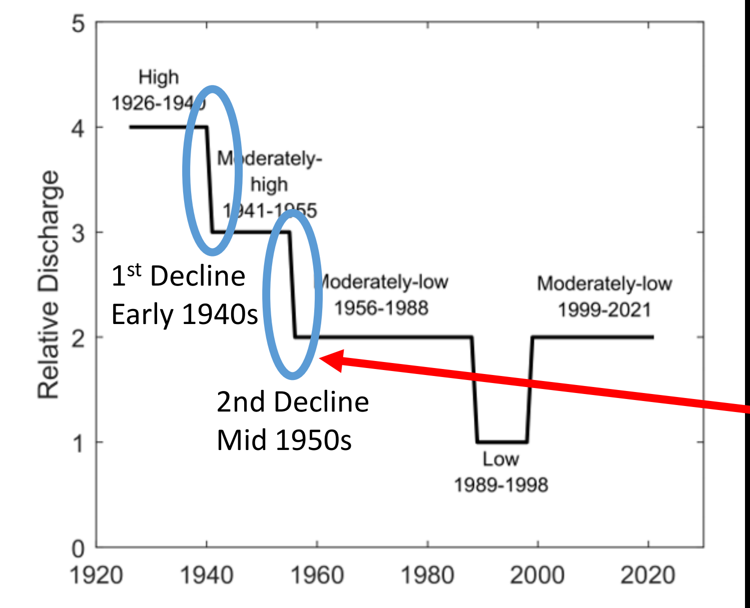
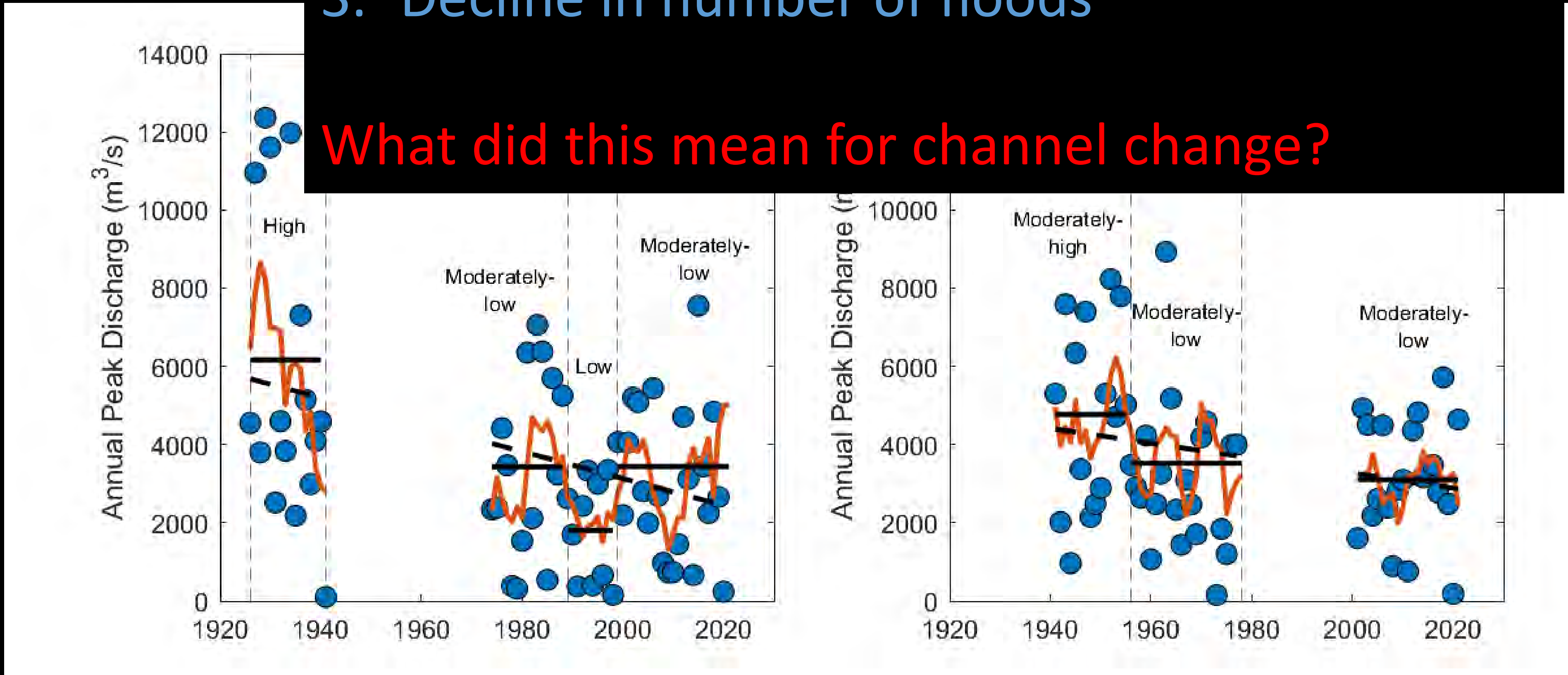


Moenkopi Wash Hydrologic Change

The mid 1950s decline in discharge unique

1. Decline in annual peak Q
2. 2 extended periods of only small floods
3. Decline in number of floods

What did this mean for channel change?



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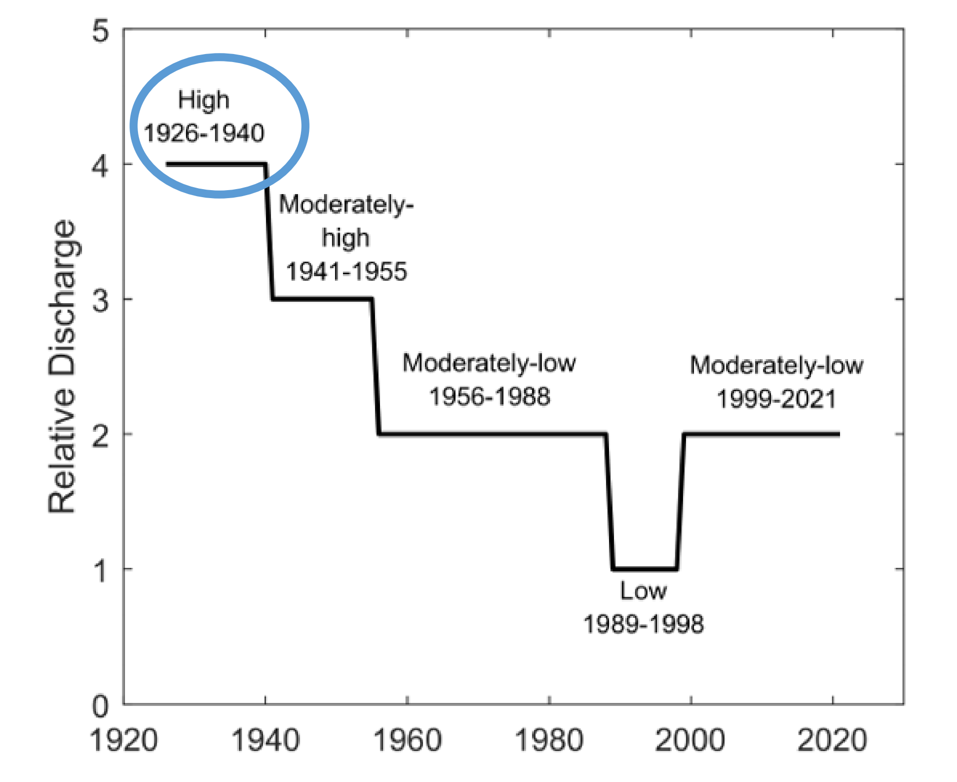
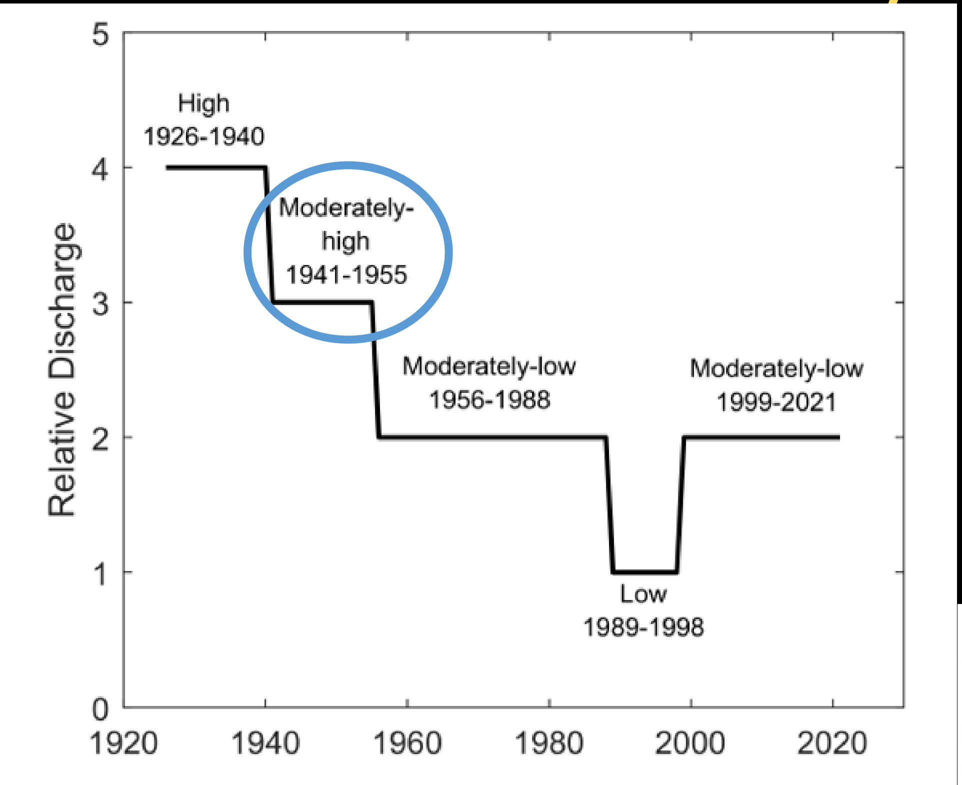
Moenkopi Wash
Physical Changes



Large bare
sandy point bars

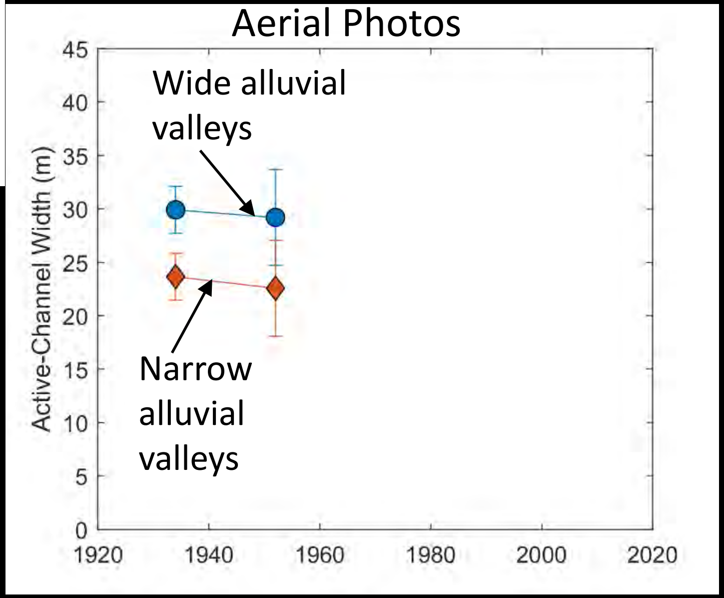
Channel Width 20-40 m wide

Moenkopi Wash Physical Changes



Initial decrease in discharge
No measurable changes in channel width

Vegetation encroachment begins



Sparse Vegetation

Sparse Vegetation

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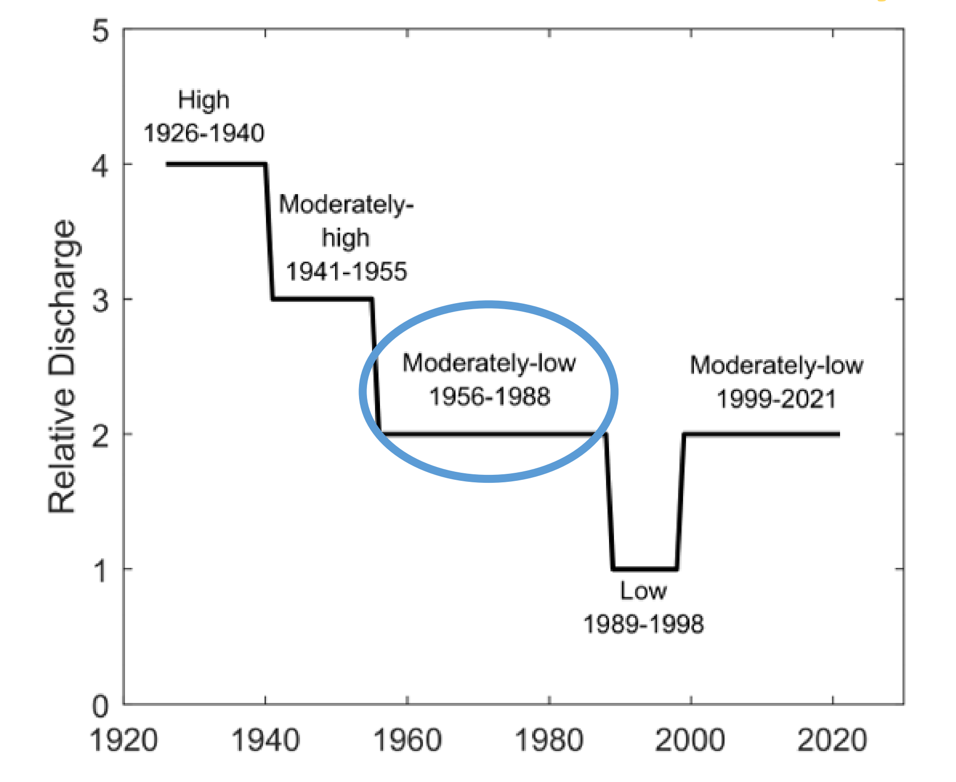
preliminary data, do not cite

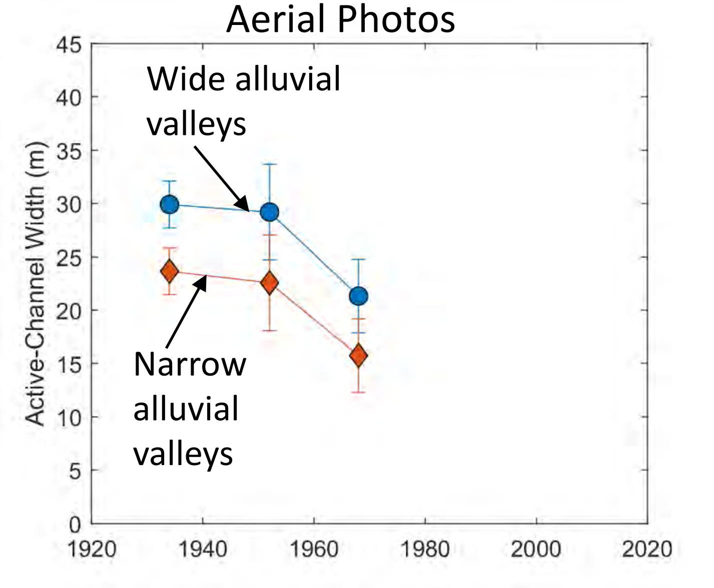
Moenkopi Wash
Physical Changes



2nd decline in discharge

Dense vegetation throughout river corridor

Reductions in channel width by ~30%



Dense
Vegetation

Dense
Vegetation

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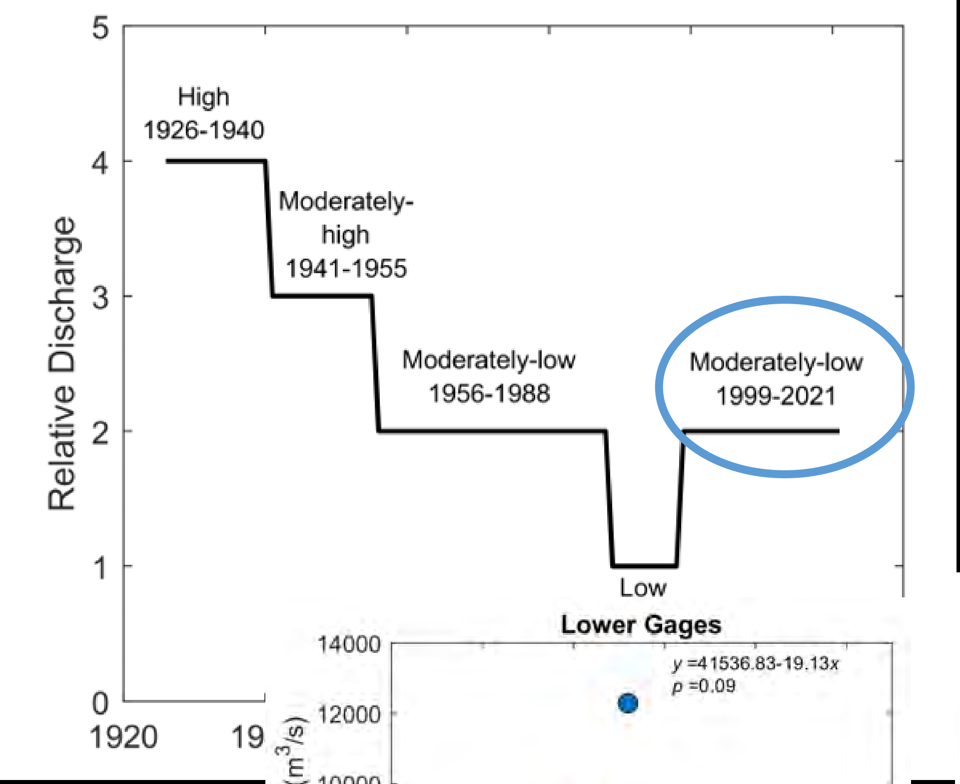
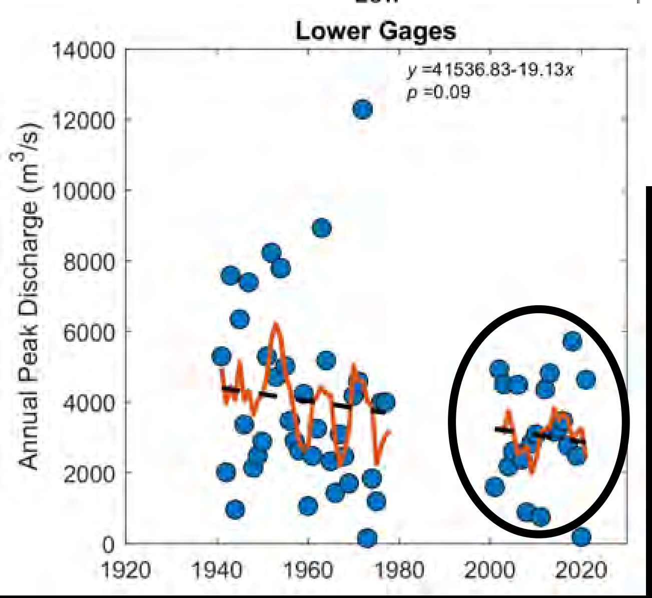
preliminary data, do not cite

Moenkopi Wash
Physical Changes

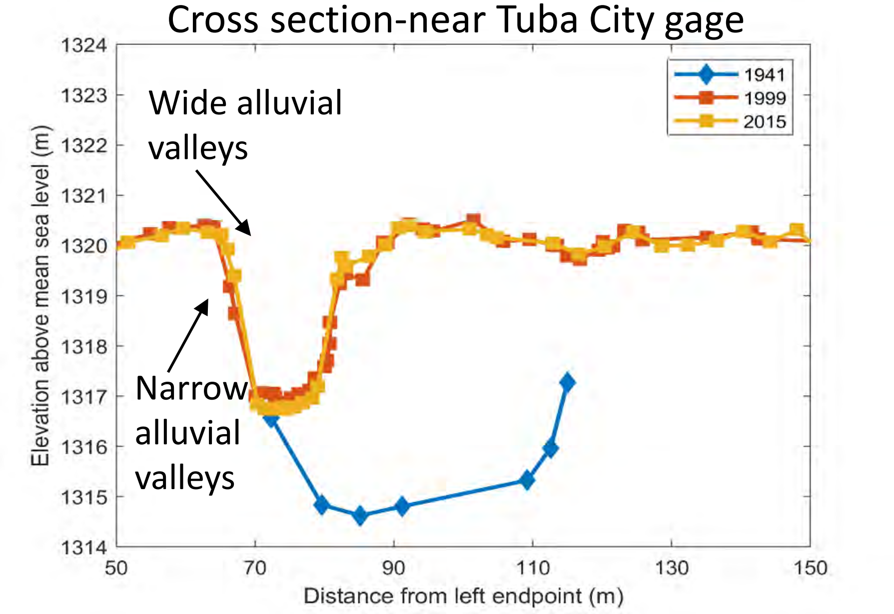




Recent decades

No sizeable floods, additional narrowing

Narrowing = long-term loss in channel capacity



preliminary data,
do not cite

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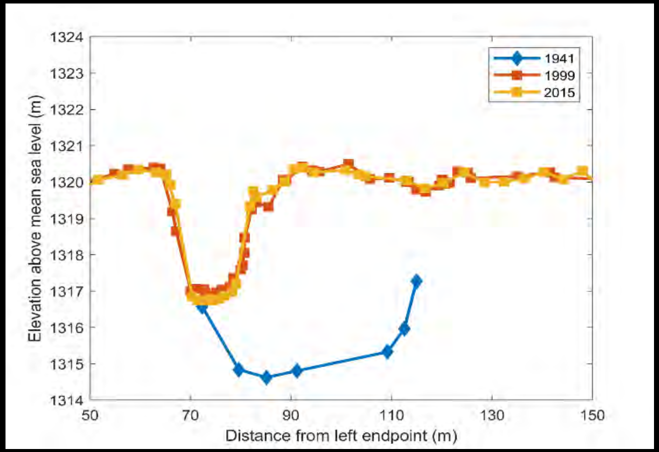
Moenkopi Wash
Effects of Physical Changes on Water Conveyance

Loss of channel capacity= Overbank flooding at lower discharge



preliminary data, do not cite

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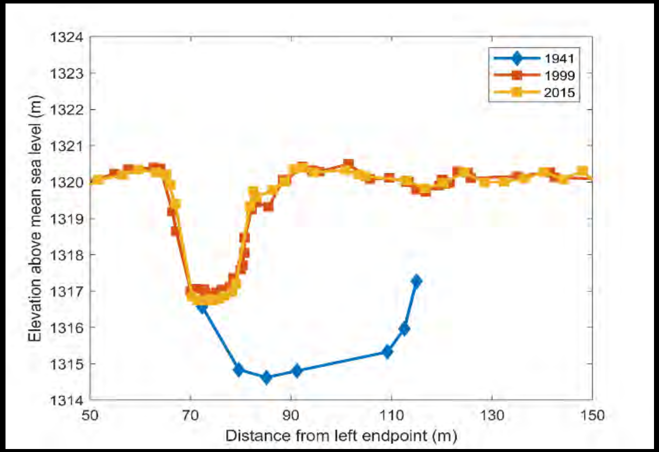

Moenkopi Wash
Effects of Physical Changes on Water Conveyance

1) Overbank Flooding at lower discharges
2) Vegetation slows water down
3) Water gets stored in floodplain depressions

4) Results in
    1) modification of hydrograph shape
    2) flood attenuation

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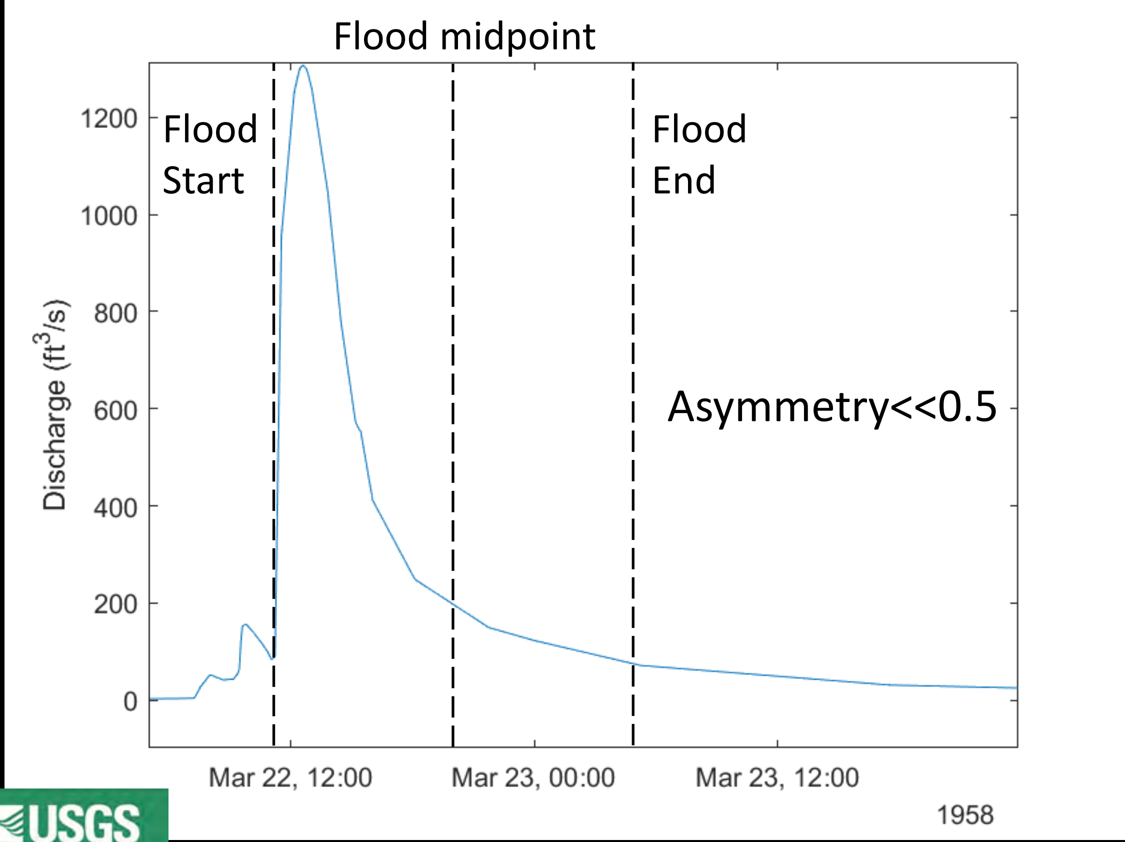
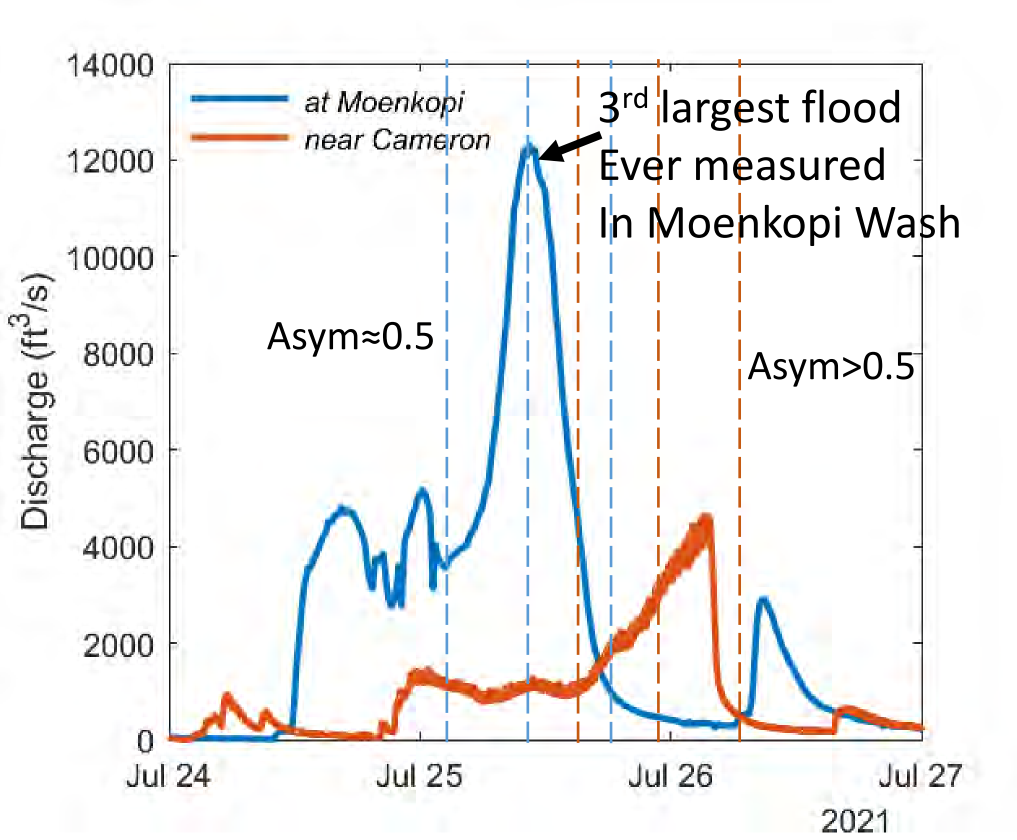
preliminary data, do not cite

Moenkopi Wash
Effects of Physical Changes on Water Conveyance
Modification of hydrograph shape





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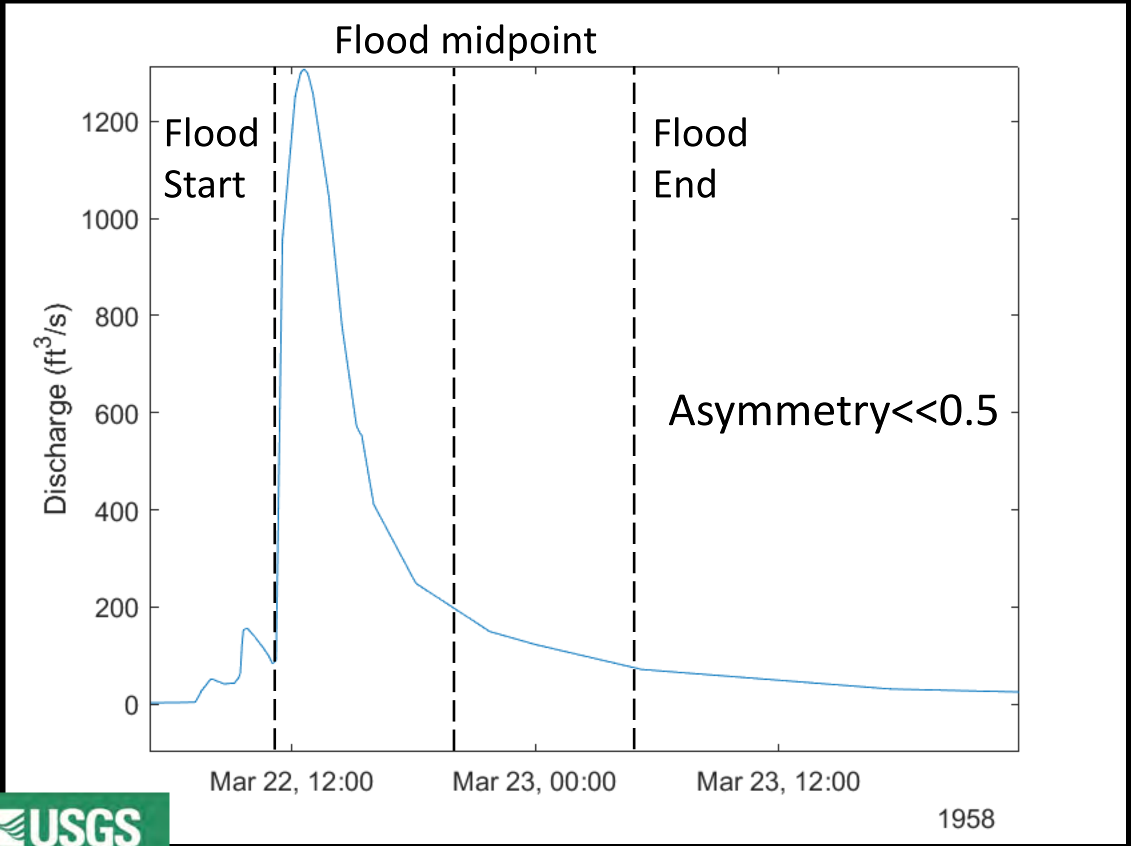
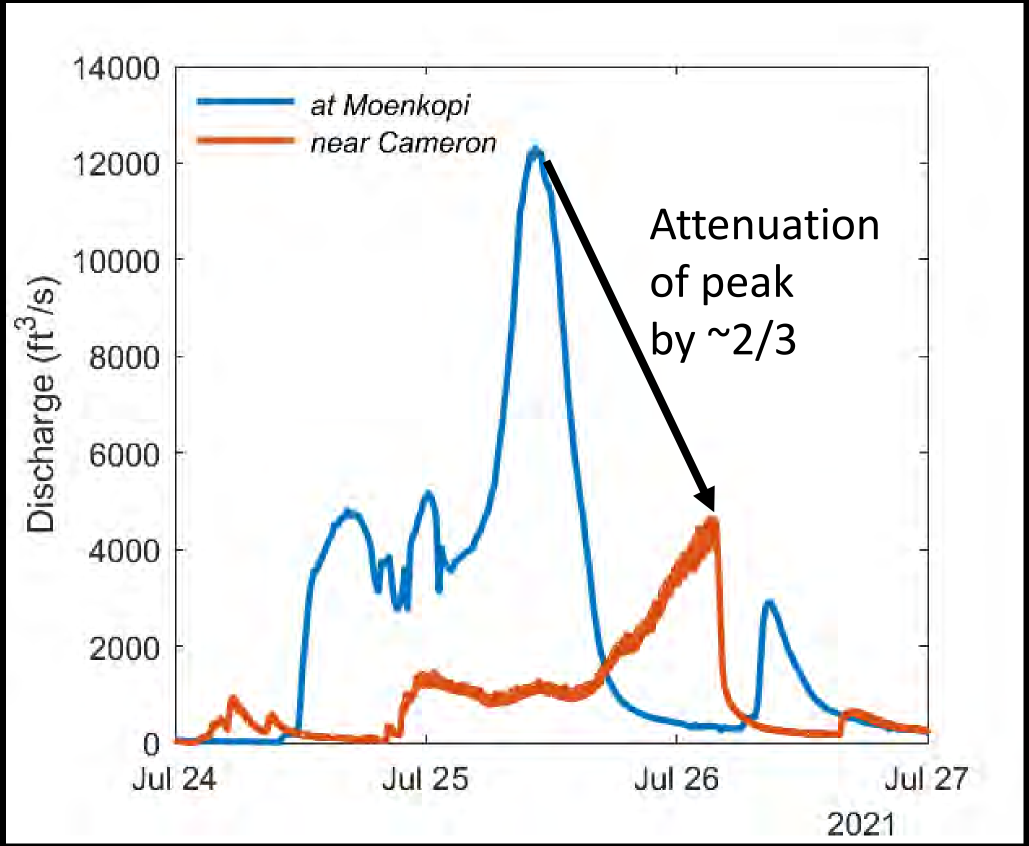
Moenkopi Wash
Effects of Physical Changes on Water Conveyance
Modification of hydrograph shape
Flood Attenuation





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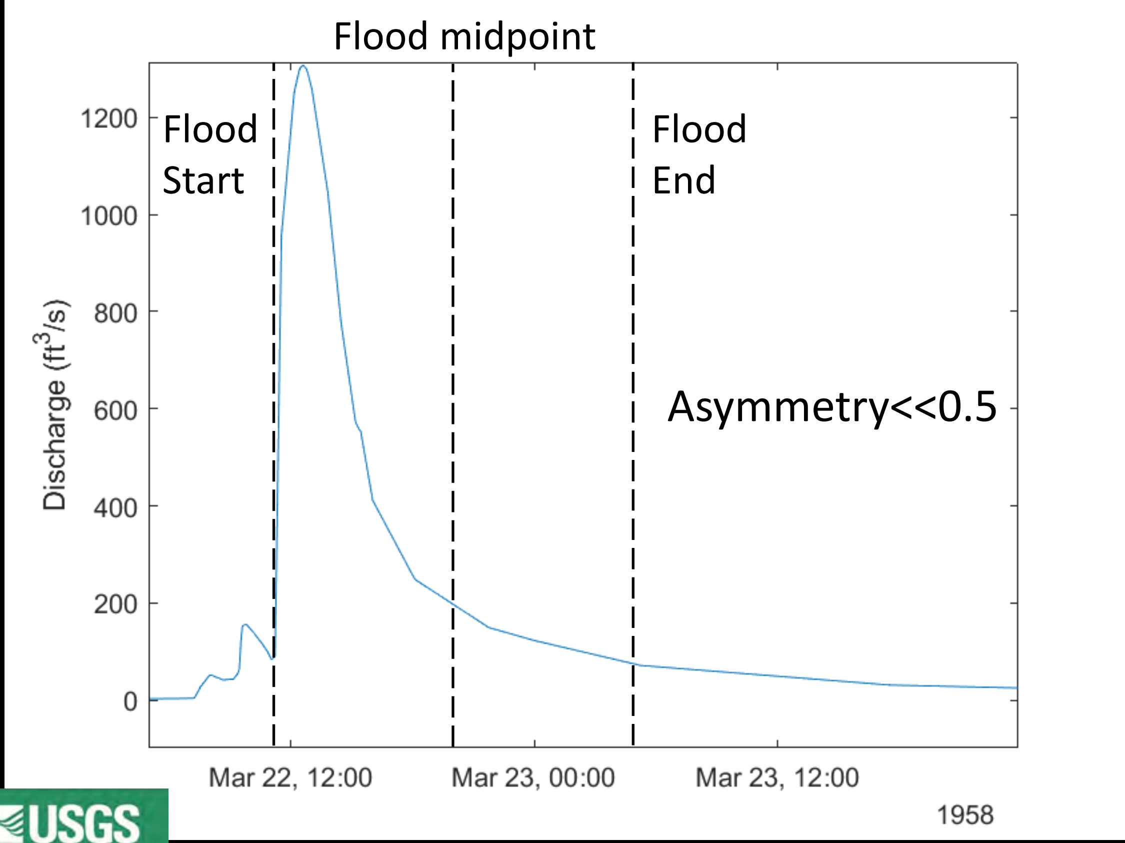
Moenkopi Wash

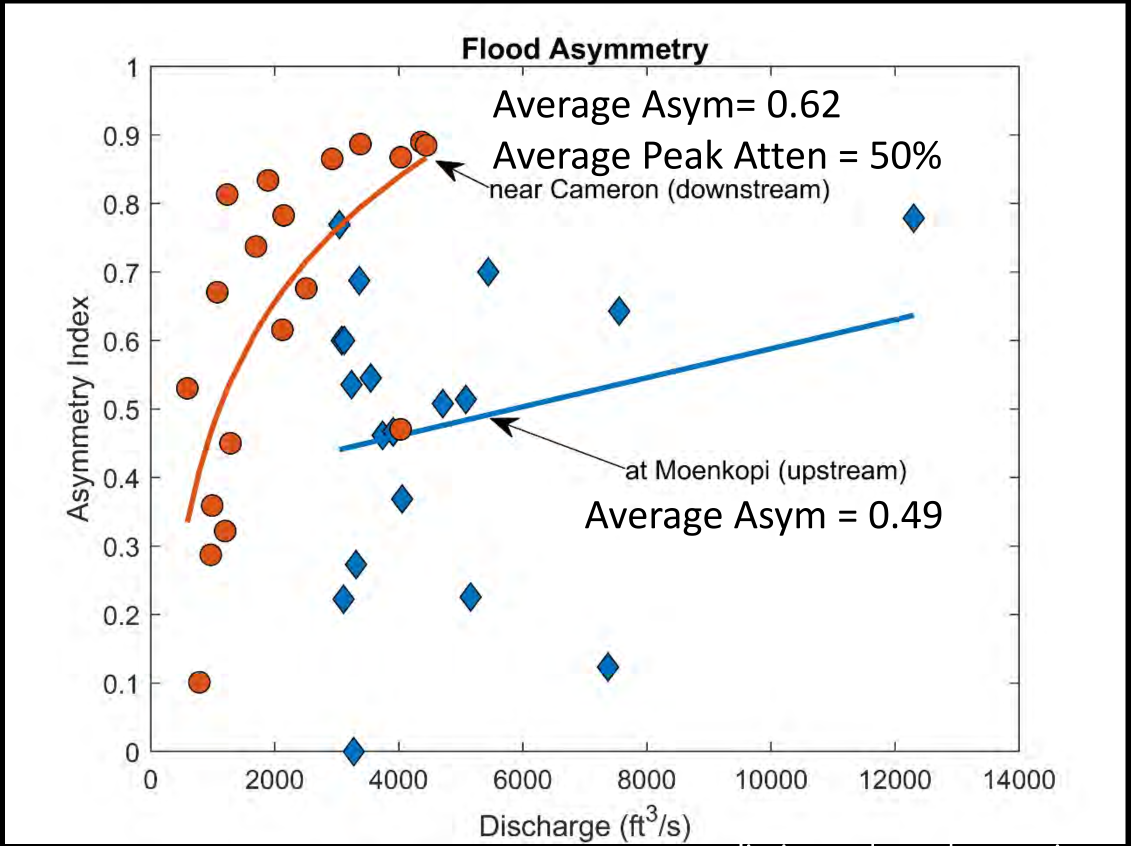
Effects of Physical Changes on Water Conveyance

Modification of hydrograph shape

Flood Attenuation



Paired Floods That Passed both
"at Moenkopi" and "near Cameron" stream gages



preliminary data, do not cite

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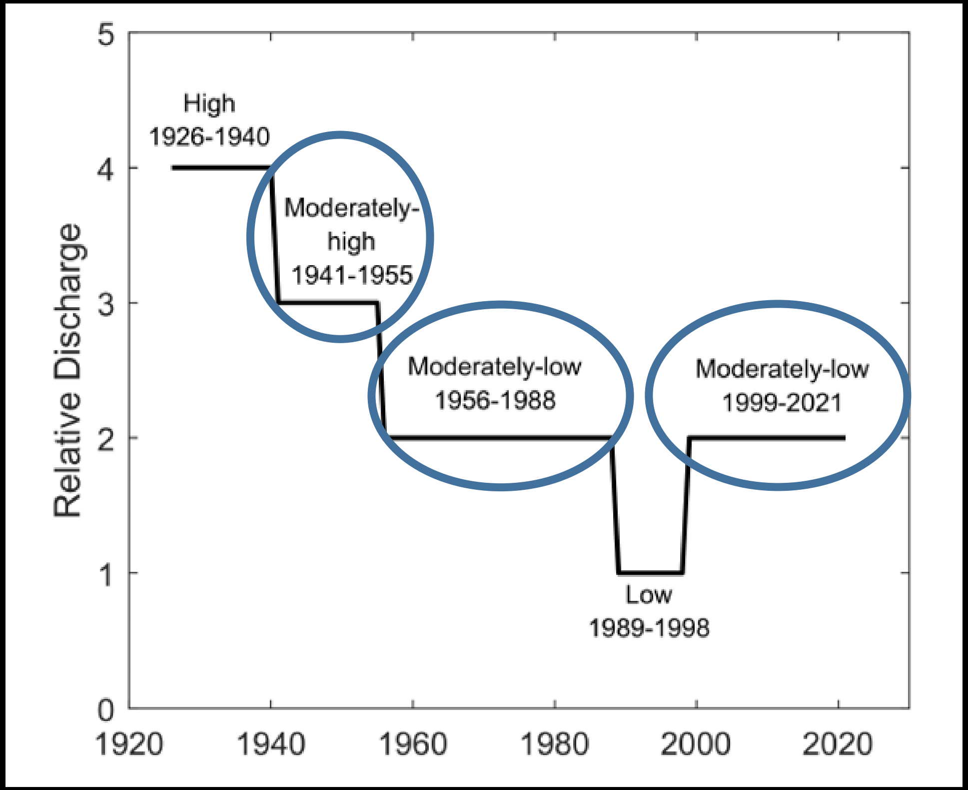
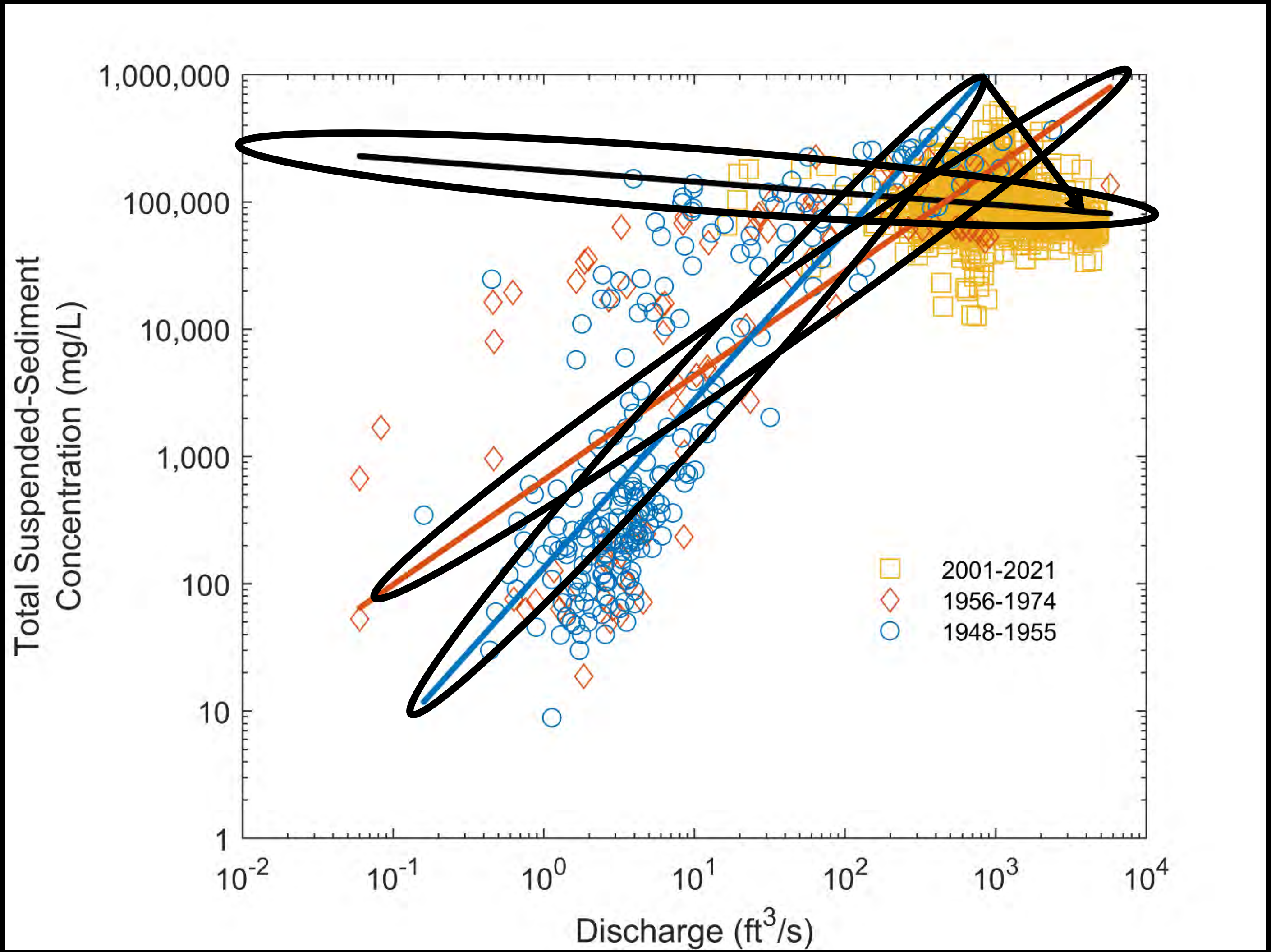
Moenkopi Wash
Effects of Physical Changes on Sediment Routing





Decline in sediment transport during Floods

Narrow, vegetated channel an inefficient conveyor of sediment

preliminary data, do not cite

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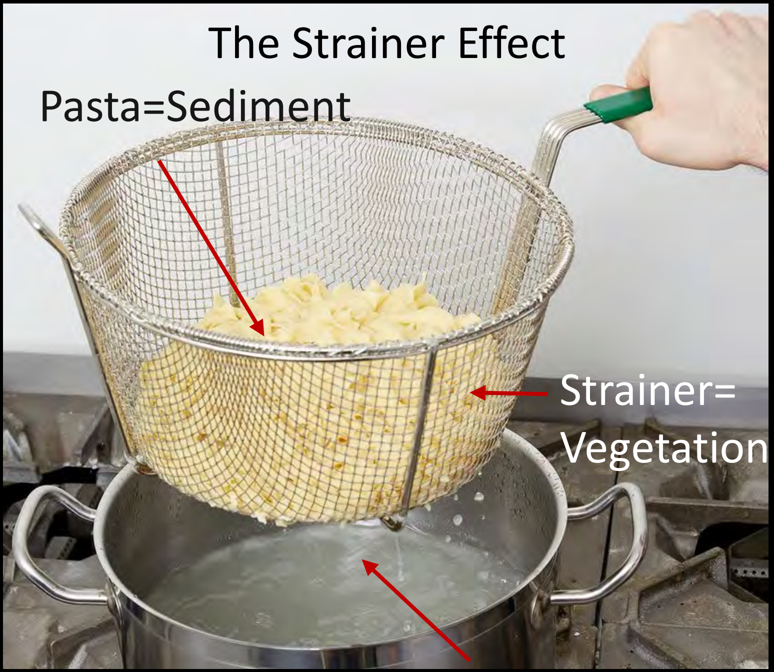
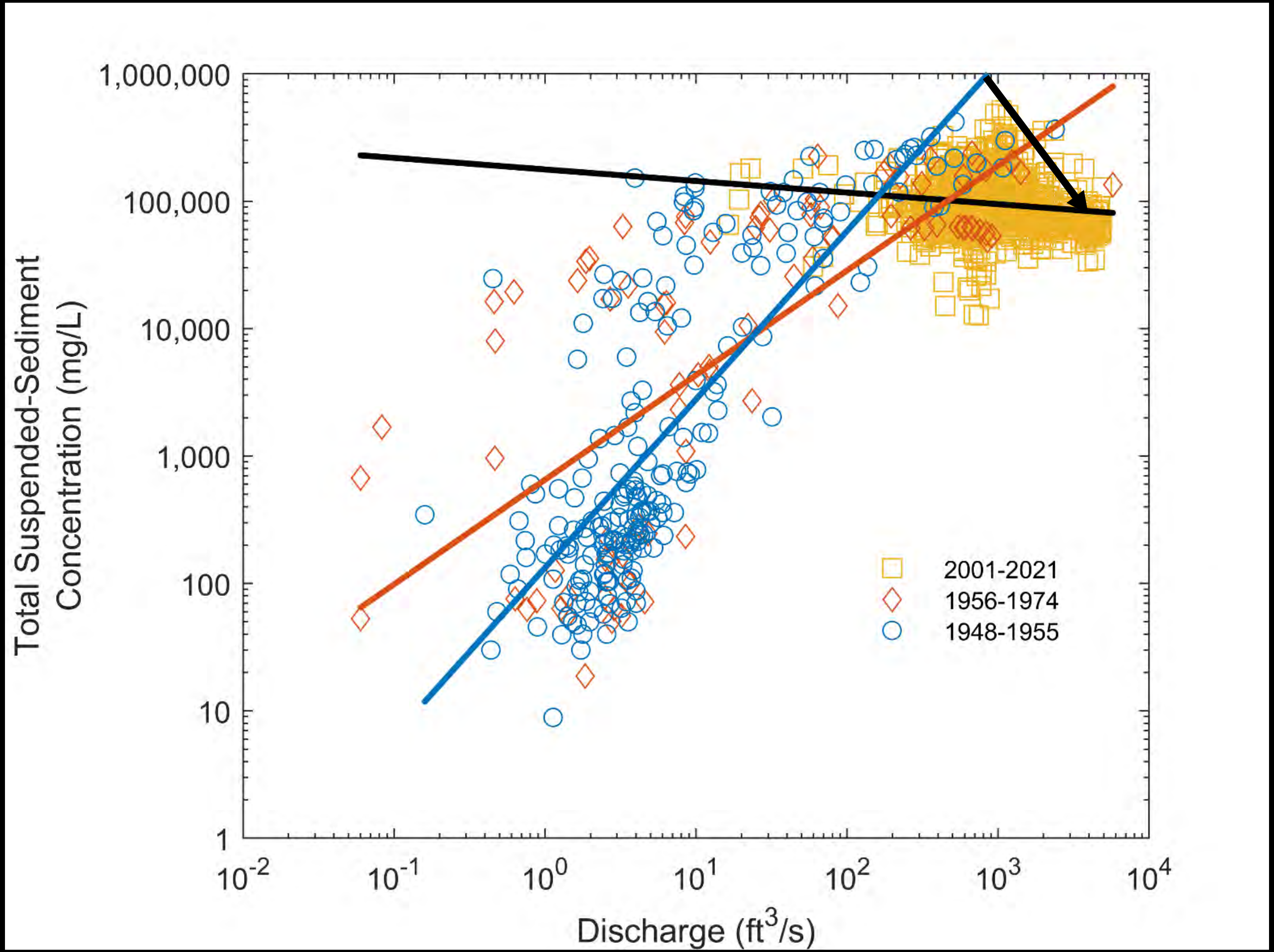
Moenkopi Wash
Effects of Physical Changes on Sediment Routing



Water = Flood water



Decline in sediment transport during Floods

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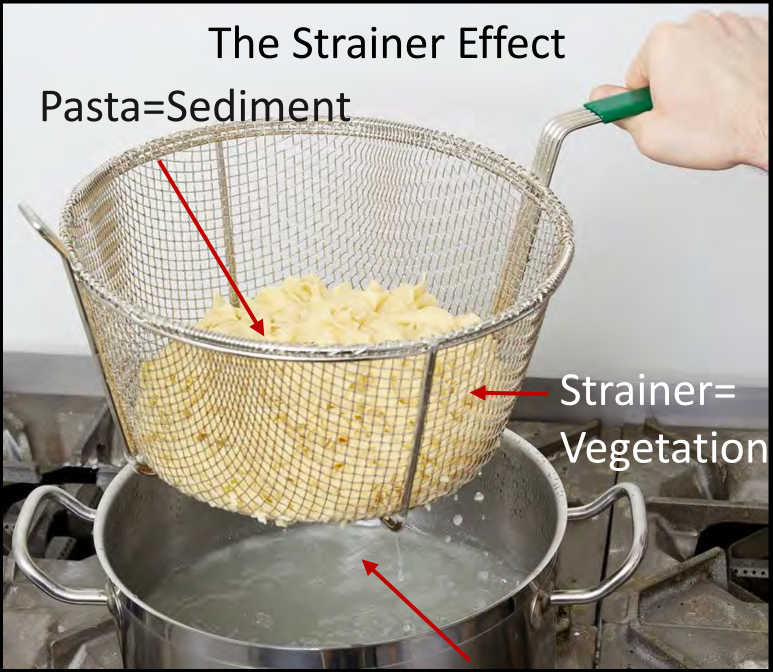
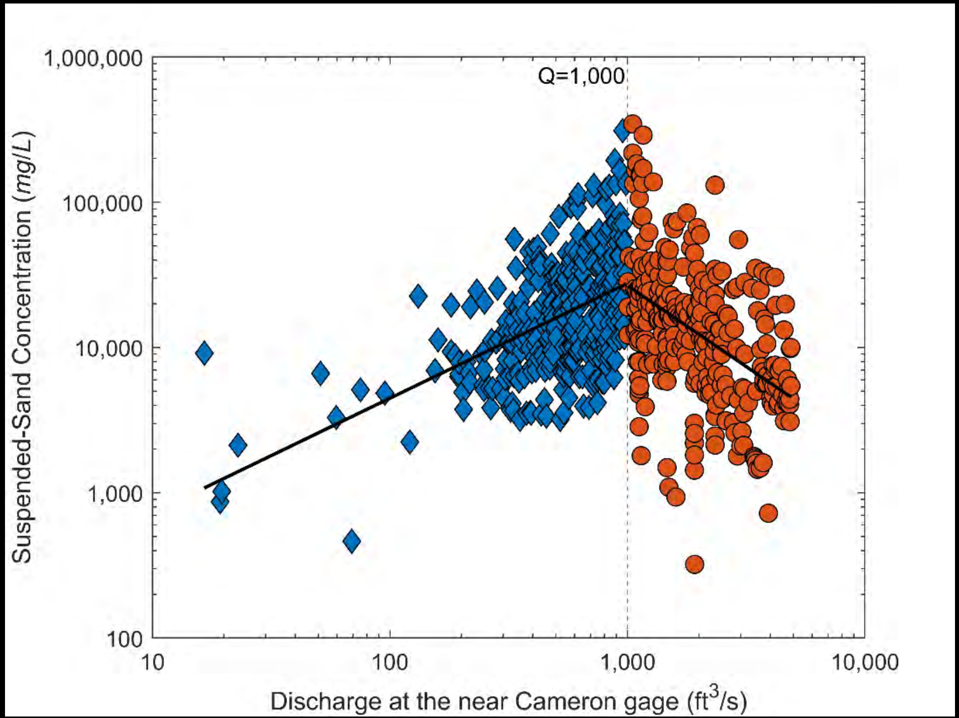
Effects of Physical Changes on Sediment Routing



Water = Flood water



preliminary data, do not cite

Decline in sediment transport during Floods

Narrow, vegetated channel an inefficient conveyor of sediment

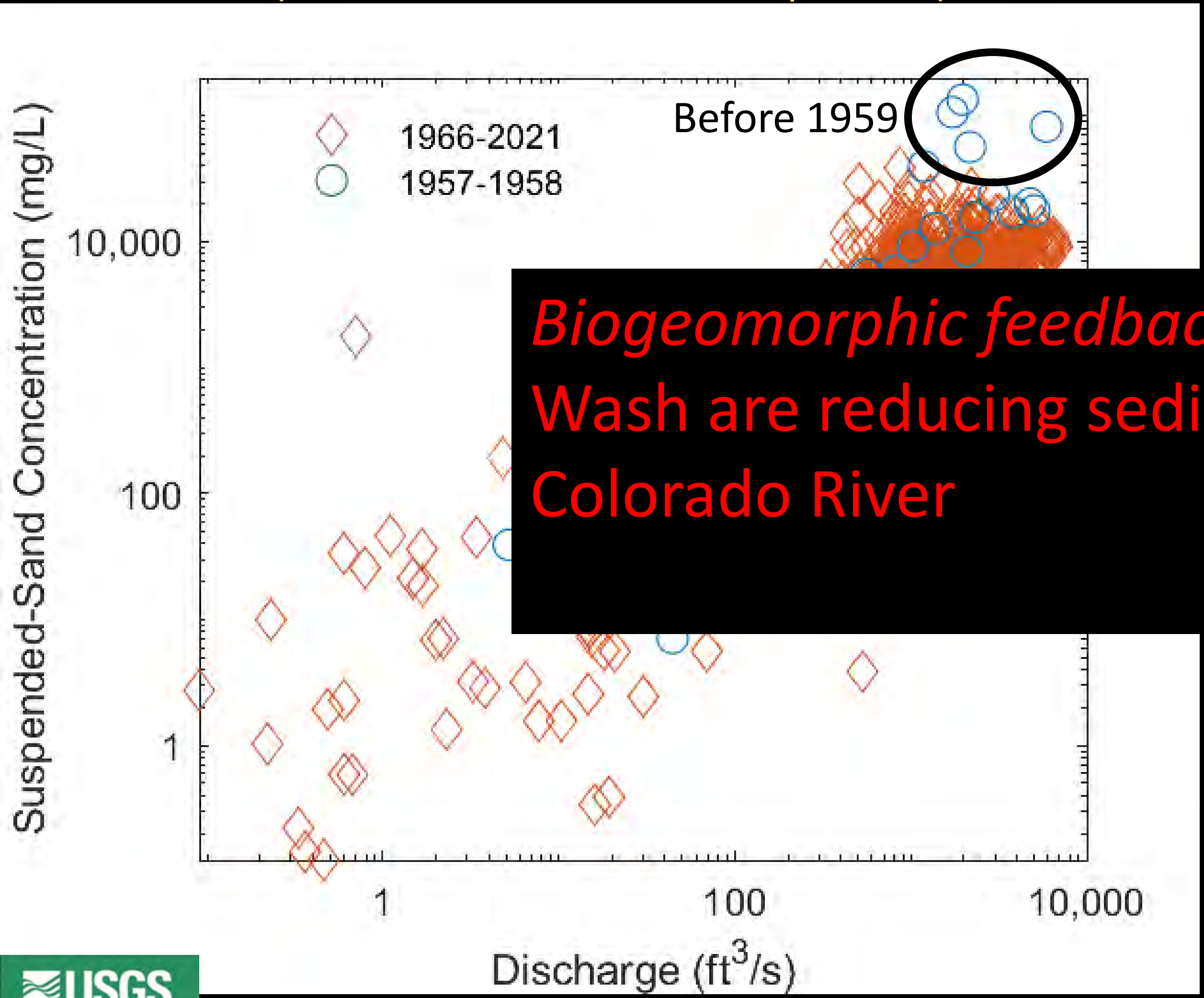
Declines in transport because of sediment trapping by veg

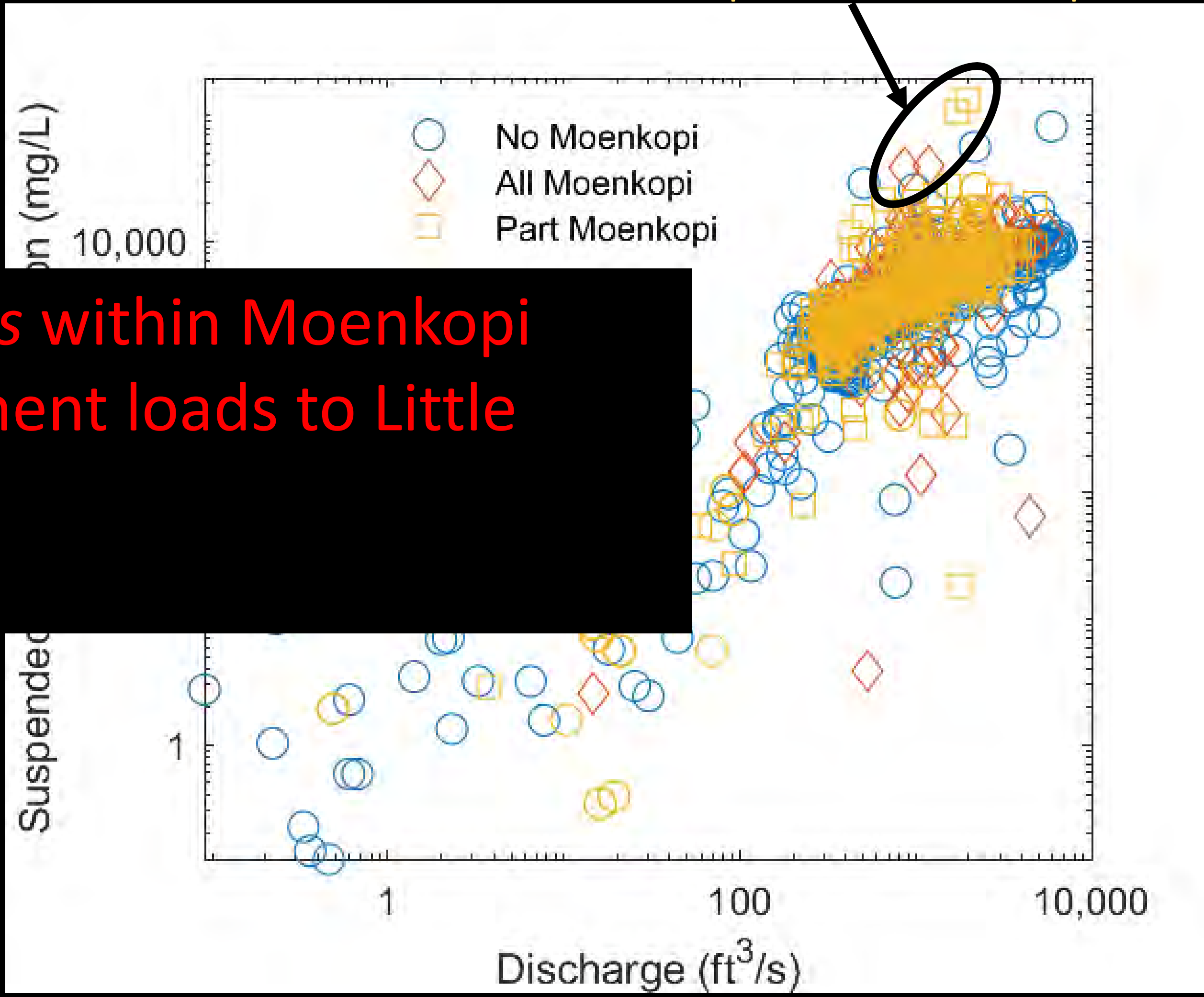
Moenkopi Wash

Why Does Moenkopi Wash Matter?

Little Colorado River near Cameron
(downstream from Moenkopi Wash)

4 of 6 largest concentration
Samples from Moenkopi

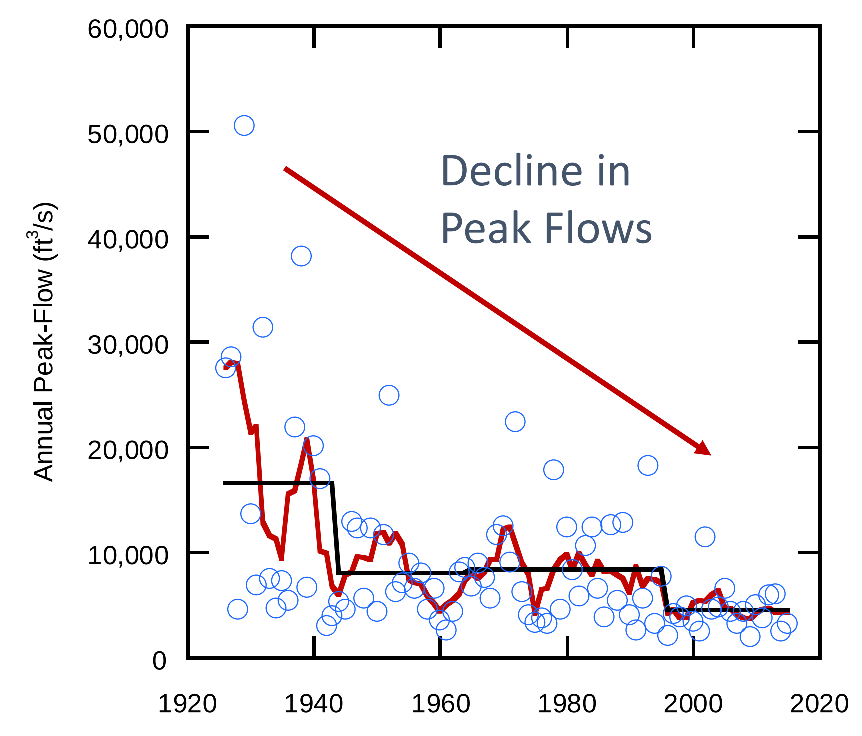




Biogeomorphic feedbacks within Moenkopi Wash are reducing sediment loads to Little Colorado River

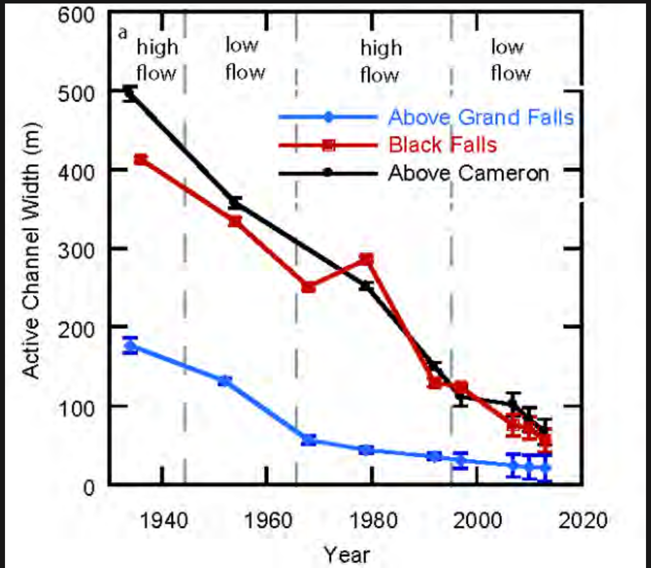
preliminary data, do not cite

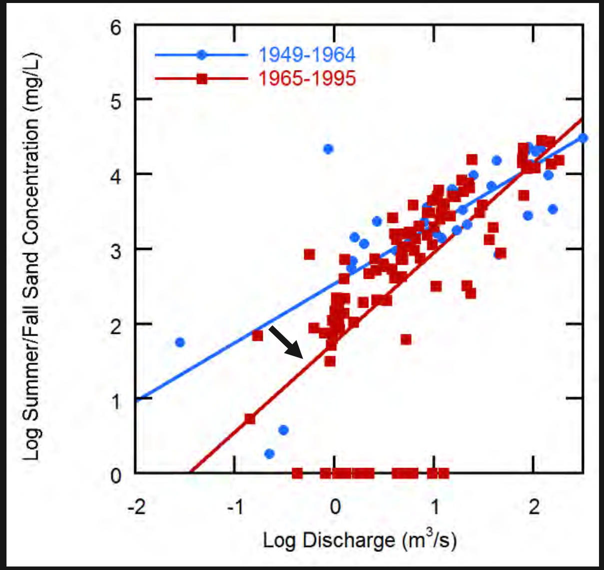
Physical Changes within the Little Colorado River

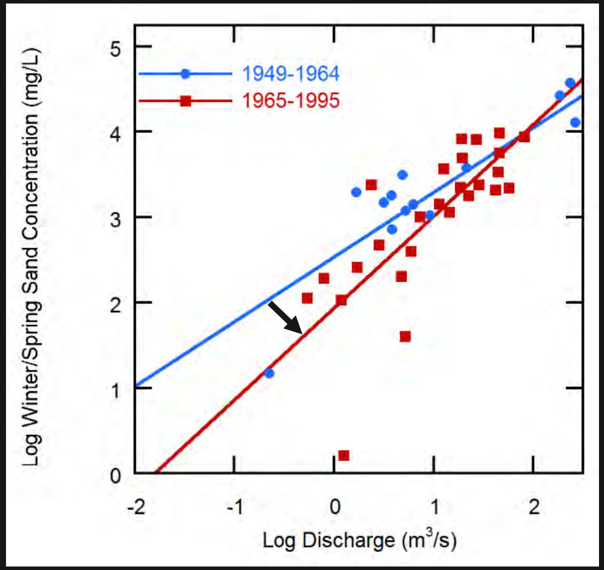


Dean and Topping, 2019, *GSA Bulletin*

Physical Changes within the Little Colorado River

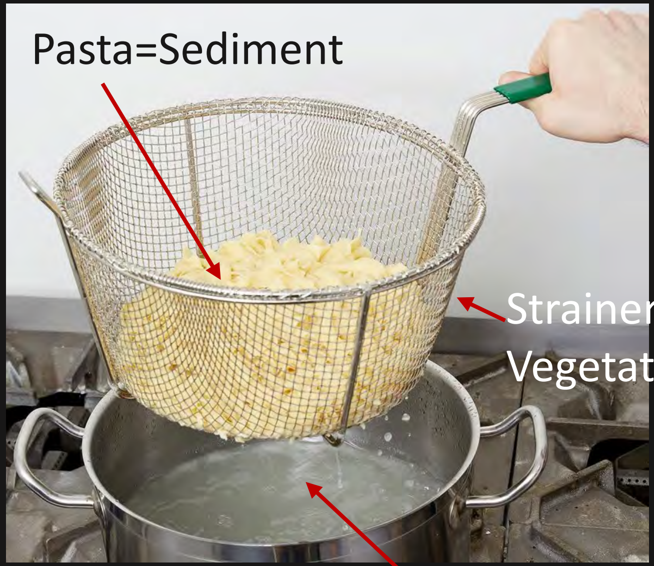






- Narrowing by > 80%
- Reductions in sediment transport

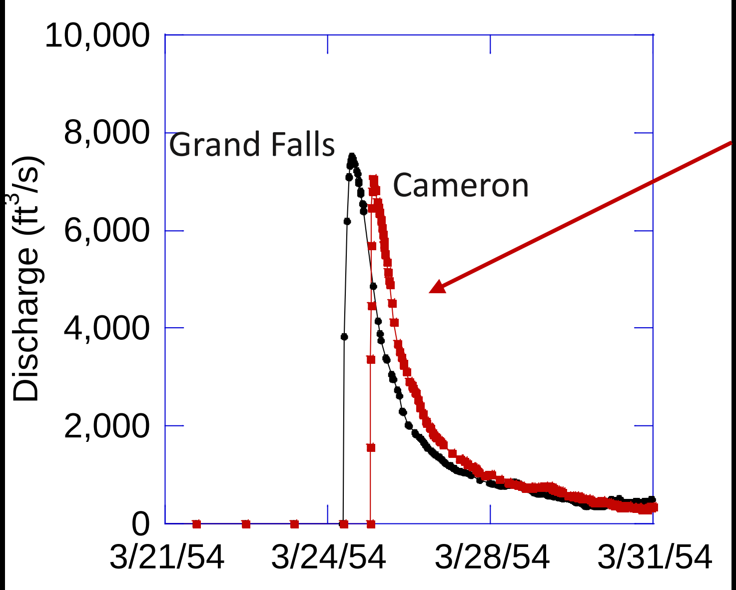
The Strainer Effect



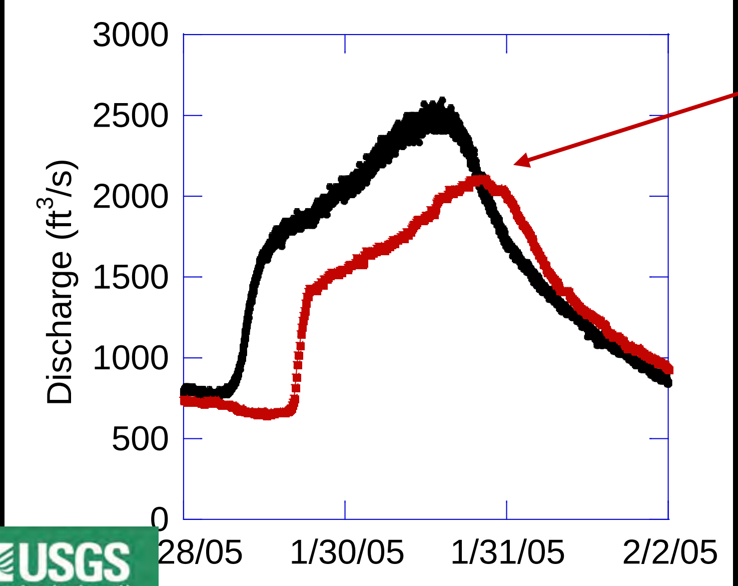
Water = Flood water

Dean and Topping, 2019, *GSA Bulletin*

Physical Changes within the Little Colorado River

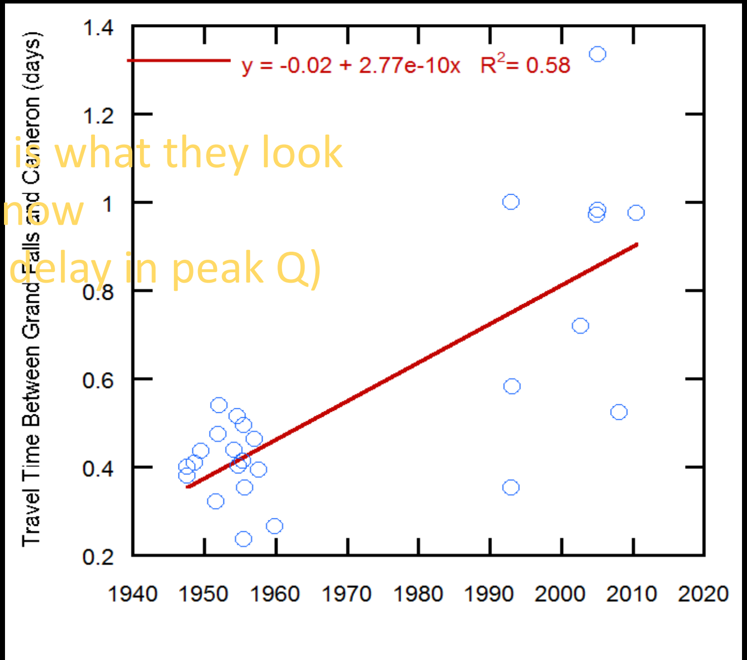


This is what flood hydrographs used to look like



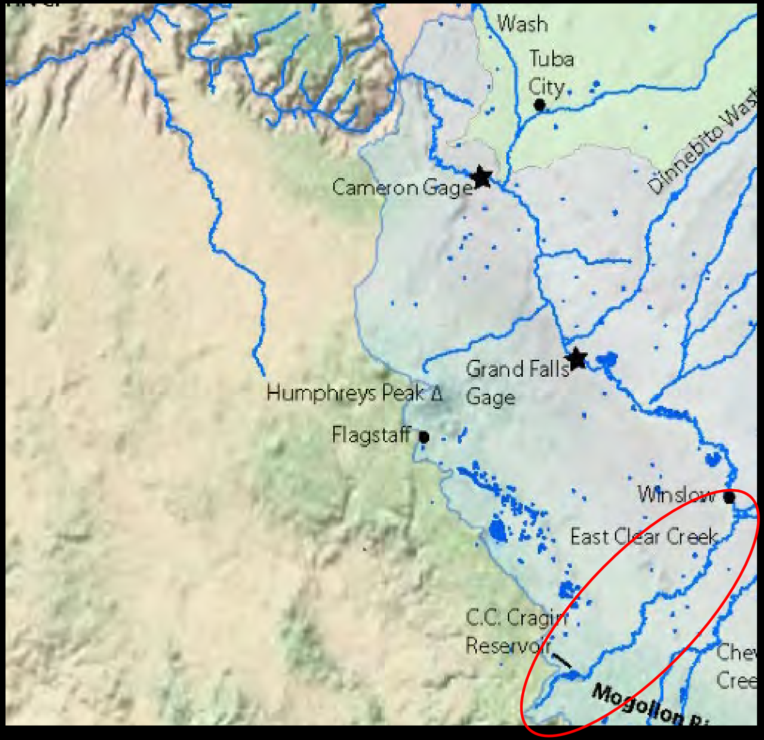
This is what they look like now (i.e. delay in peak Q)

Increase in Travel Time of Floods

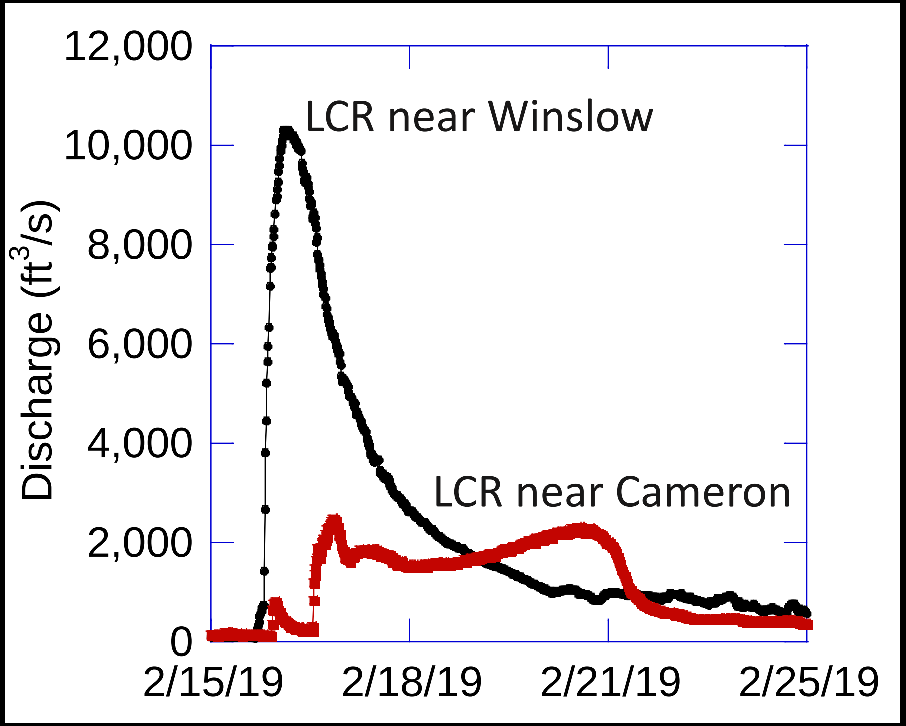


Dean and Topping, 2019, *GSA Bulletin*

February 2019 Flood Attenuation



Rain on Snow- East Clear Creek



preliminary data, do not cite

- Flood peak attenuation by ~85%
- No large reservoirs or diversion structures

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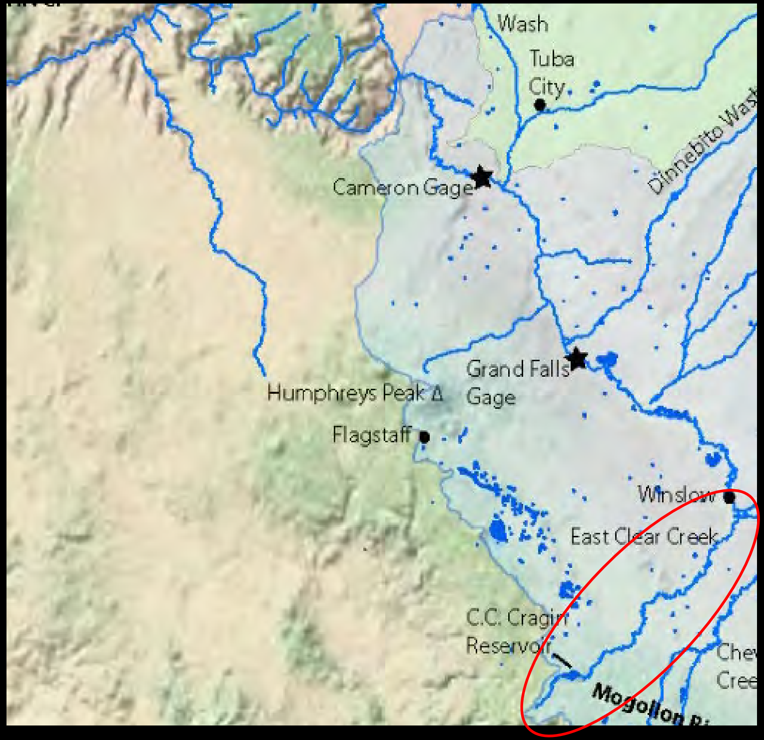
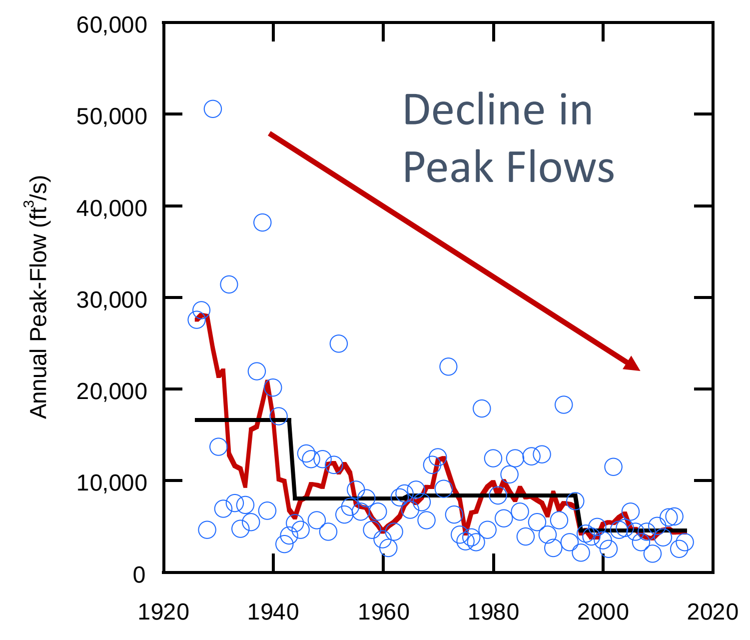
February 2019 Flood Attenuation





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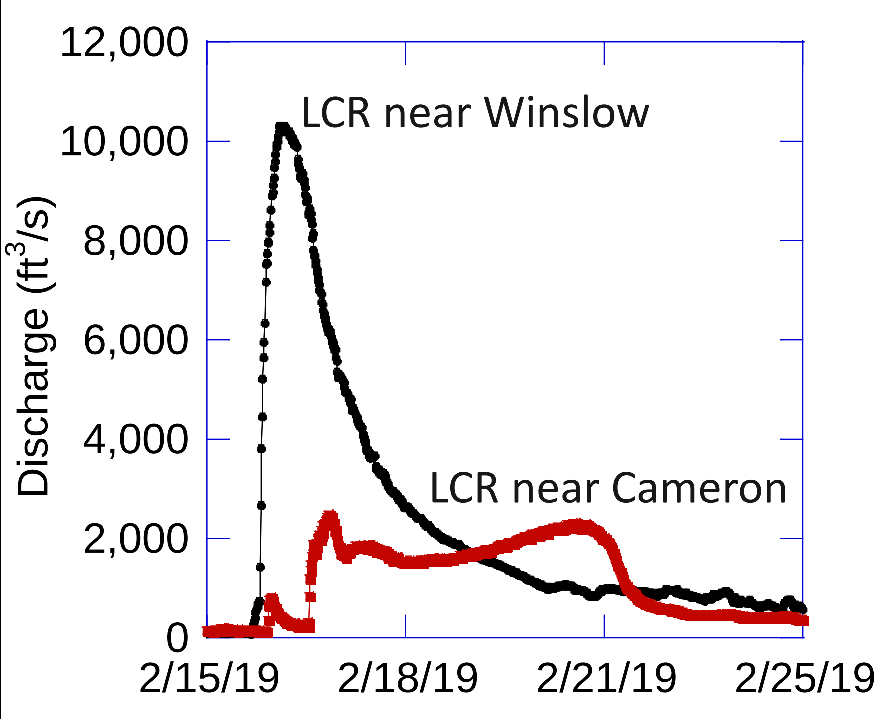


preliminary data, do not cite

- Attenuation likely solely caused by the bio-geomorphic feedbacks.

Summary: Moenkopi Wash and LCR

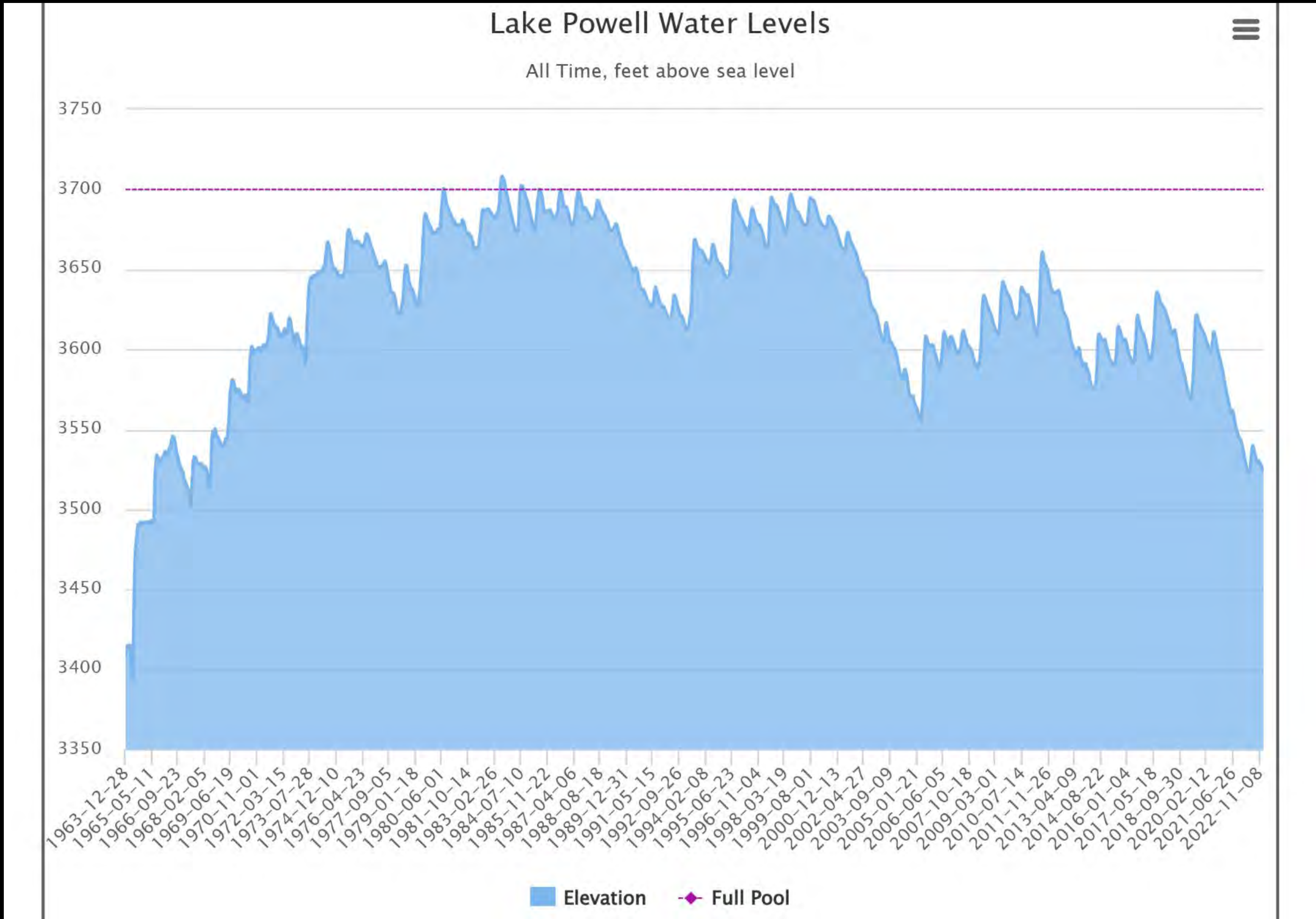
- Channel narrowing and vegetation invasions
  - Dense vegetation slows floodwater – reductions in peak discharge (attenuation) Dean and Topping, 2019, GSA Bulletin
    - In lower LCR, progressive growth of travertine dams? Impact fish habitat/passage? (Unema et al., 2021)
  - Dense vegetation traps sediment – reductions in sediment transport Dean and Topping, 2019, GSA Bulletin

- Sediment loads from Moenkopi Wash have been reduced to LCR (preliminary data, do not cite)
- Sediment loads from LCR have been reduced to Colorado River (preliminary data, do not cite)
- Reduction in sediment loads unlikely to be reversed

3) Colorado River in Grand Canyon

How will possible low GCD releases affect vegetation and geomorphology in Colorado River?

Desire to maintain Lake Powell elevations above minimum power pool (3490')



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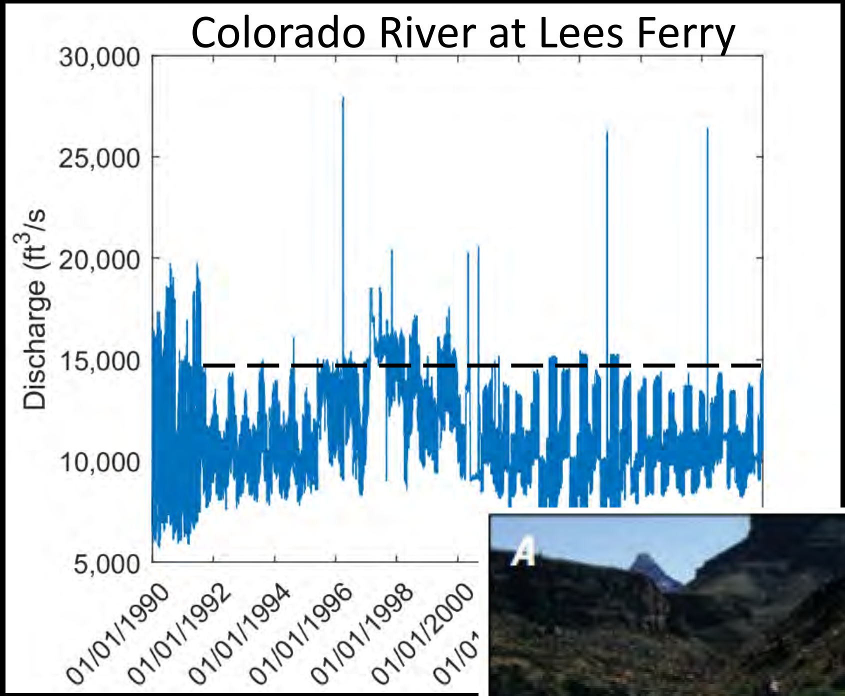
preliminary data, do not cite

Vegetation will track large changes in river stage.



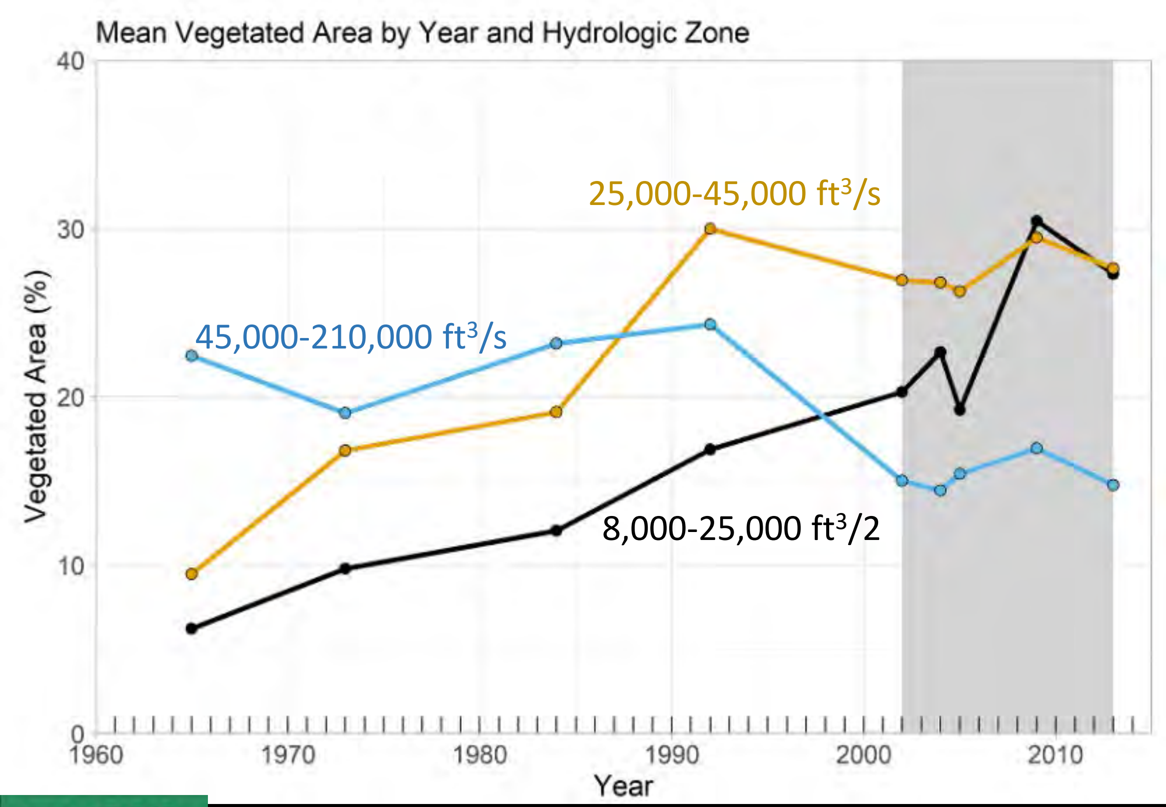
Riparian Zone will encroach upon the river IF

- Decrease in disturbance (e.g. decline in flood peaks)
- Increase in baseflow

Hazel et al., 2022, *USGS Professional Paper*

Vegetation will track large changes in river stage.

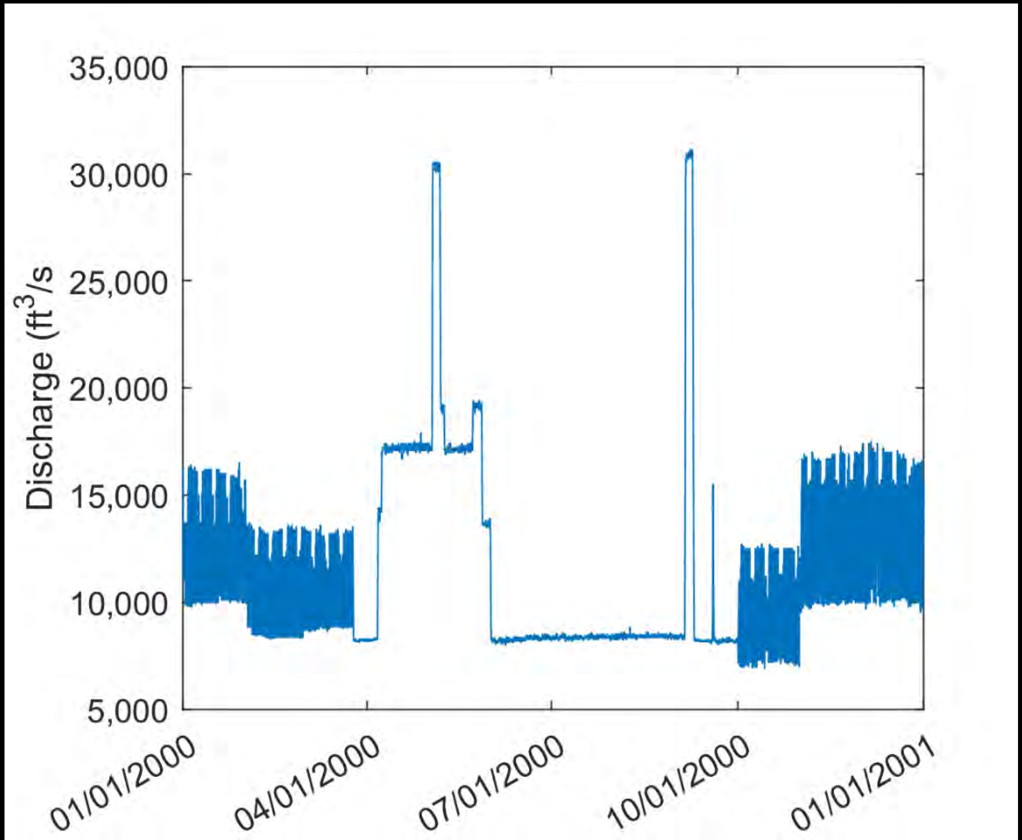
Increase in baseflows = vegetation expansion above 8,000 ft^3/s stage
Lack of flood disturbance = greater vegetation at higher elevations 25,000-45,000 ft^3/s

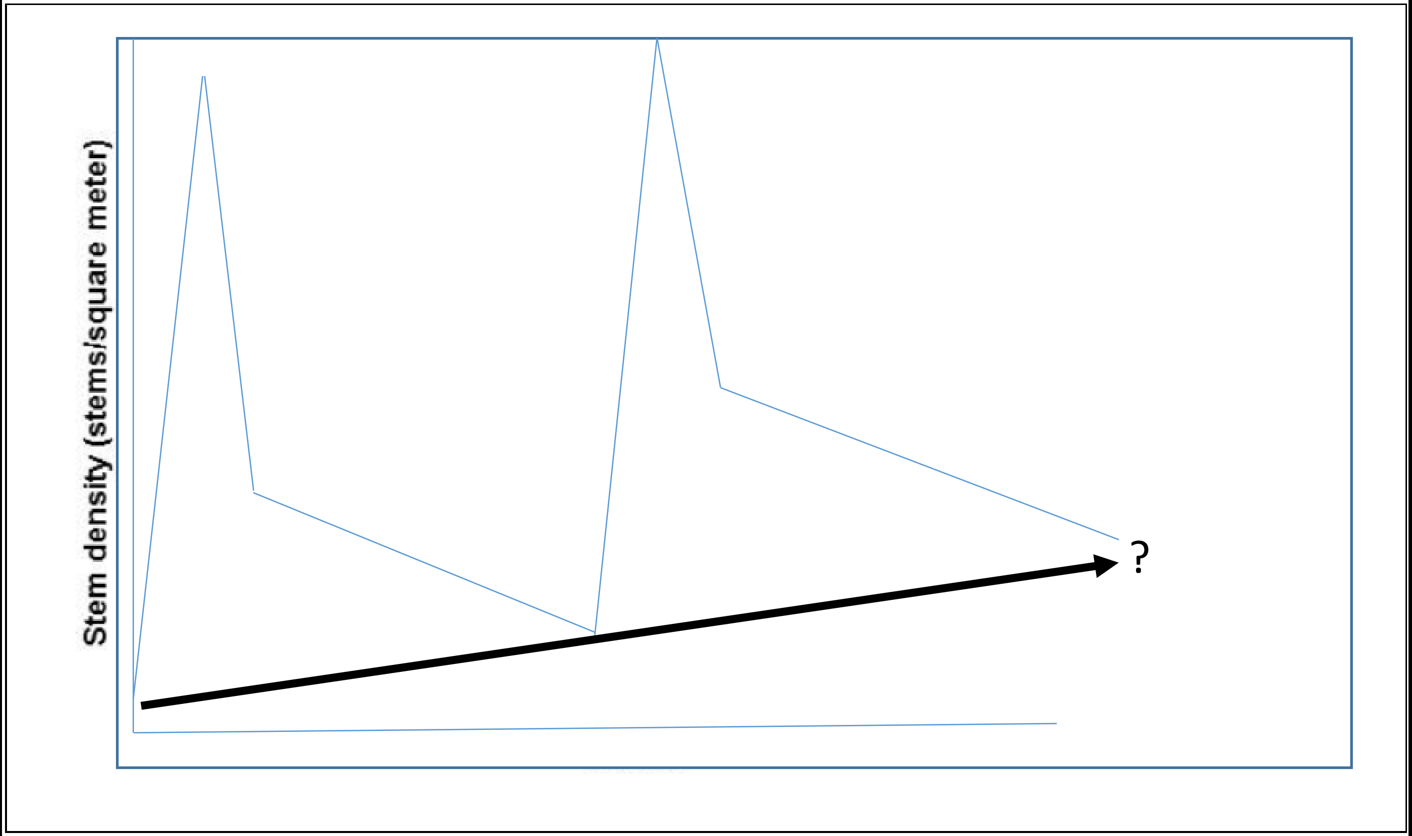


Durning et al., 2021, *Ecohydrology*

2000 – Low Steady Summer Flow experiment

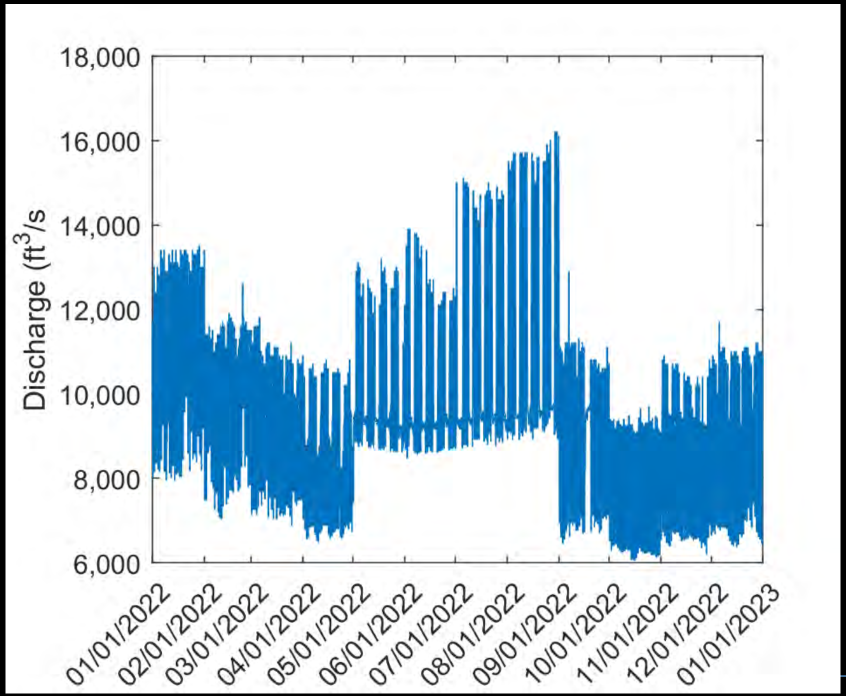
- Dramatic increase in vegetation during low flows
- HMF (habitat maintenance flows) reduced stem density
- Additional declines in stem density after resuming "normal" operations
- However, not all vegetation was removed…some residual survival





Ralston, 2011, *USGS Open-File Report*

2022 Flows



Discharge (ft^3/s)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
01/01/2022
02/01/2022
03/01/2022
04/01/2022
05/01/2022
06/01/2022
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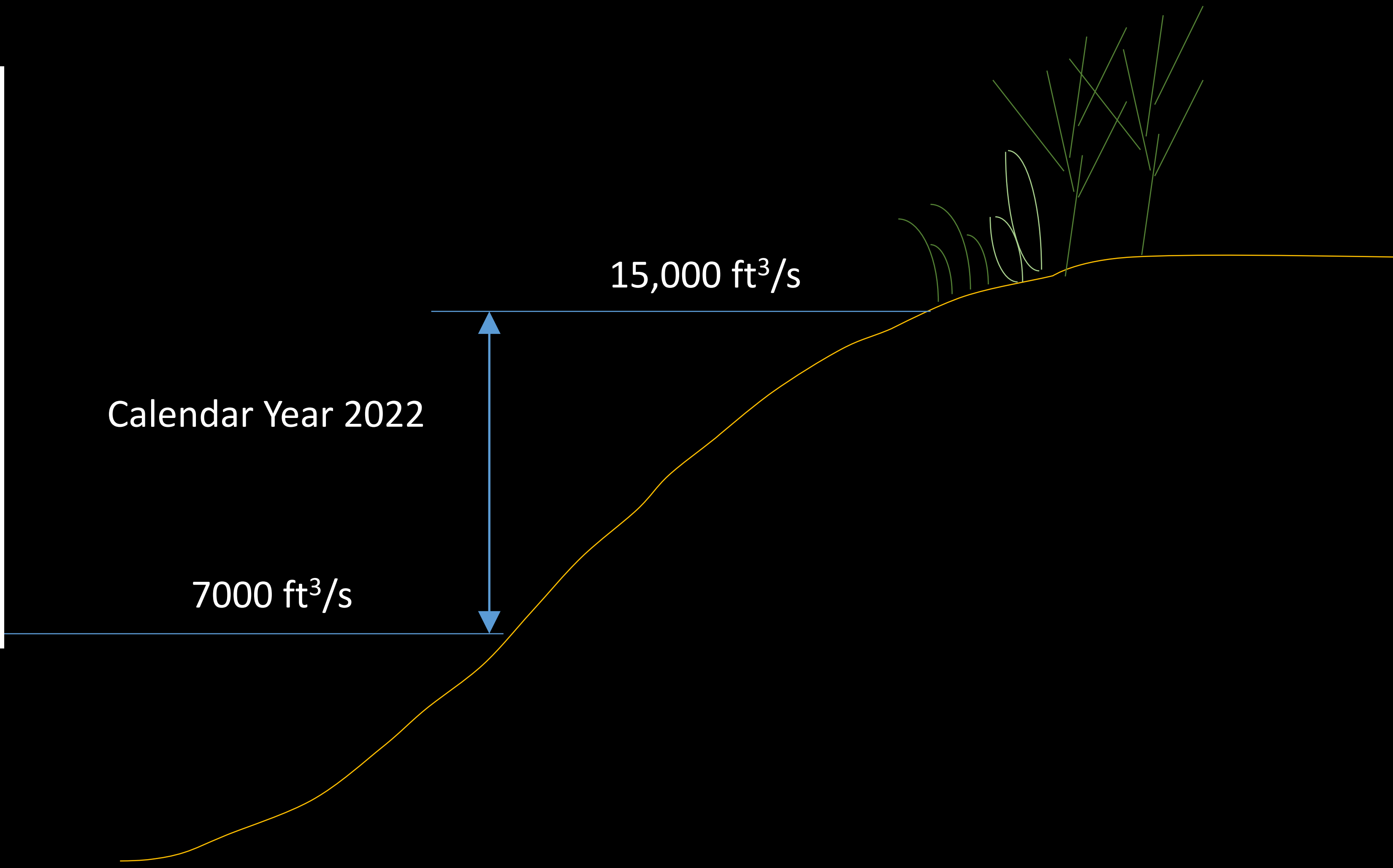
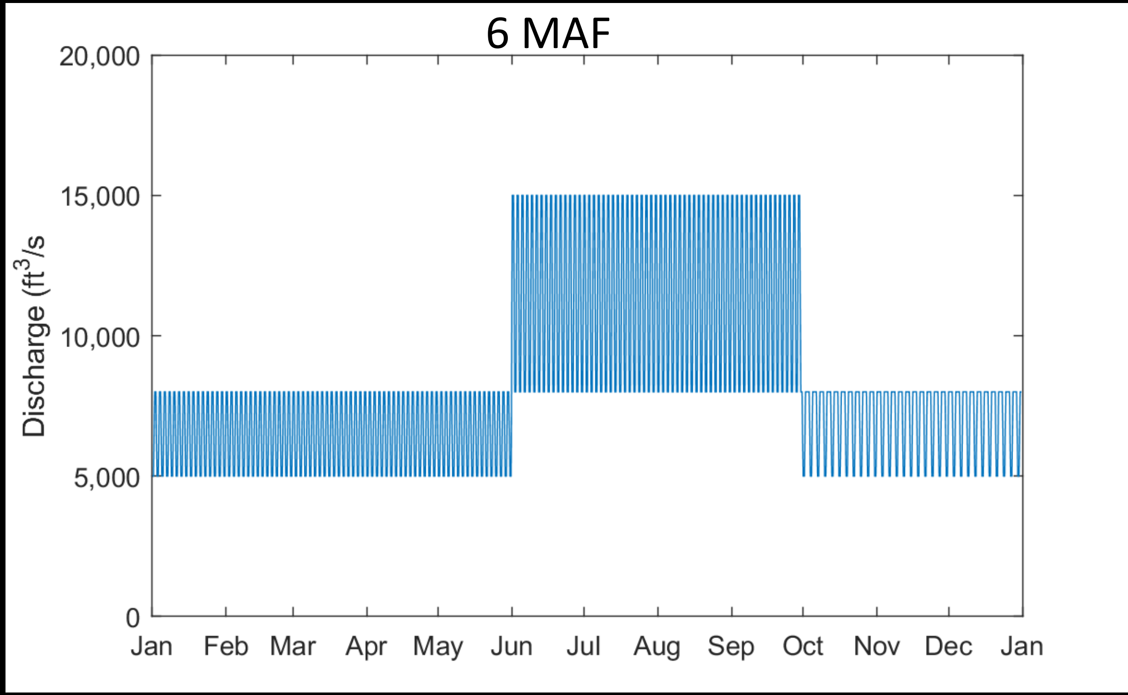
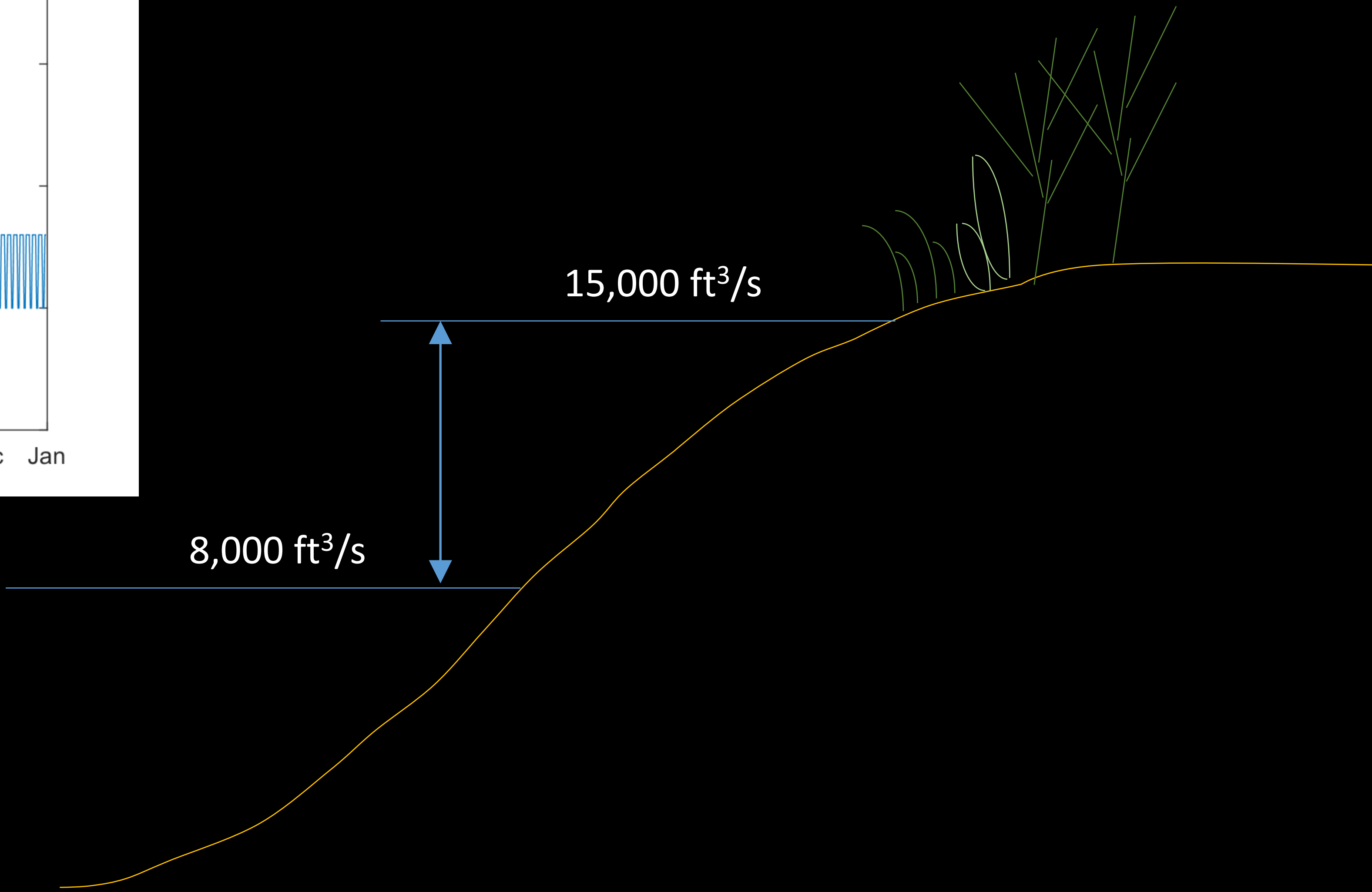
11/01/2022
12/01/2022
01/01/2023



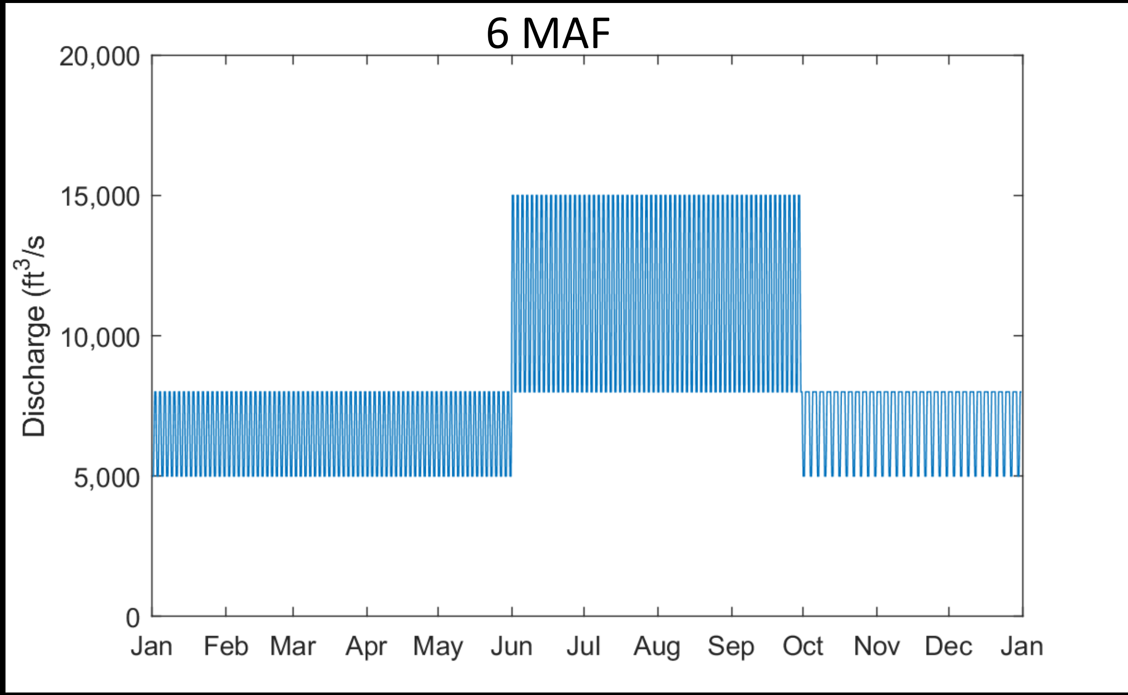
15,000 ft^3/s
Calendar Year 2022
7000 ft^3/s

Possible low flows to stay above power pool

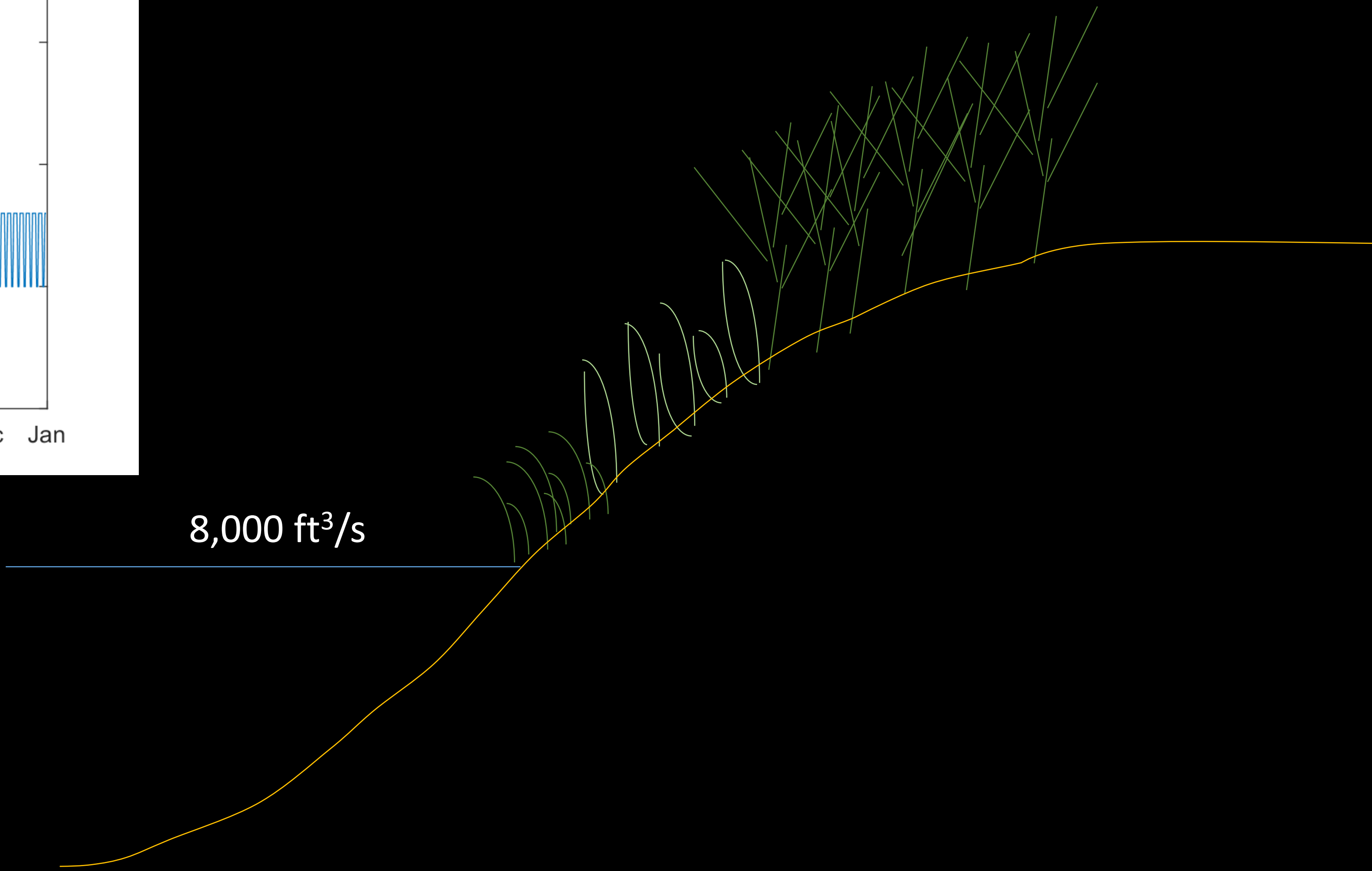




Possible low flows to stay above power pool

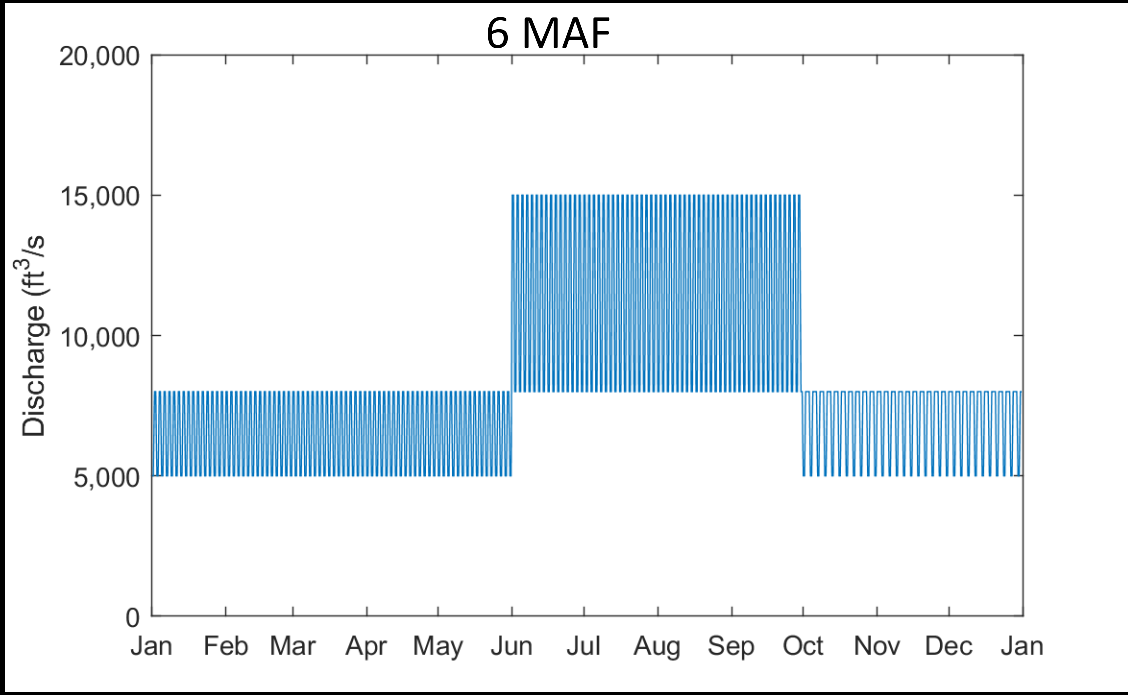


Low flow encroachment

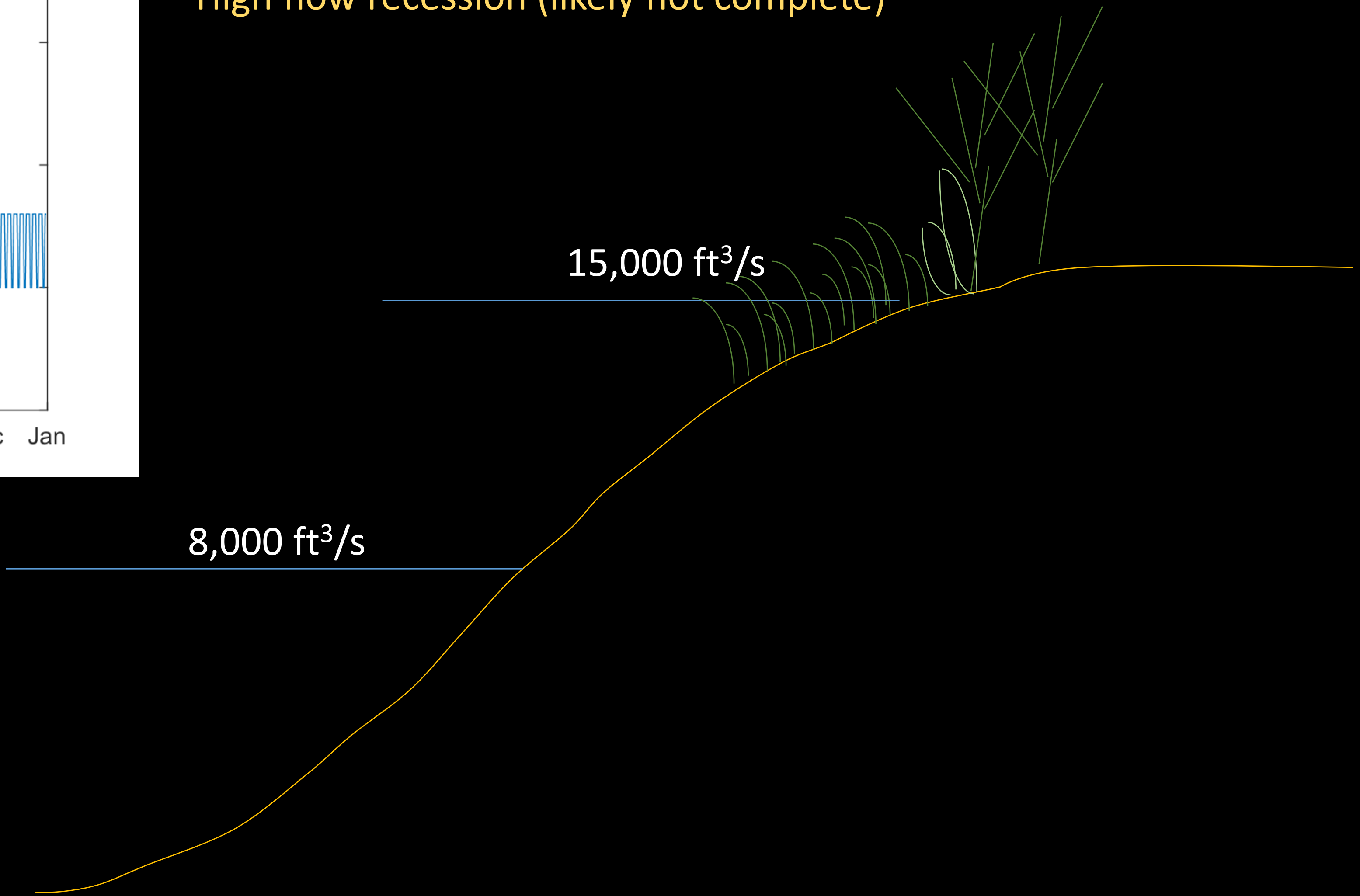


preliminary data, do not cite

Possible low flows to stay above power pool

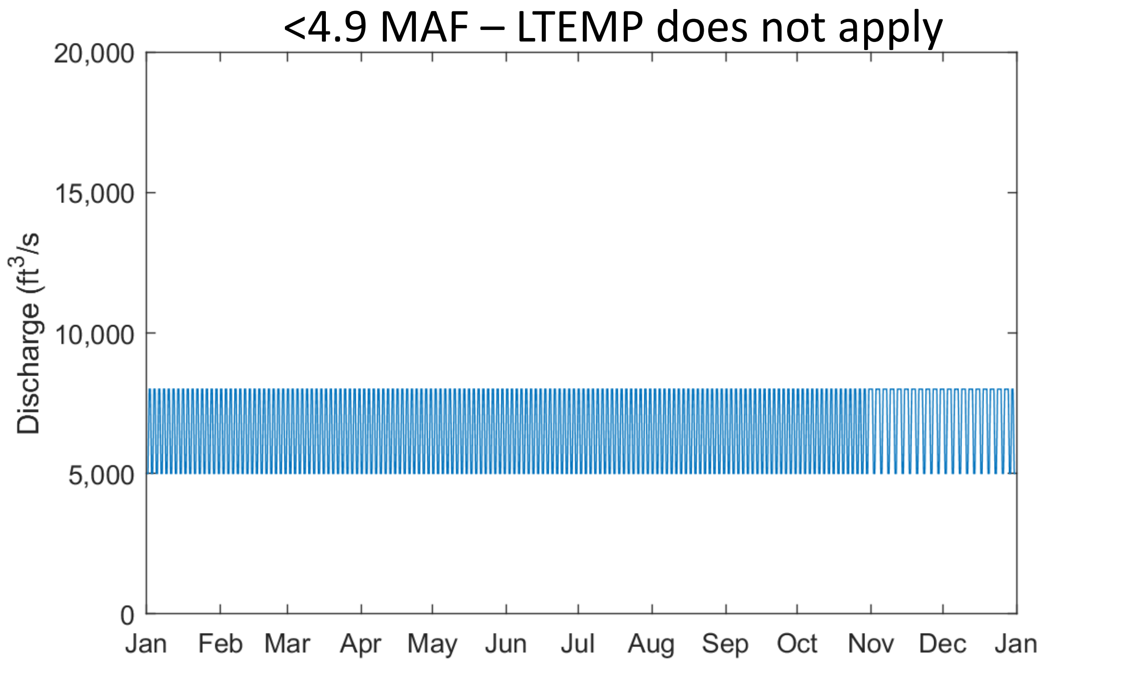


Low flow encroachment
High flow recession (likely not complete)

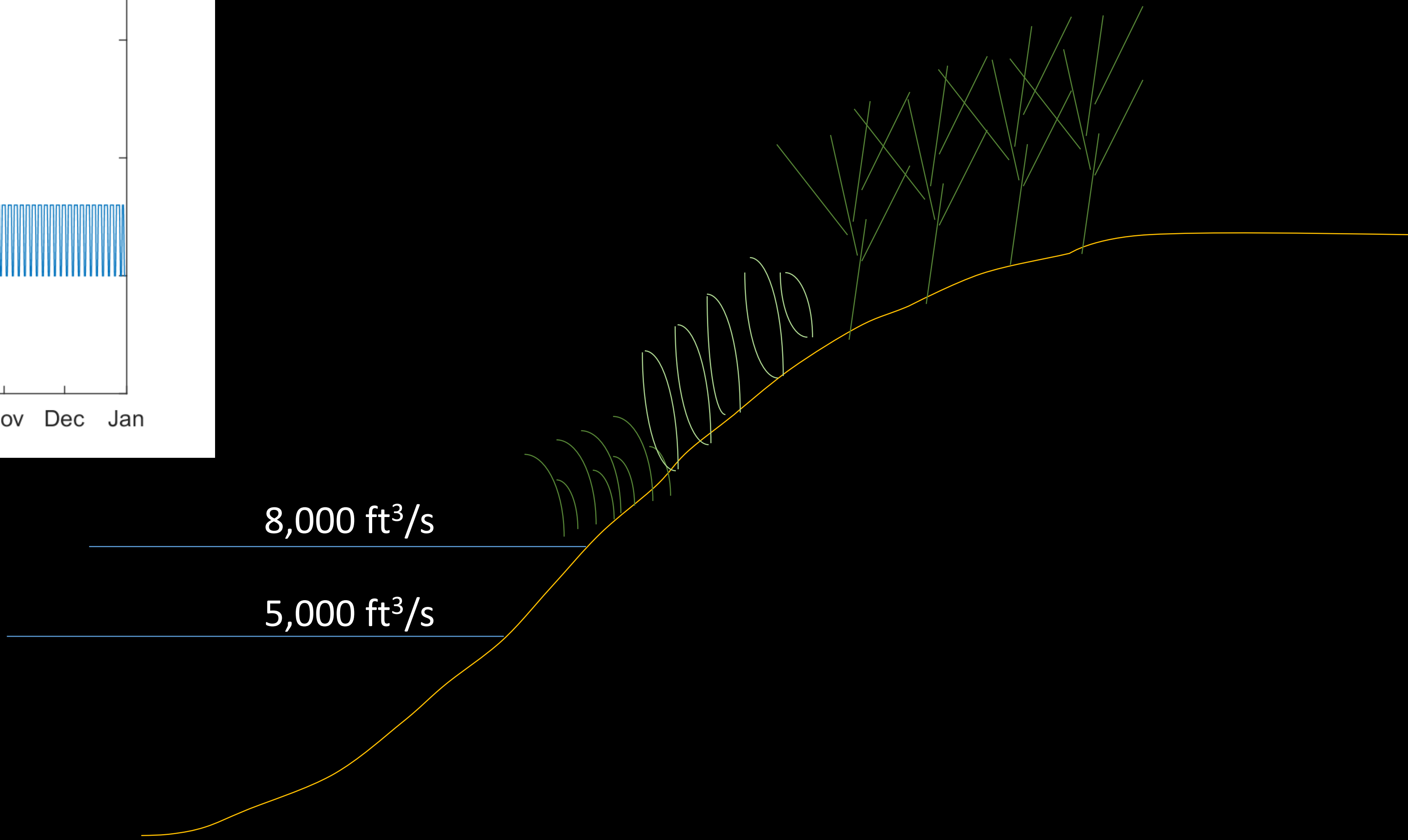


preliminary data, do not cite

Possible low flows to stay above power pool

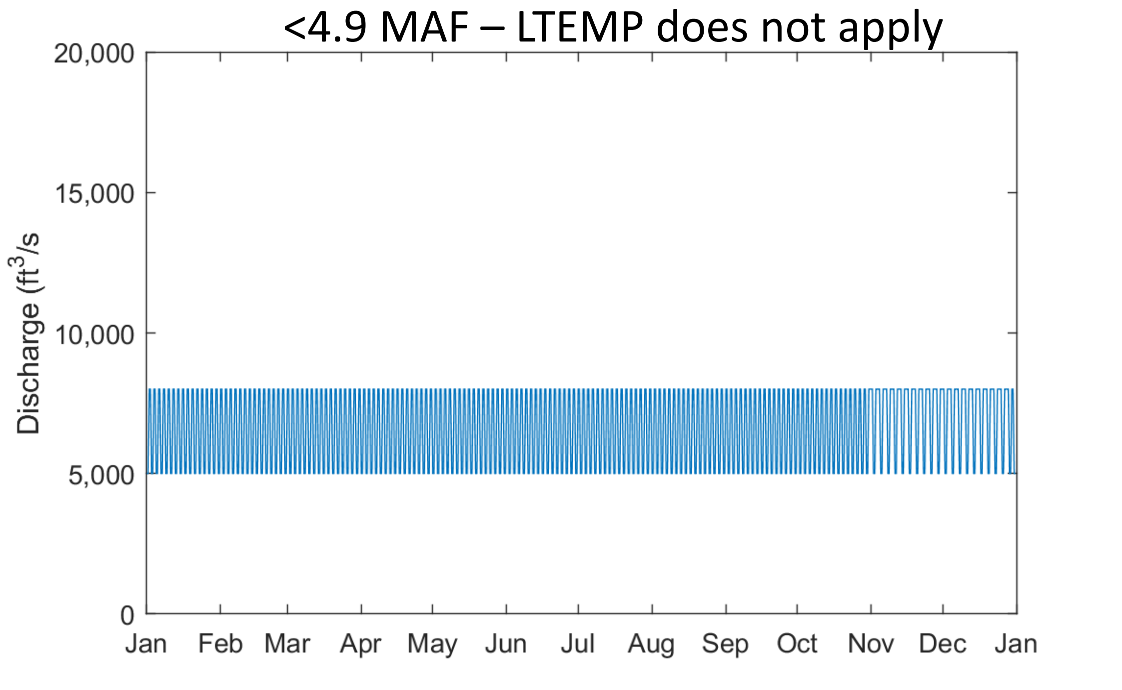


Low flow encroachment

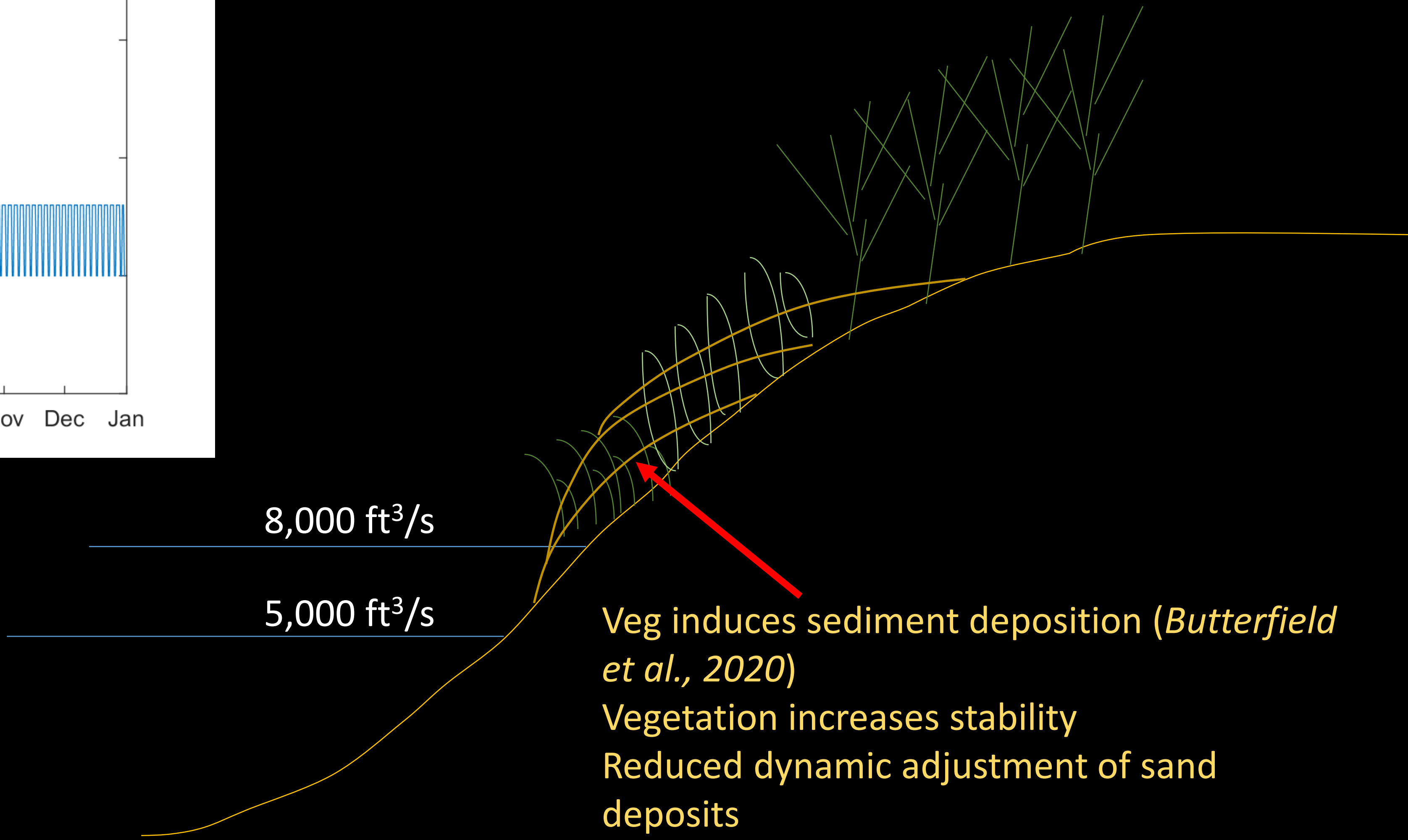


preliminary data, do not cite

Possible low flows to stay above power pool



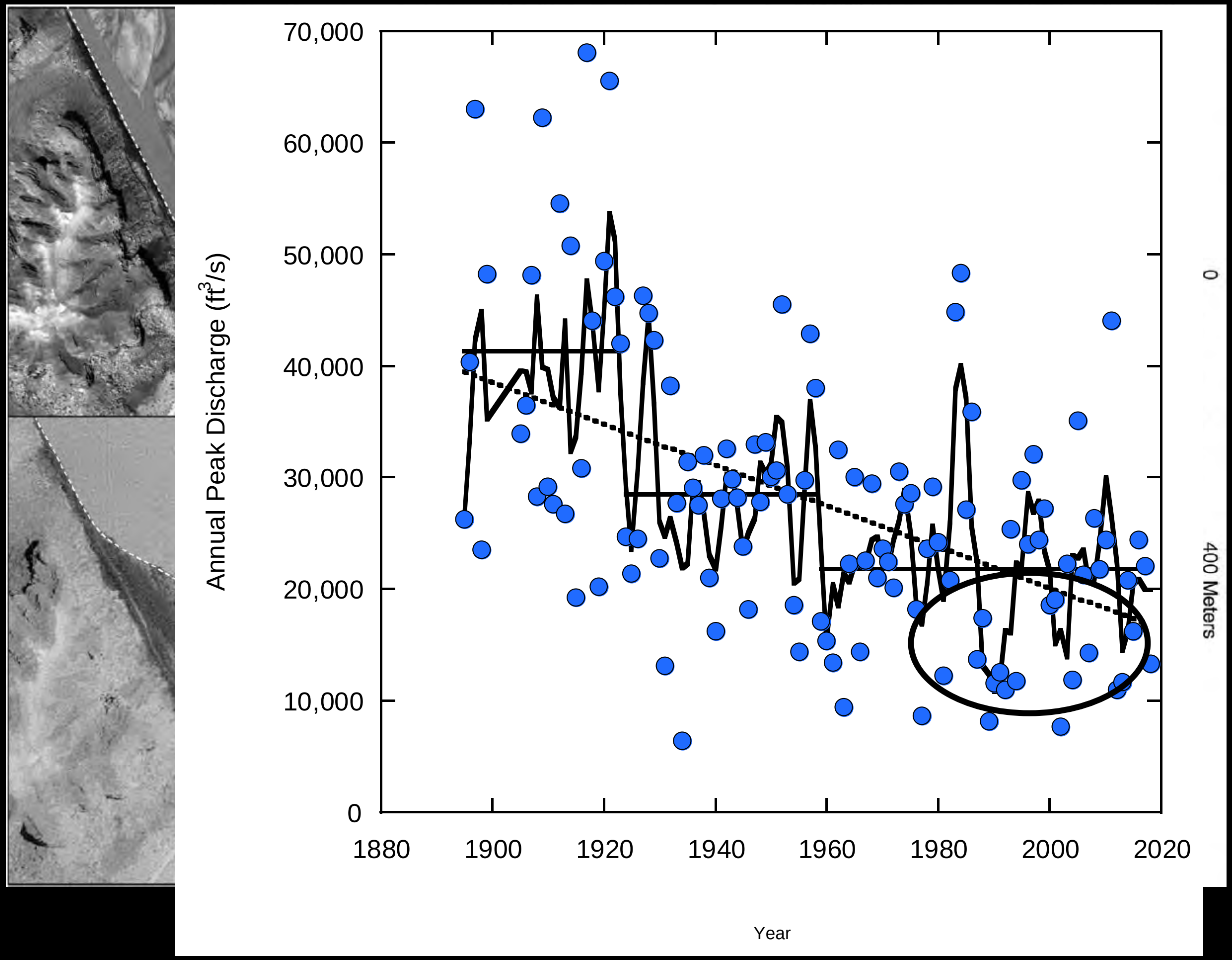
Low flow encroachment



Veg induces sediment deposition (*Butterfield et al., 2020*)
Vegetation increases stability
Reduced dynamic adjustment of sand deposits
Once established, very difficult to remove

Channel Narrowing in other rivers (e.g. Green River)

- Vegetation encroachment during low-flow years
  - stabilize deposits and trap additional sediment.
  - Channel narrowing
  - No widening after subsequent Increases in discharge



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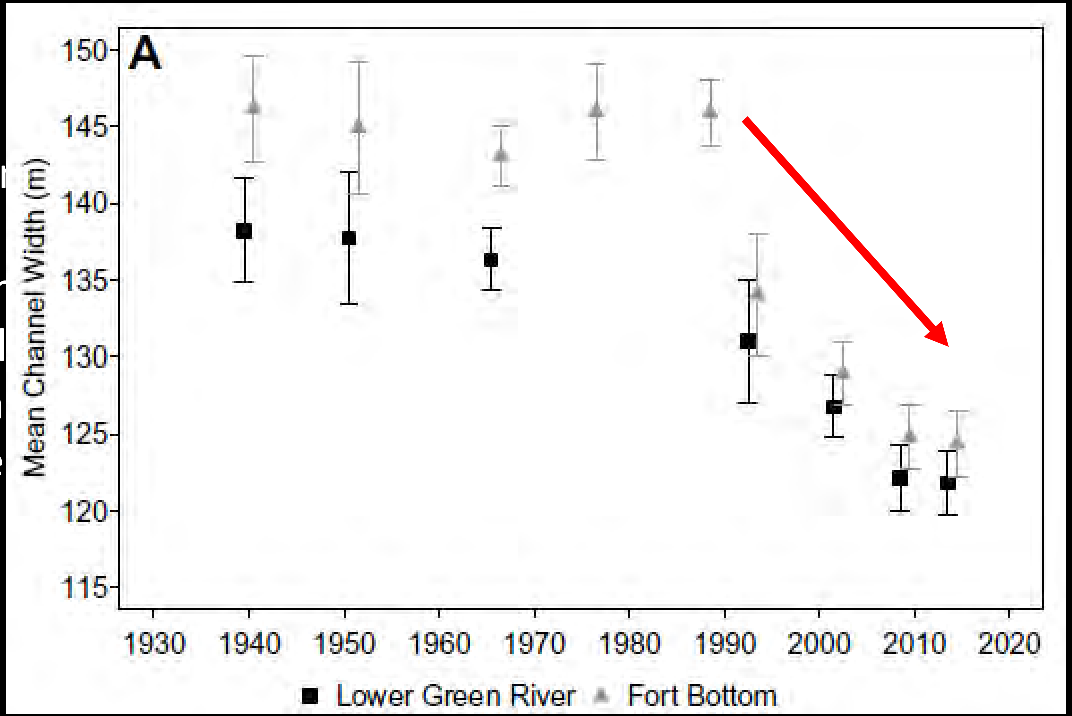
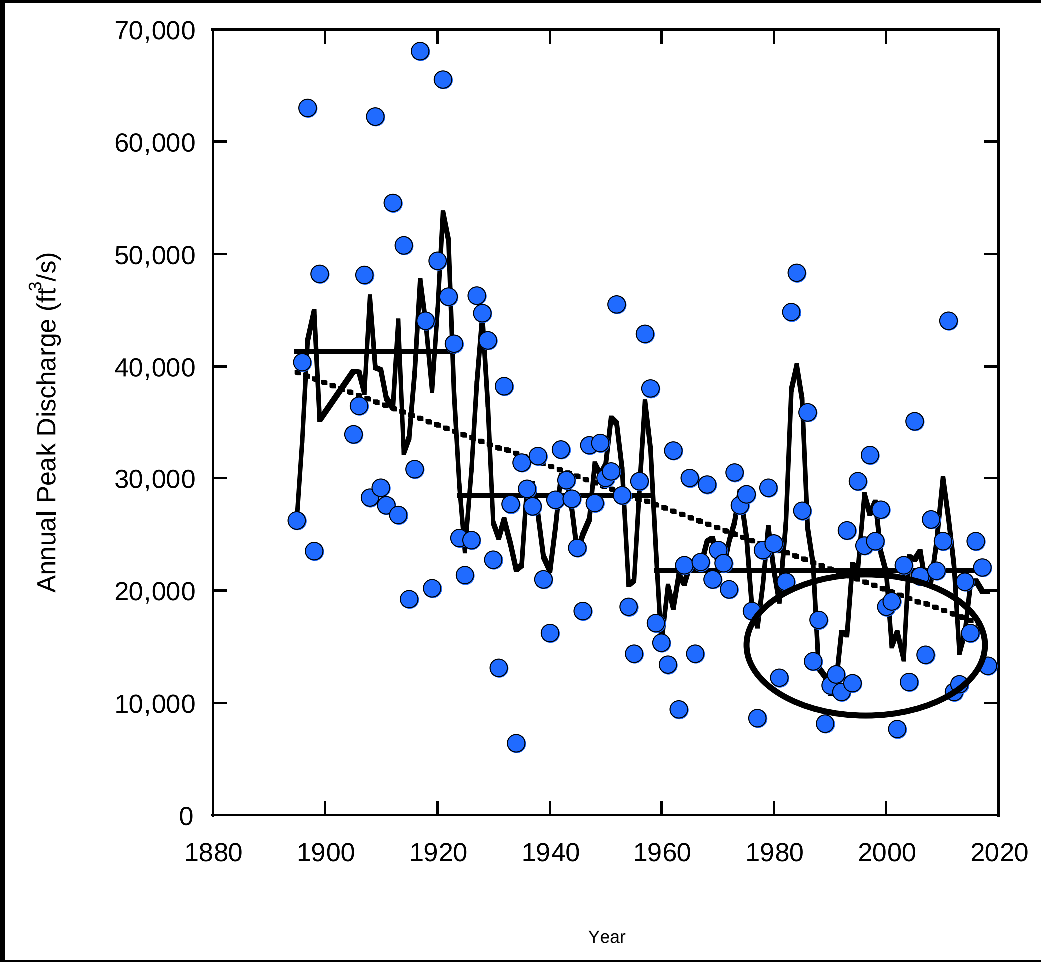


Walker et al., 2020, *GSA Bulletin*

Channel Narrowing in other rivers (e.g. Green River)



- Vegetation encroachment during low-flow years
  - stabilize deposits and trap additional sediment.
  - Channel narrowing
  - No widening after subsequent

  Increases in discharge

Even a few years of reduced flows may result in nearly irreversible changes to channel morphology

Walker et al., 2020, *GSA Bulletin*

Summary: Colorado River in Grand Canyon

- Reduced flows – vegetation encroachment upon river
- A few years of reduced flows – vegetation maturation, very difficult to remove
- Mature vegetation will trap sediment
  - Channel narrowing
  - Loss of important aquatic habitats (e.g. backwaters)

Questions

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