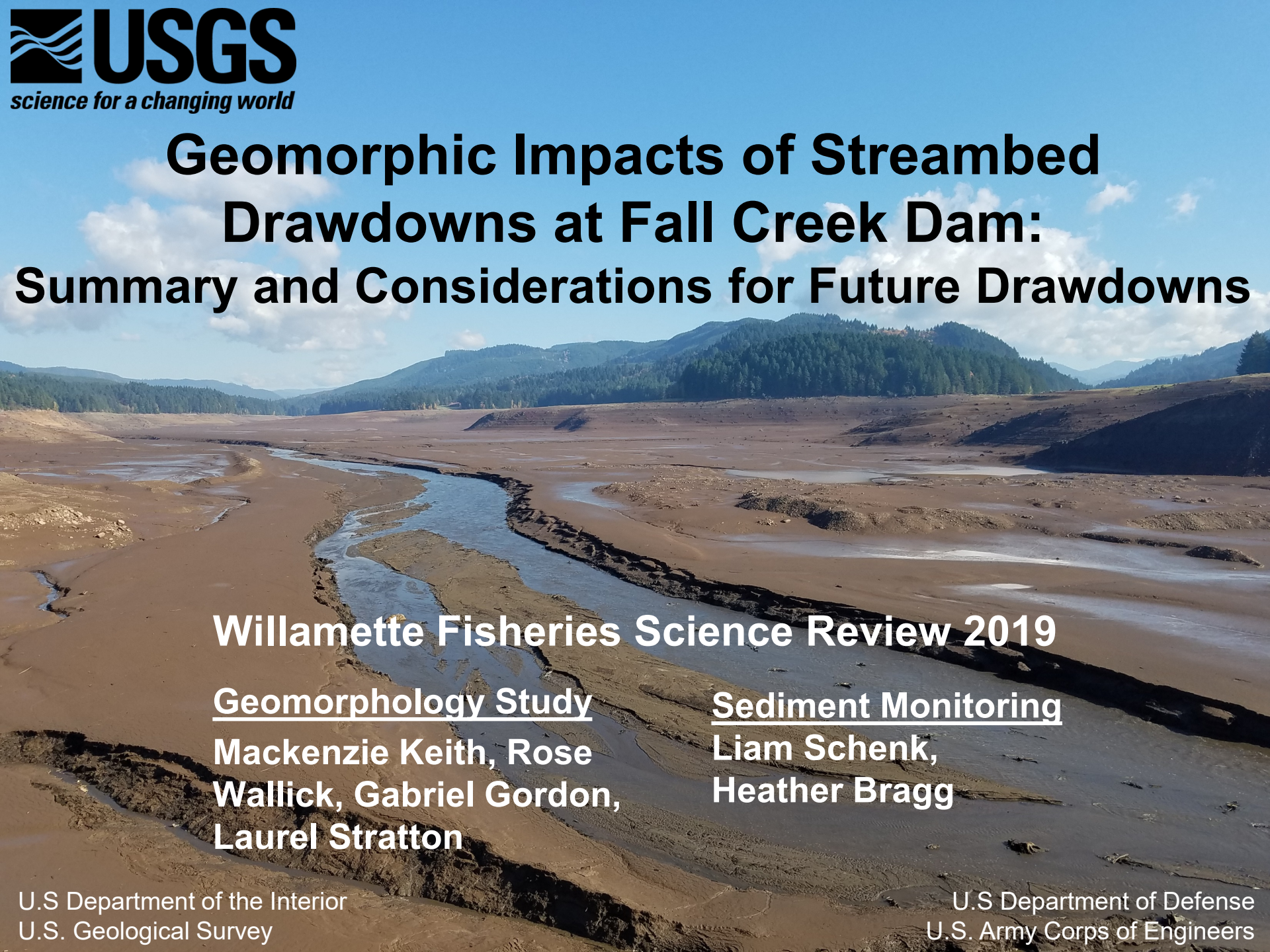

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Geomorphic Impacts of Streambed Drawdowns at Fall Creek Dam:
Summary and Considerations for Future Drawdowns

Willamette Fisheries Science Review 2019

Geomorphology Study
Mackenzie Keith, Rose Wallick, Gabriel Gordon, Laurel Stratton

Sediment Monitoring
Liam Schenk, Heather Bragg

U.S Department of the Interior
U.S. Geological Survey

U.S Department of Defense
U.S. Army Corps of Engineers

Acknowledgments

Funding for this study was provided by the USACE.

USACE: Greg Taylor, Jacob Macdonald, Chad Helms, Doug Garletts, Mary Karen Scullion, Yamen Hoque, Kathryn Tackley, Kathryn Warner, Kristin Powers, Norman Buccola, Chris Edwards, Doug Swanson, Jim Burton

USGS: Joseph Mangano, James White, Jon Major, Scott Anderson, Tess Harden, Erin Poor, Alex Costello, Heather Bervid, Brandon Overstreet, Casie Smith, Lisa Faust, Jeff Sloan, Todd Burton, Jim O'Connor, Charlie Cannon

ODFW: Brian Bangs

Land owners: Jeff and Joan Devore, John and Pam Baumann, Pat and Kerney Simpson, Carol Brewer

The Nature Conservancy: Melissa Olson and Jason Nuckols

OSU: Christina Murphy

DOGAMI: Jake Edwards

USFS: Gordon Grant, Sherri Johnson Lisa Kurian, Matt Helstab, Mark Richardson, Wendy Peterson

Frontier Precision: Chase Fly

Brown-Western Aviation: Gary and Mary Brown

El Museo Nacional de Ciencias Naturales: Mikel Calle Navarro

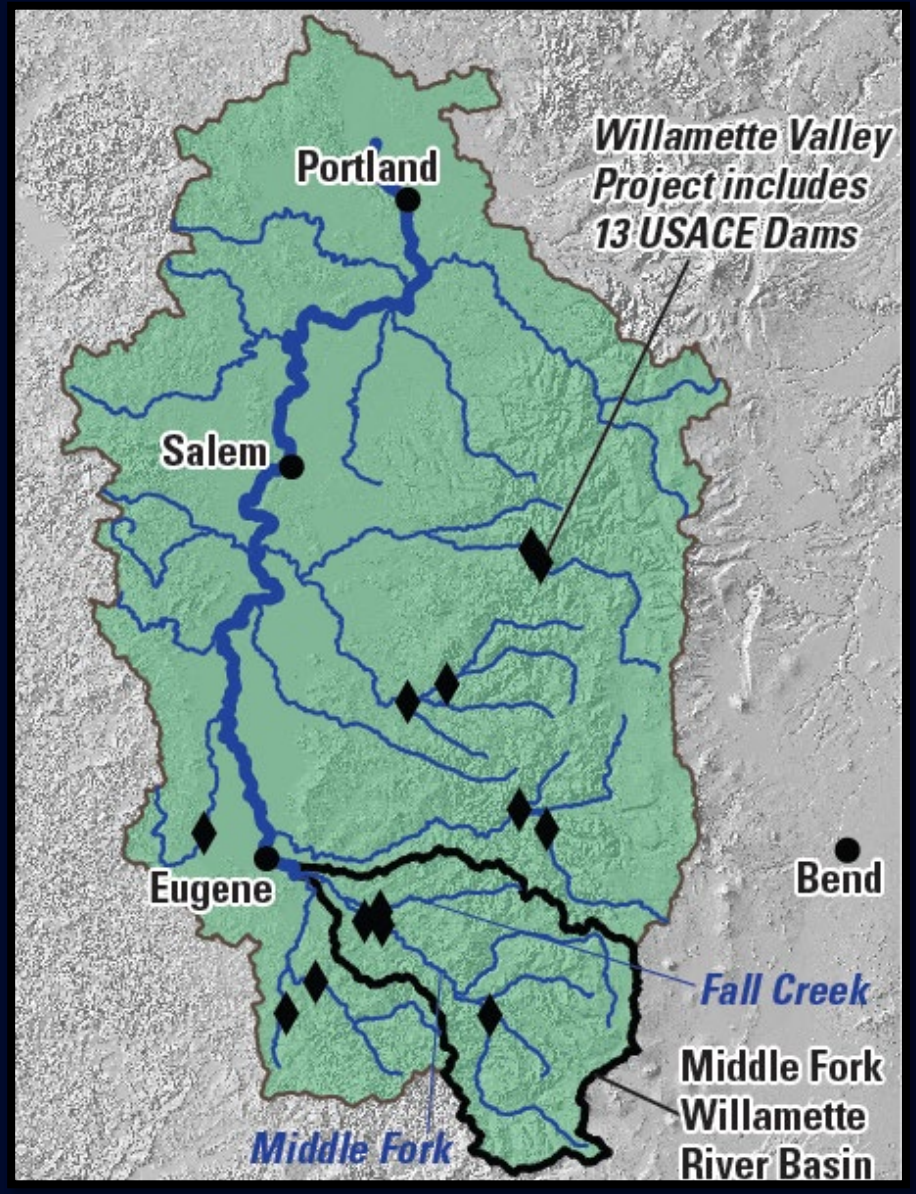
USGS

Study Objectives

Document reach-scale geomorphic responses

Evaluate links between
- reservoir operations and erosion
- downstream sediment transport and deposition

Place responses within context of geomorphic stability and historical geomorphic changes



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Presentation Overview

Key Findings

- Reservoir evolution
- Sediment monitoring
- Downstream geomorphic change

Framework for Streambed Drawdown Responses at Fall Creek WYs 2012-18

Considerations for Future Changes in Sediment Erosion and Delivery Downstream

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Photo credit: M. Keith, USGS, March 2016

Fall Creek Reservoir

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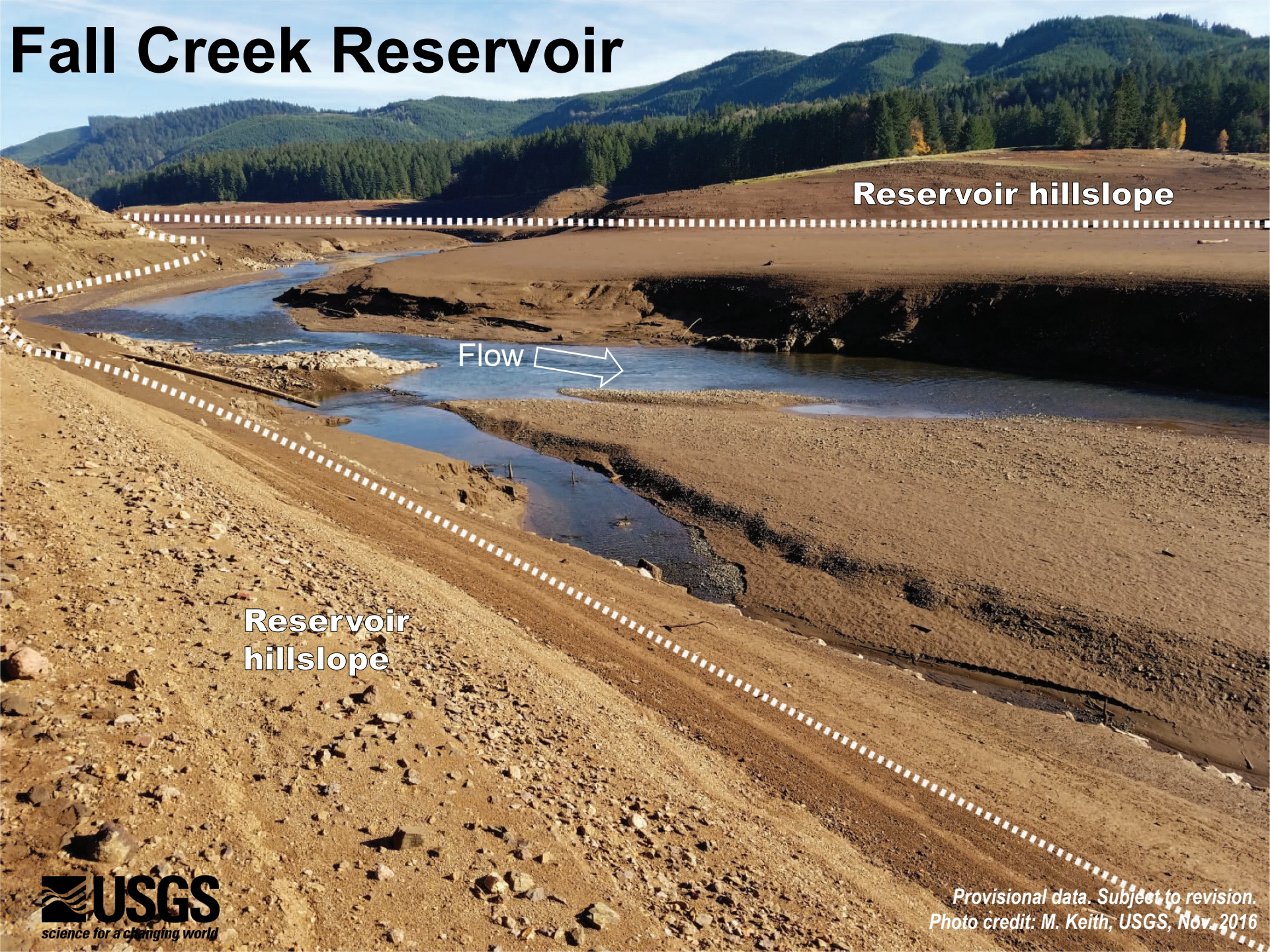
Provisional data. Subject to revision.
Photo credit: M. Keith, USGS, Nov. 2016


Fall Creek Reservoir
Reservoir hillslope
Flow
Reservoir hillslope
USGS
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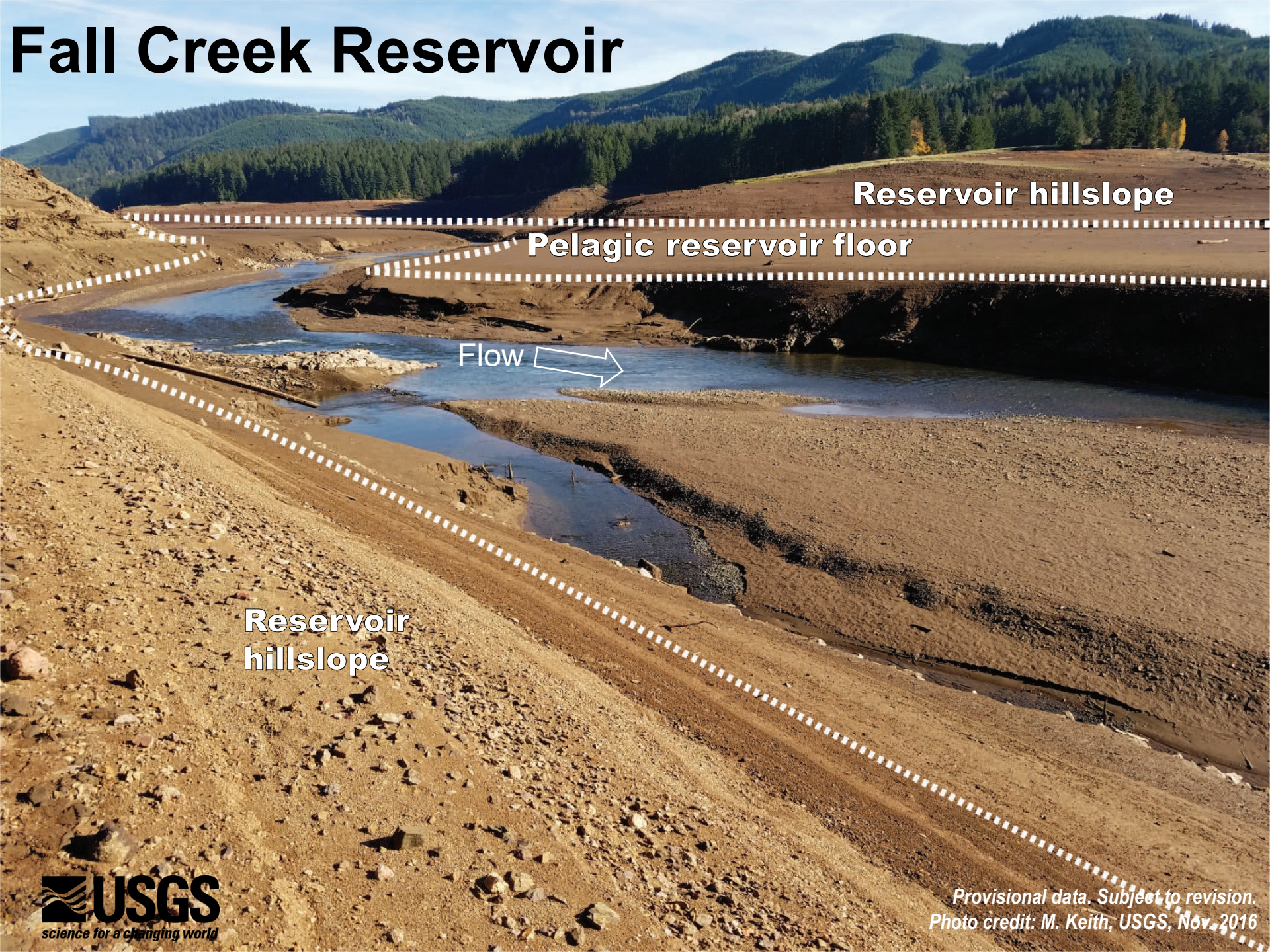
Provisional data. Subject to revision.
Photo credit: M. Keith, USGS, Nov. 2016


Fall Creek Reservoir
Reservoir hillslope
Pelagic reservoir floor
Flow
Reservoir hillslope
USGS
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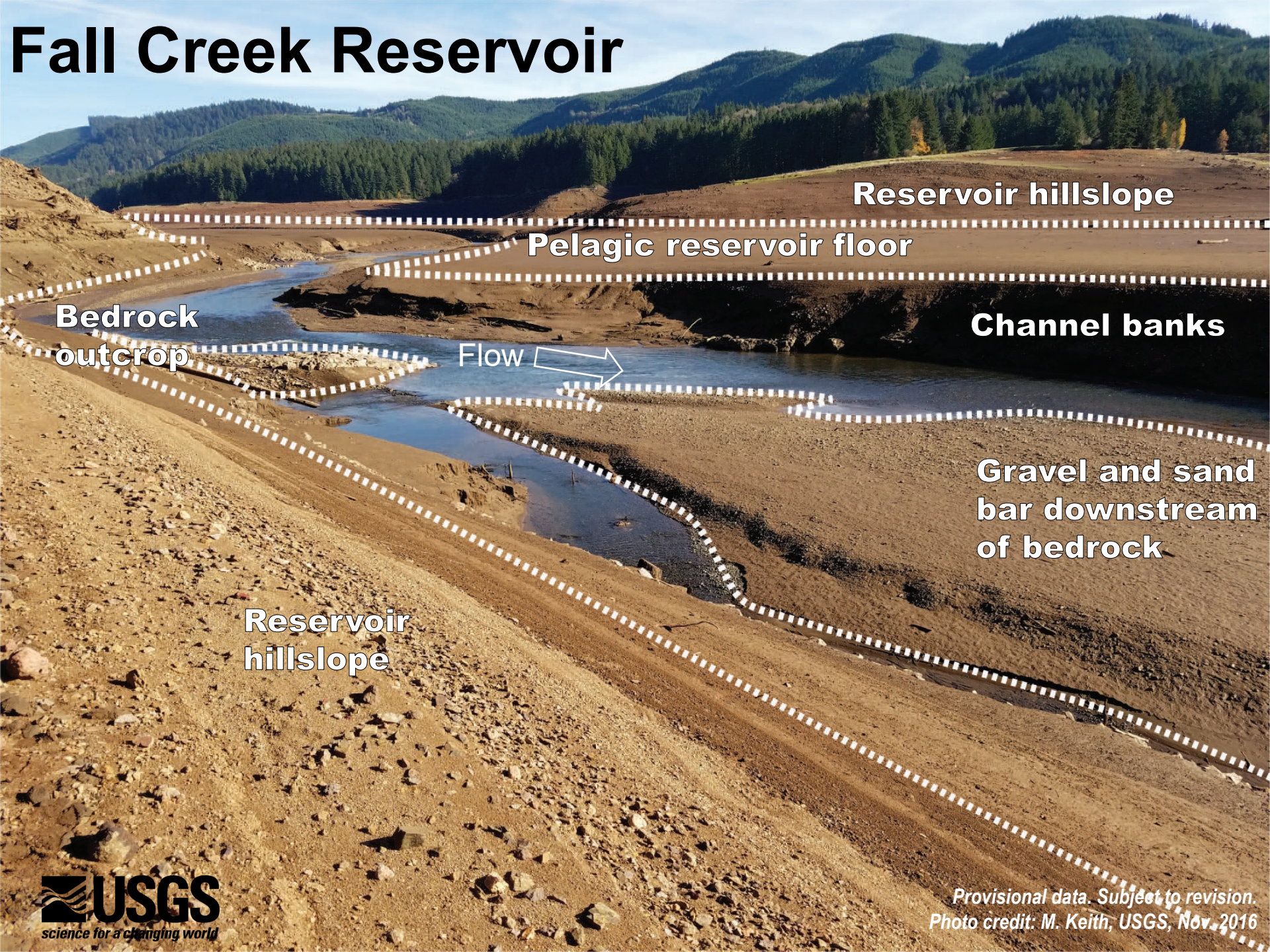
Provisional data. Subject to revision.
Photo credit: M. Keith, USGS, Nov. 2016


Fall Creek Reservoir
Reservoir hillslope
Pelagic reservoir floor
Bedrock outcrop
Channel banks
Flow
Gravel and sand bar downstream of bedrock
Reservoir hillslope
USGS
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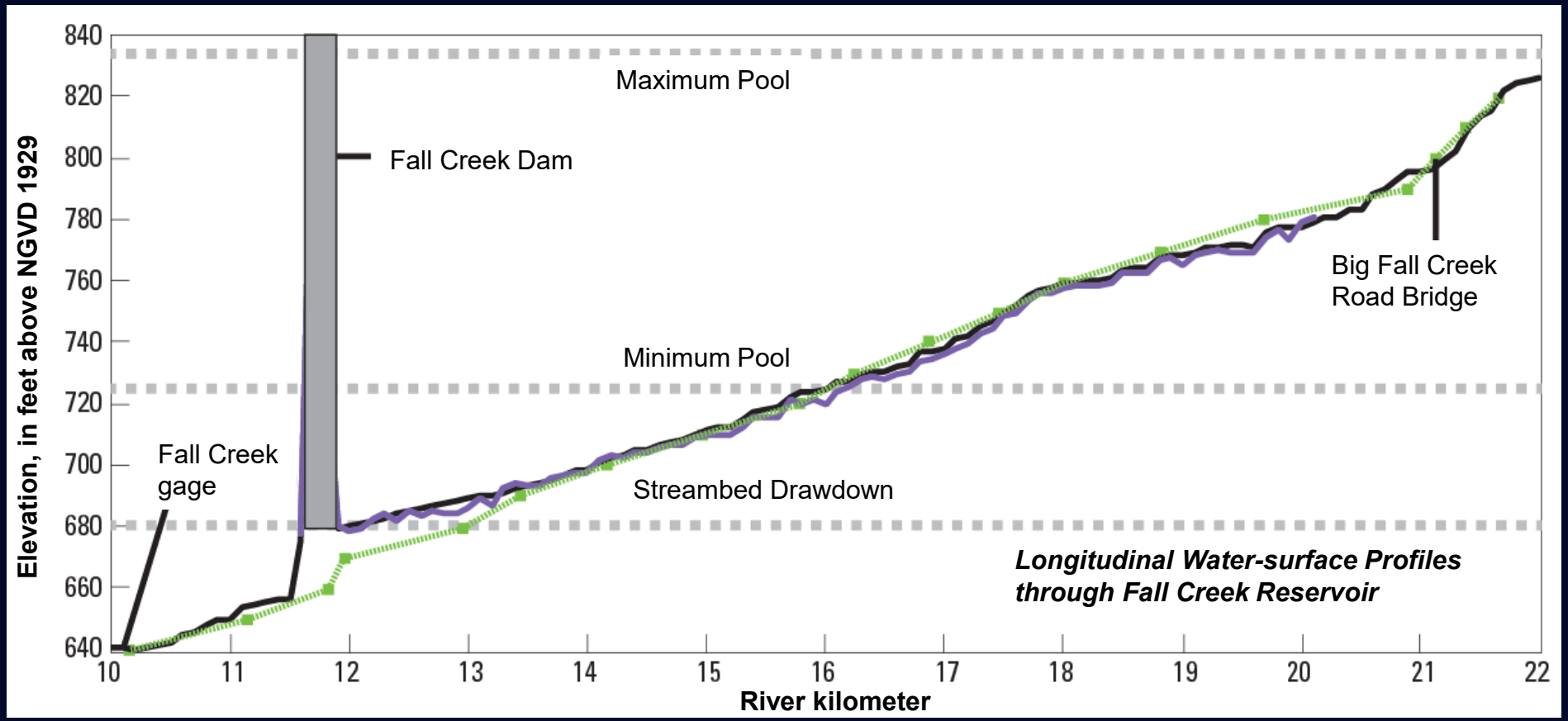
Provisional data. Subject to revision.
Photo credit: M. Keith, USGS, Nov. 2016

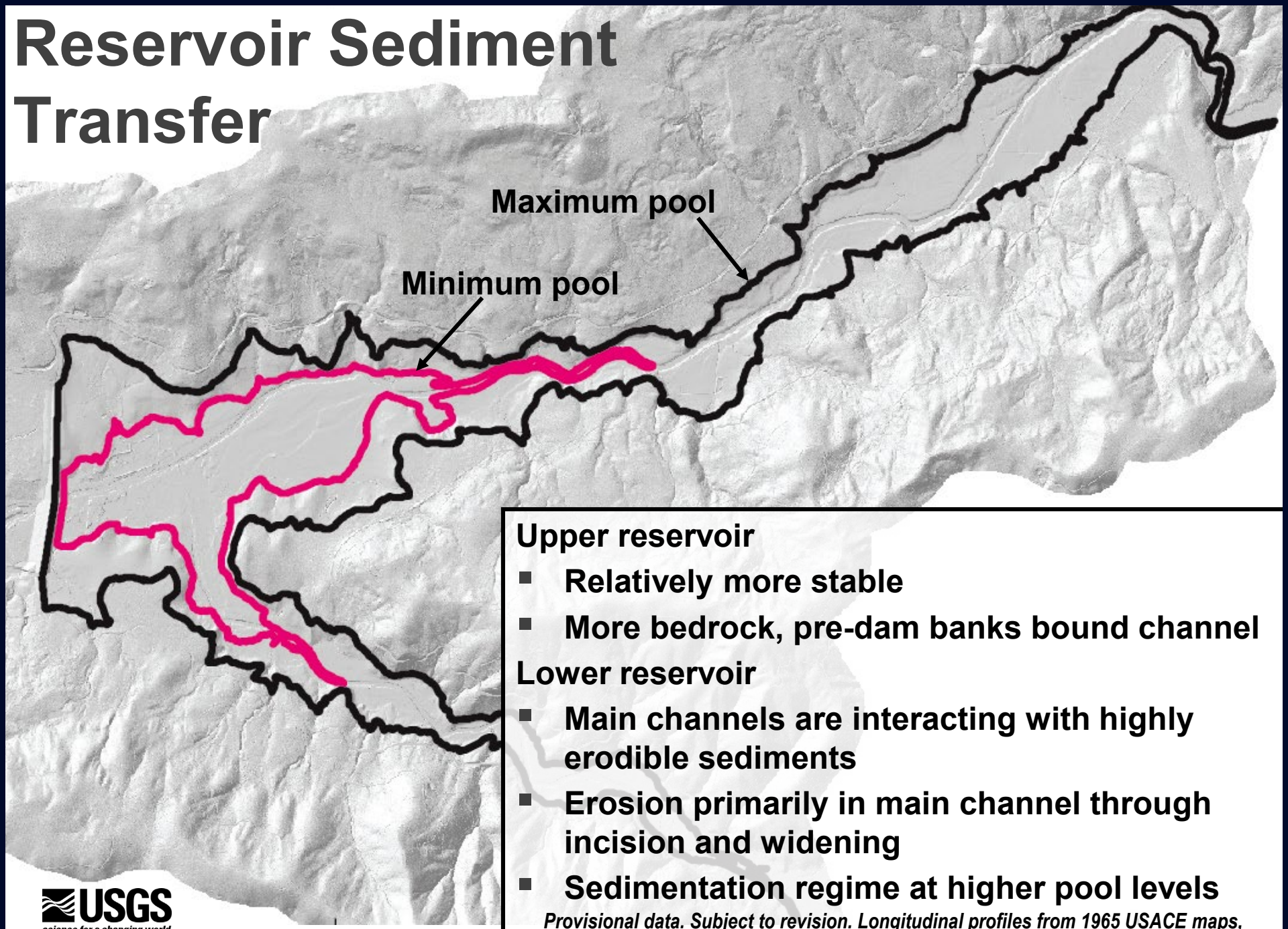
Patterns of Long-term Reservoir Sedimentation and Recent Erosion



USGS

Provisional data. Subject to revision. Longitudinal water-surface profiles from 1965 USACE maps, 2012 lidar data, and 2016 structure-from-motion data collected for this study.

Reservoir Sediment Transfer



Upper reservoir

- Relatively more stable
- More bedrock, pre-dam banks bound channel

Lower reservoir

- Main channels are interacting with highly erodible sediments
- Erosion primarily in main channel through incision and widening
- Sedimentation regime at higher pool levels

Provisional data. Subject to revision. Longitudinal profiles from 1965 USACE maps, 2012 lidar data, and 2016 structure-from-motion data collected for this study.

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Sediment Transport Below Fall Creek Dam

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Provisional data. Subject to revision.
Photo credit: M. Keith, USGS, Nov. 2018

Sediment Transport Below Fall Creek Dam

High suspended-sediment loads at gage

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Photo credit: M. Keith, USGS, Nov. 2018

Sediment Transport Below Fall Creek Dam

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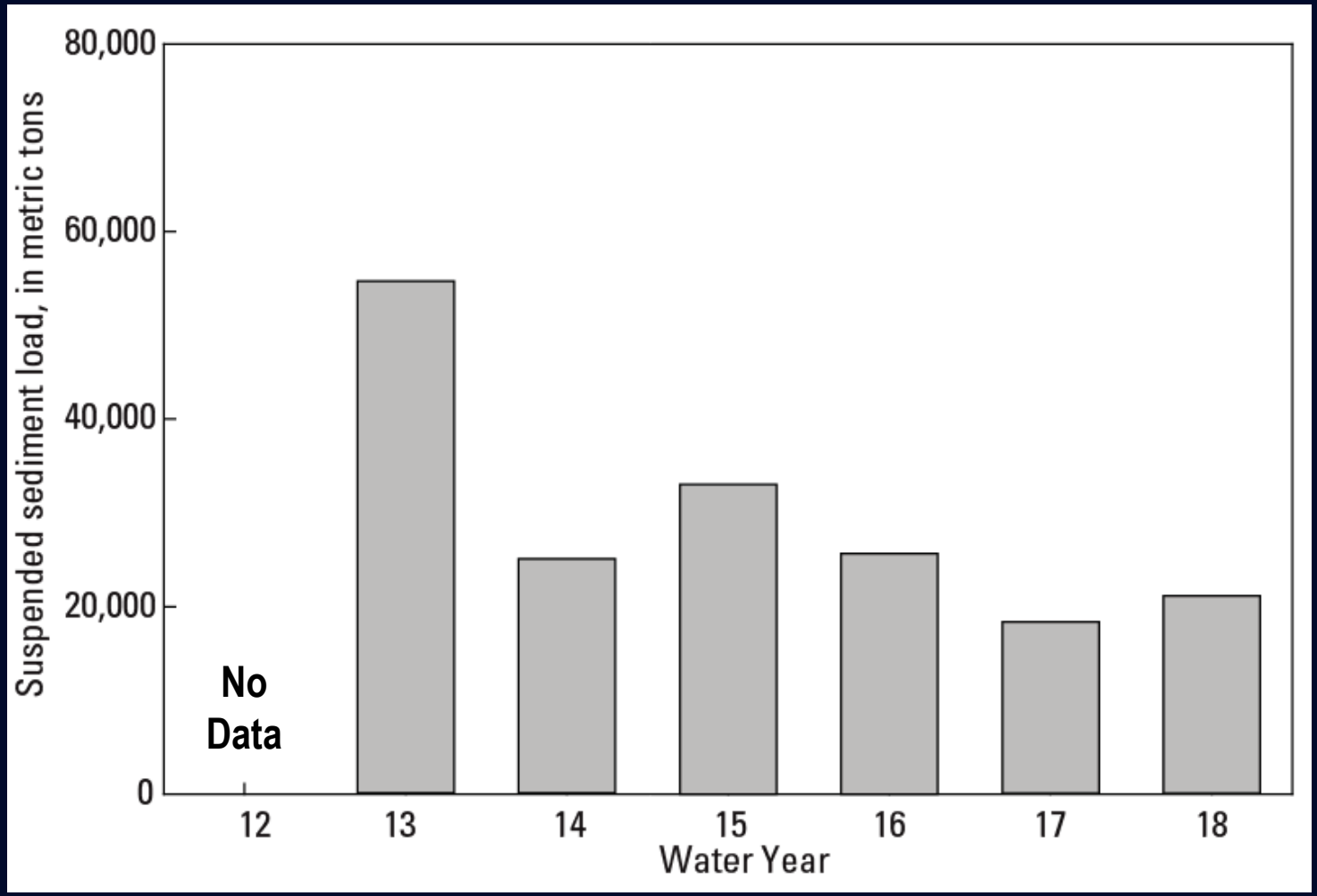
Photo credit: M. Keith, USGS, Nov. 2018

Sediment Gaging: Computed Suspended Sediment Loads



USGS

Data for Water Years 13-16 from Schenk and Bragg, 2014, 2015; NWIS database. Data for Water Years 17-18 provisional. Subject to revision. Loads computed from turbidity-suspended sediment concentration relations spanning the streambed drawdown. Data collected for partial water years. Average annual erosion from reservoir change detection analyses.

Geomorphic Change Downstream of Fall Creek Dam

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Provisional data. Subject to revision.
Photo credit: M. Keith, USGS, Oct. 2015

Geomorphic Change Downstream of Fall Creek Dam

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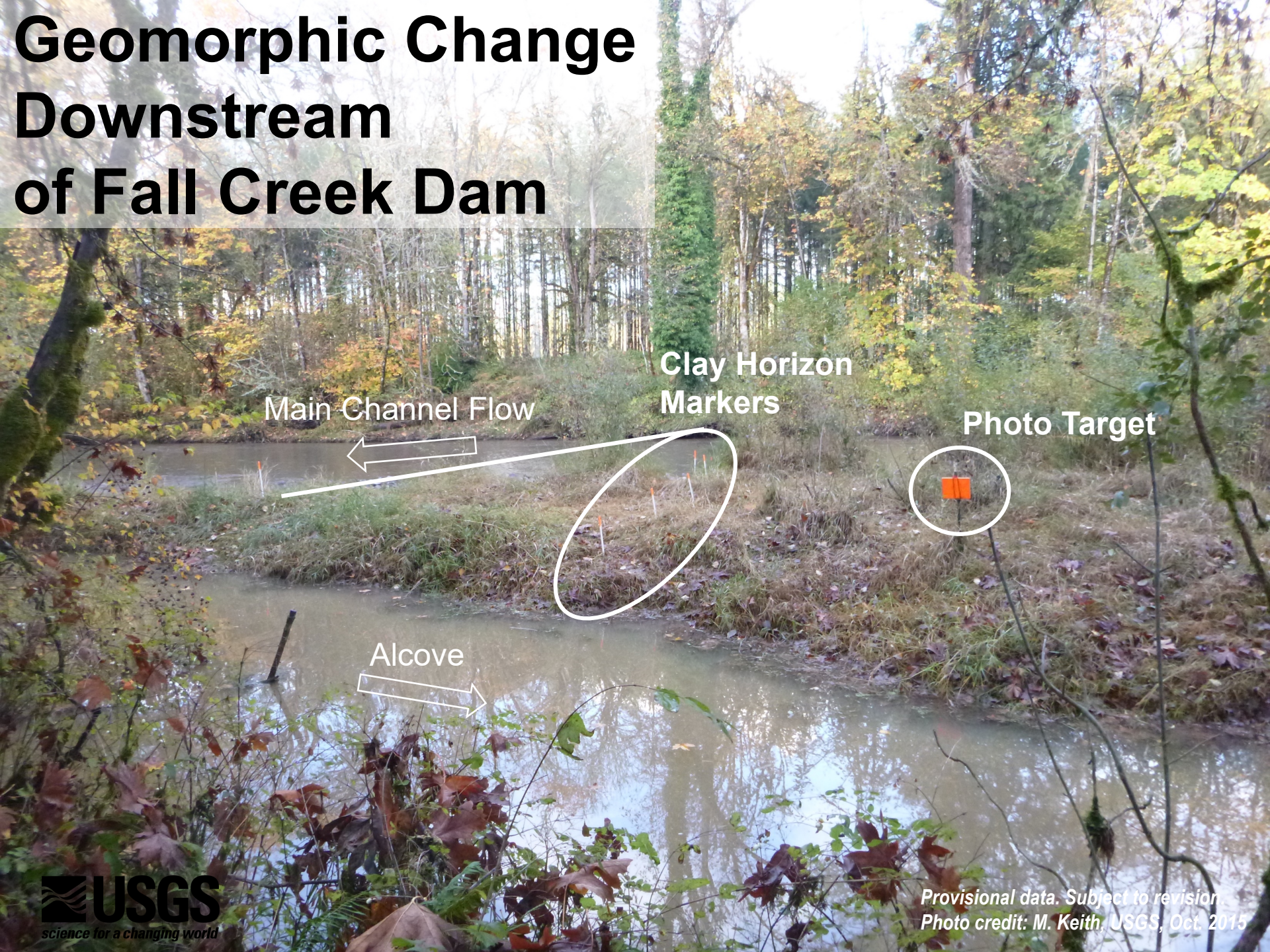
Geomorphic Change Downstream of Fall Creek Dam



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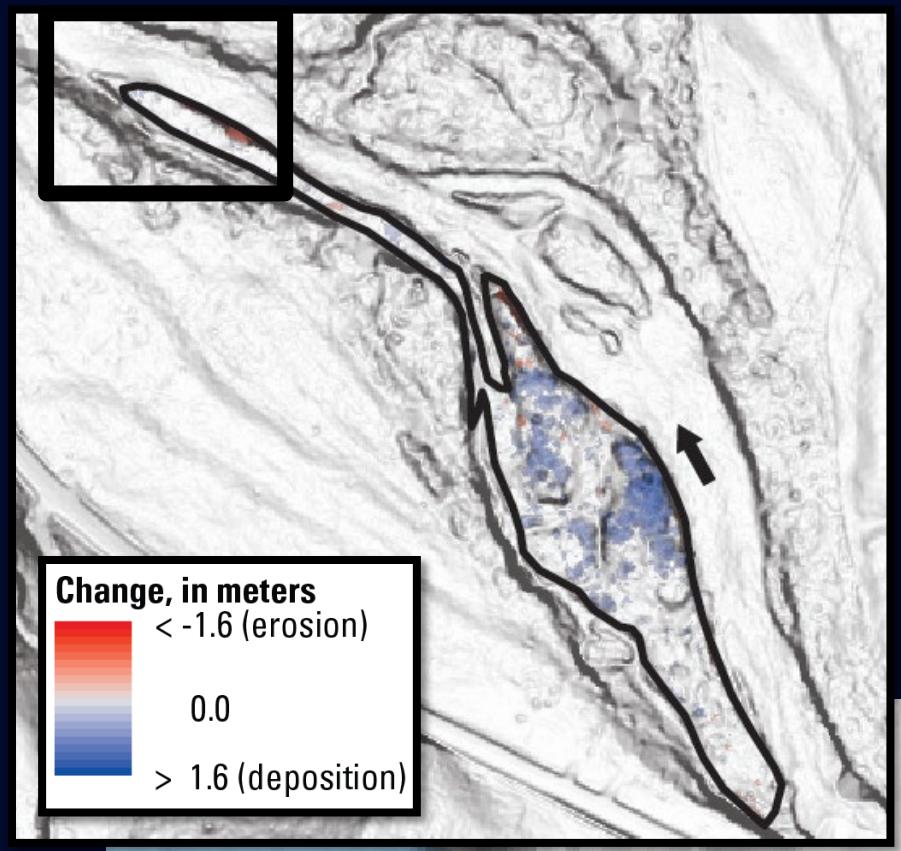
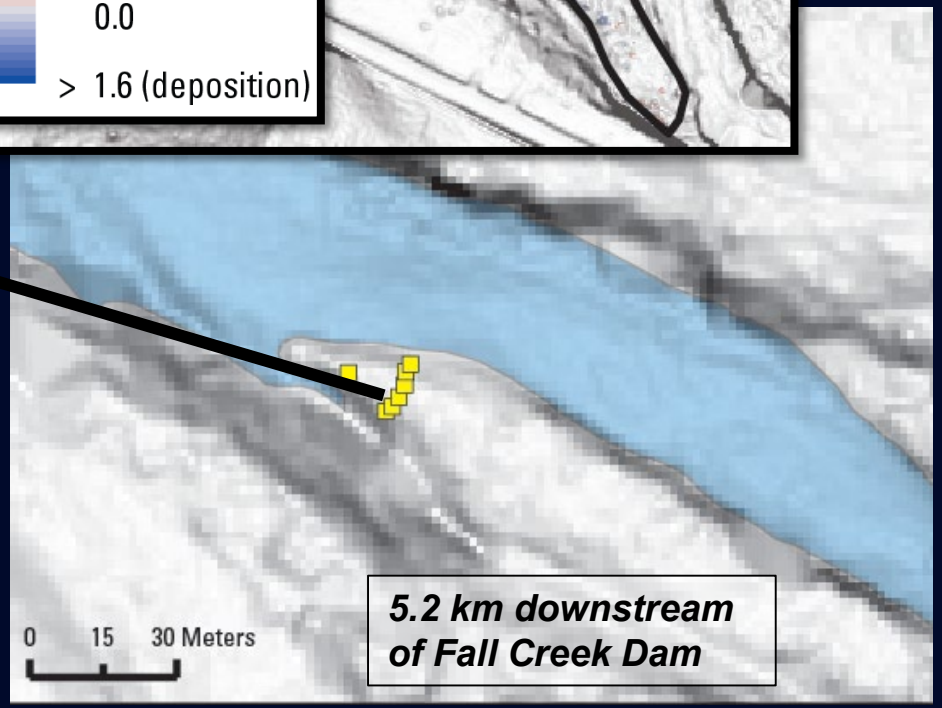
Provisional data. Subject to revision.
Photo credit: M. Keith, USGS, Oct. 2015

Sand and Silt Deposition

Photo credit: M. Keith, USGS, March. 2016

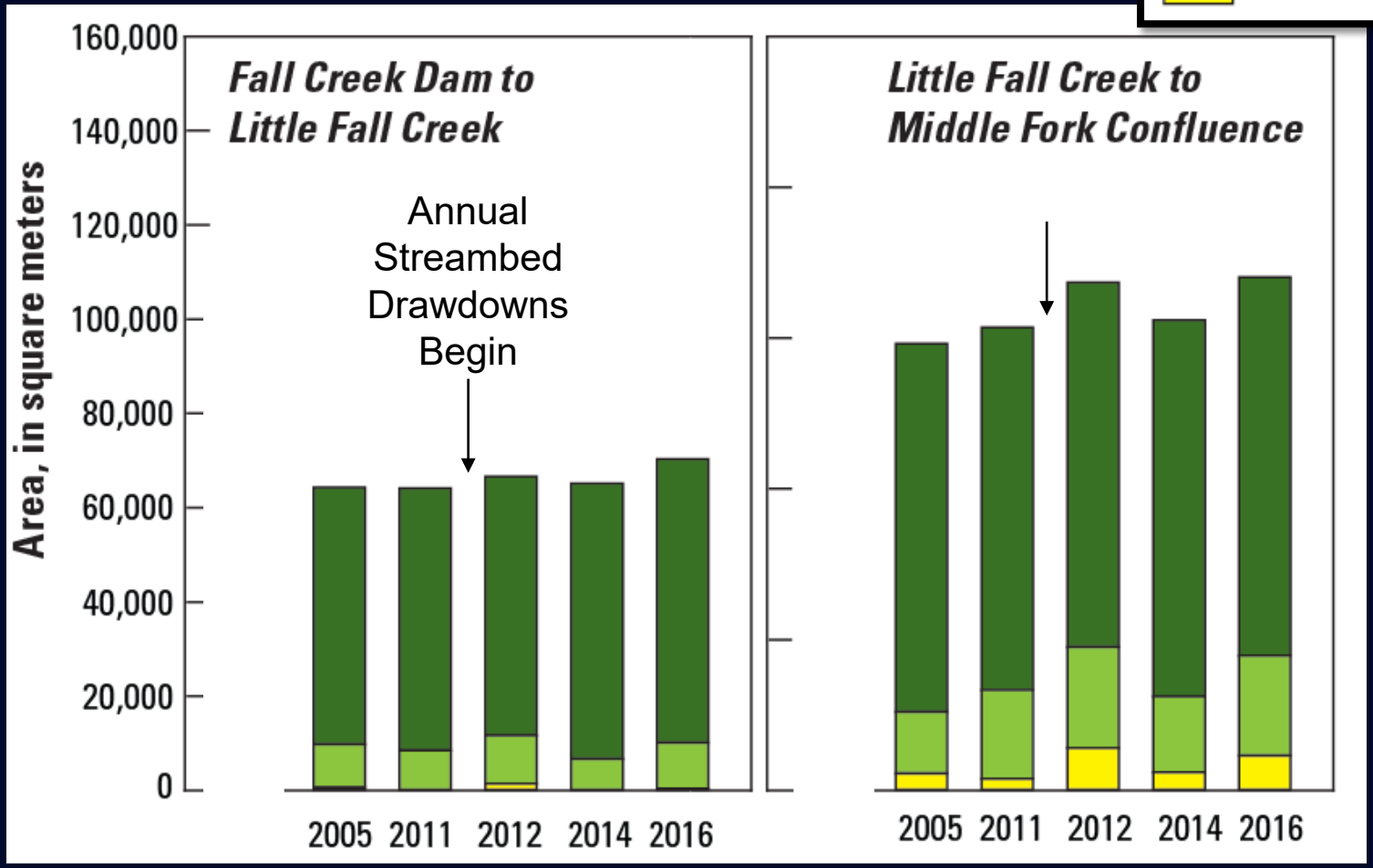




USGS

Provisional data. Subject to revision. Finding from clay-horizon markers, geomorphic change analyses, specific-gage analyses, geomorphic mapping, and particle-size measurements

Reach-scale Changes in Bar Landforms



USGS

Changes in Bare Sediment and Vegetated Bars within the Fall Creek Active Channel

Provisional data. Subject to revision. Repeat geomorphic mapping data from aerial photographs.

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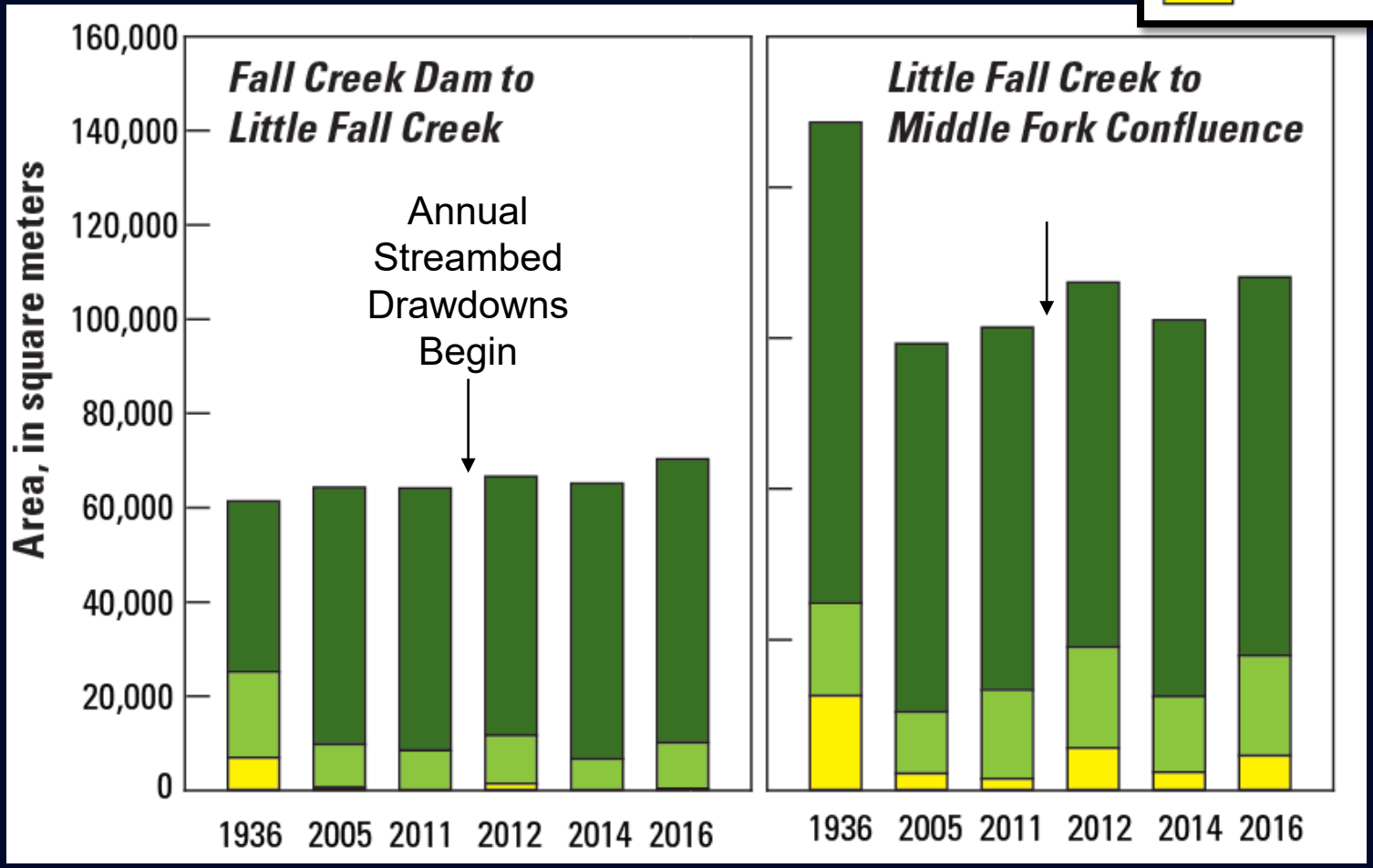

USGS

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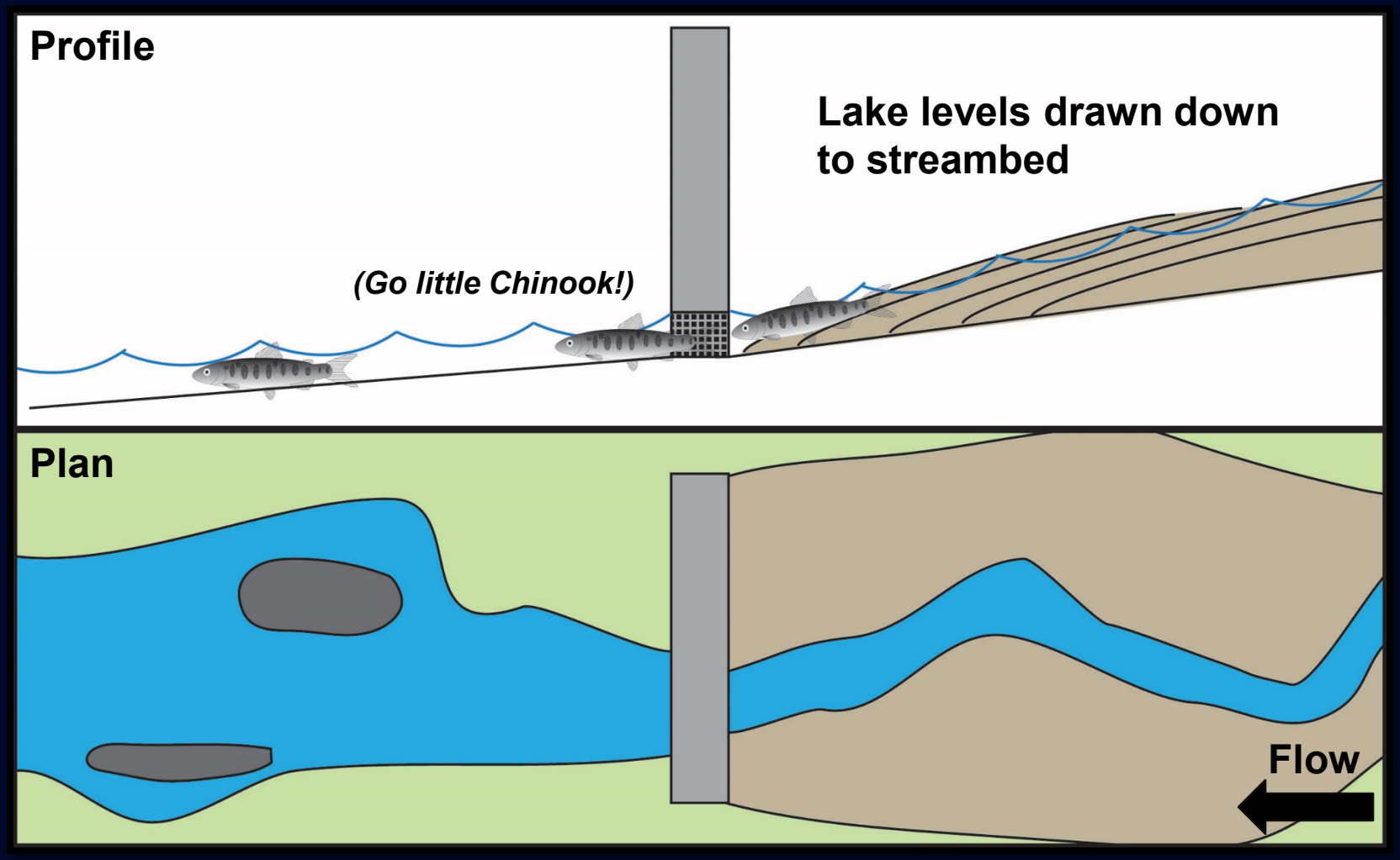
Fall Creek: Coupled Upstream-Downstream Responses WY12-18



USGS

Provisional data. Subject to revision.

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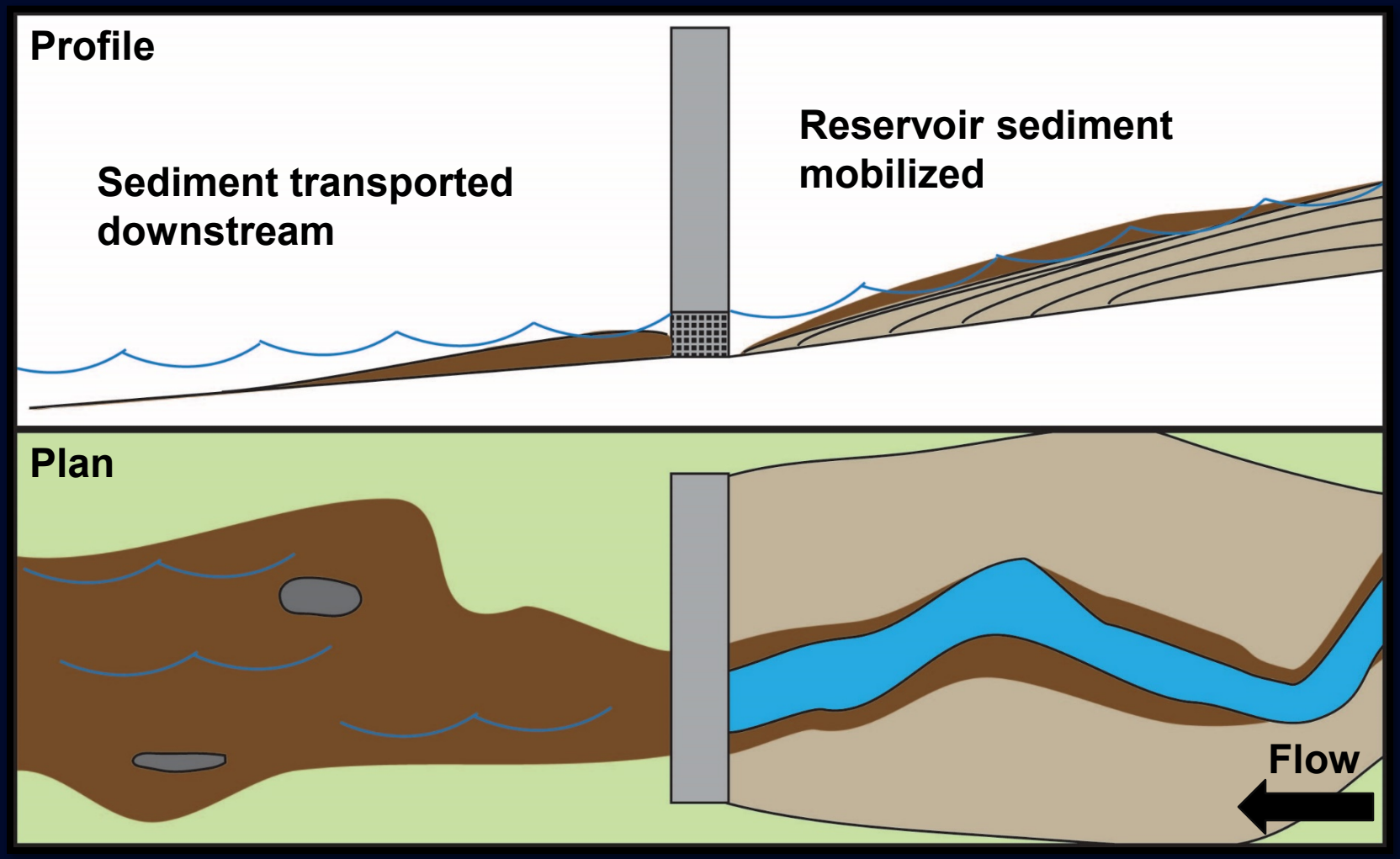

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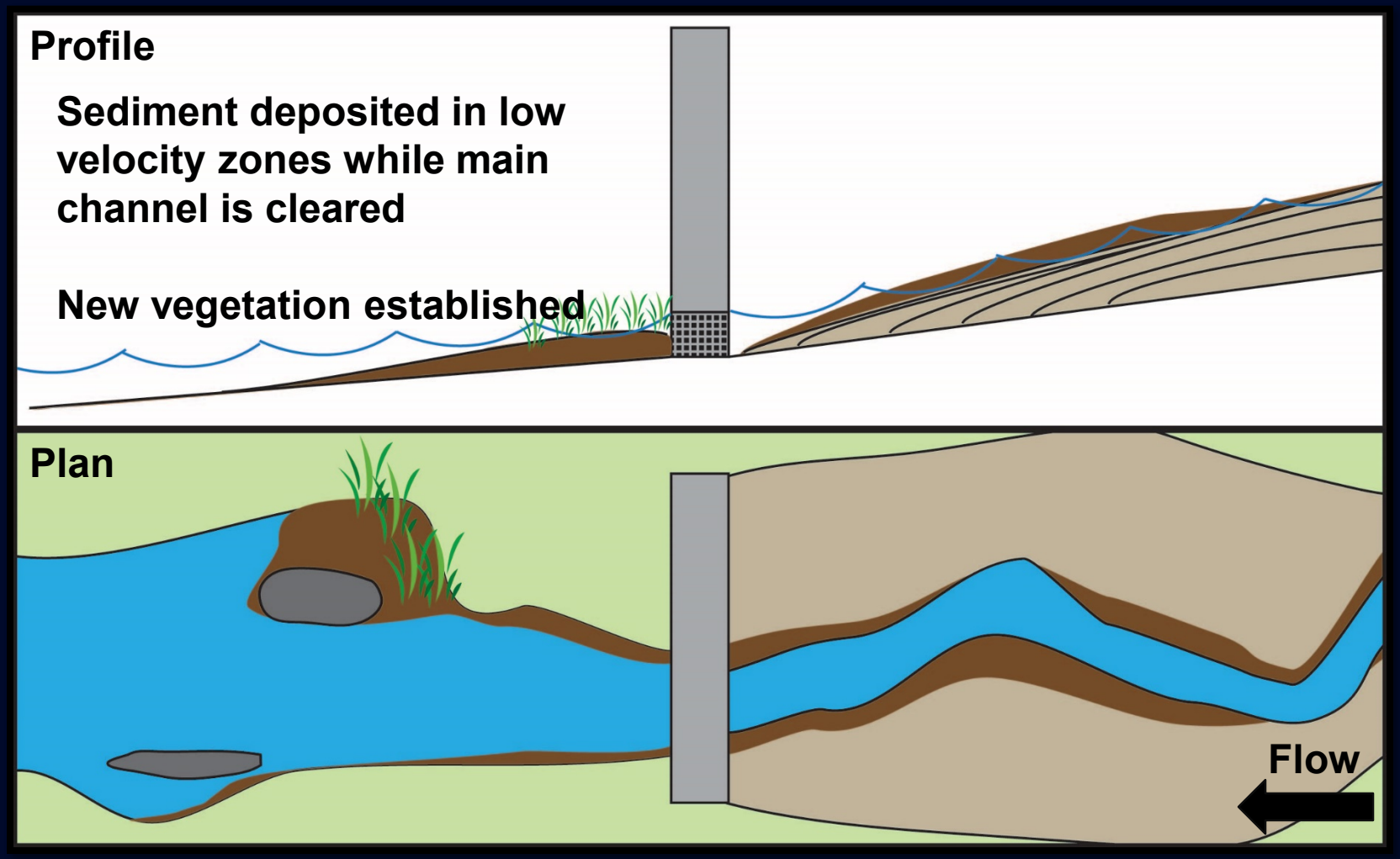
Fall Creek: Coupled Upstream-Downstream Responses WY12-18



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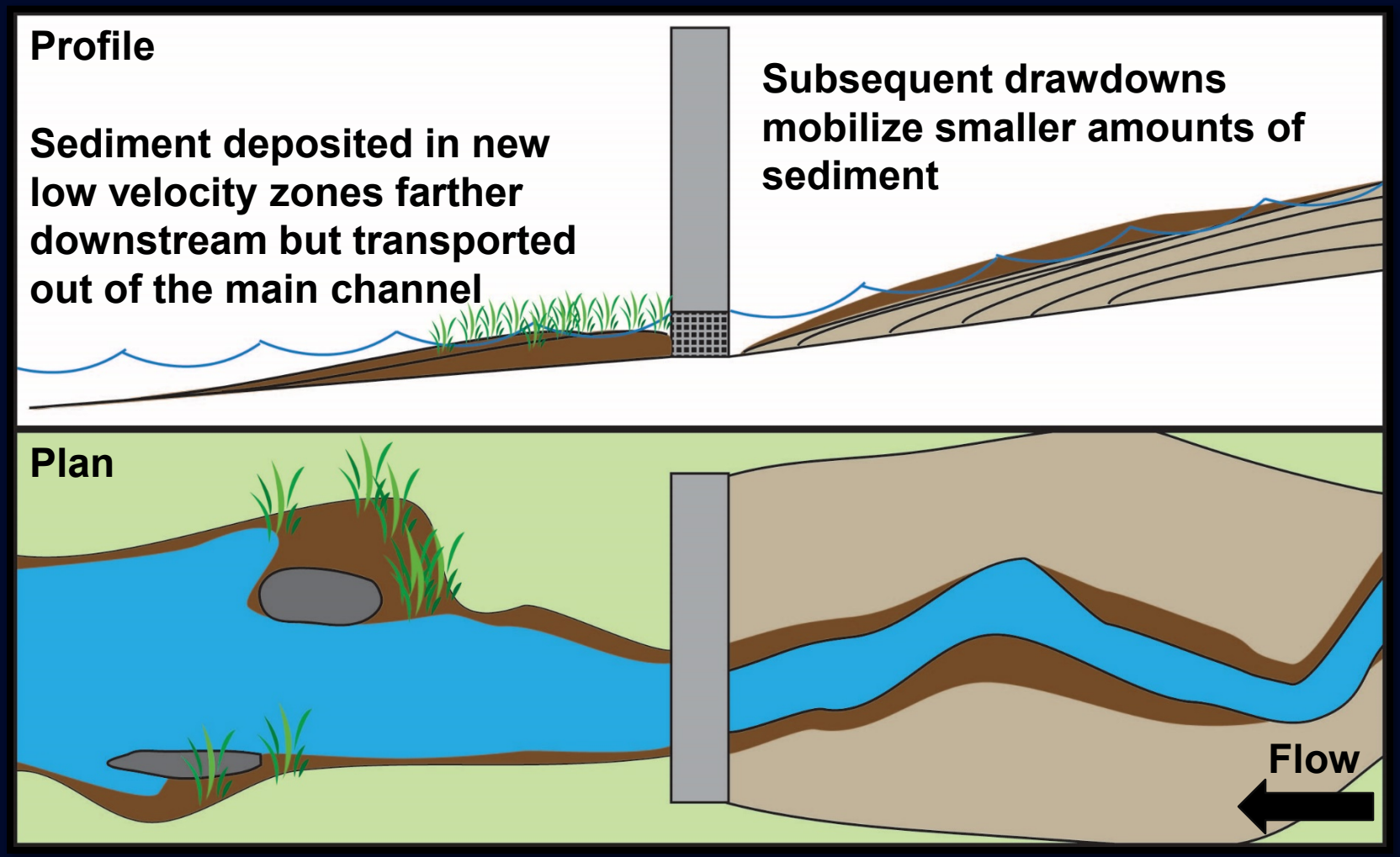

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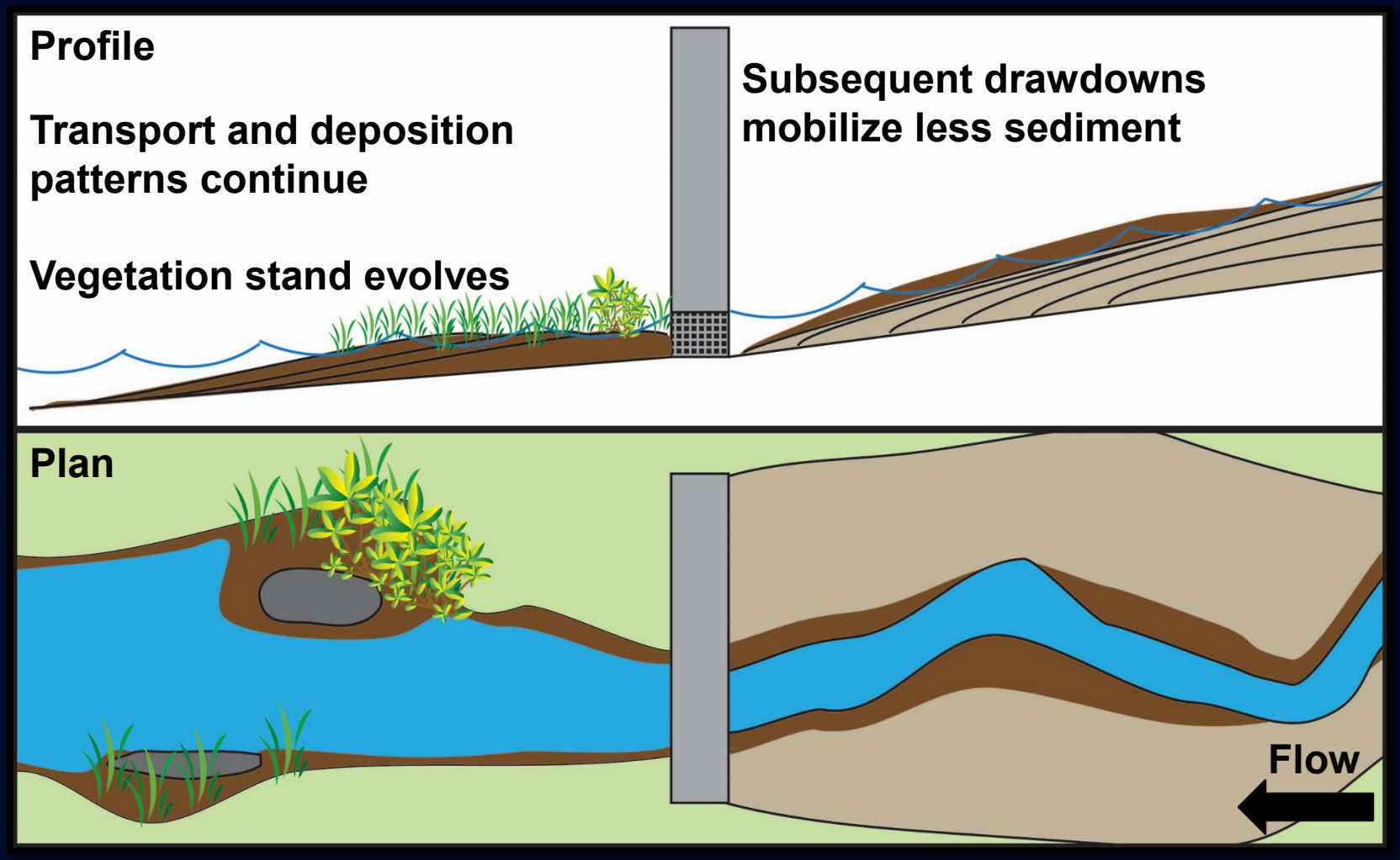

USGS

Provisional data. Subject to revision.

Multiple Factors Influence Geomorphic Responses to Streambed Drawdowns

Example Factors

- Sediment yield
- Reservoir morphology
- Reservoir sediment deposit magnitude, geometry, character
- Reservoir Inflow
- Downstream channel morphology
- Precipitation and temperature during drawdown operations
- Dam infrastructure
- Dam operations
  - Duration
  - Time of year
  - Rate of pool change
  - Regulated flows

USGS

Provisional data. Subject to revision.

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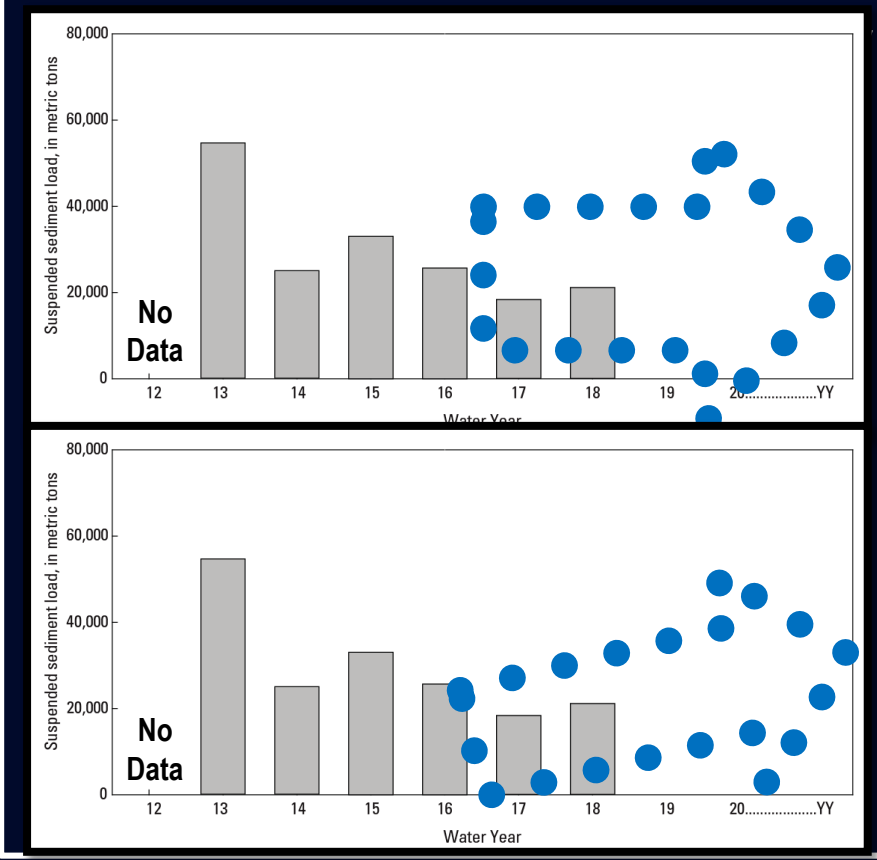
Potential Trends in Future Reservoir Sediment Export



USGS

Provisional data. Subject to revision.

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Example Considerations in Reservoir Channel Adjustment

Decreasing/similar sediment export

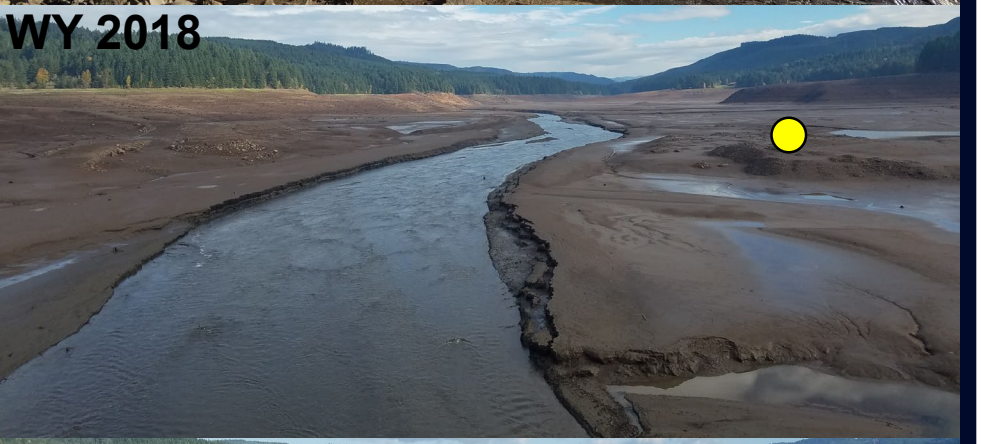
- Continued incision
- Continued widening
- Bed reaches historical channel bottom or bedrock

Increasing sediment export

- Increased incision
- Increased widening
- Lateral migration
- Avulsion

USGS

Provisional data. Subject to revision.



luence Geomorphic
mbed Drawdowns

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Example Considerations in Streambed Drawdown Duration

Decreasing/similar sediment export

- Shorter duration near streambed
- Move less sediment overall
- Move newly deposited sediment near dam

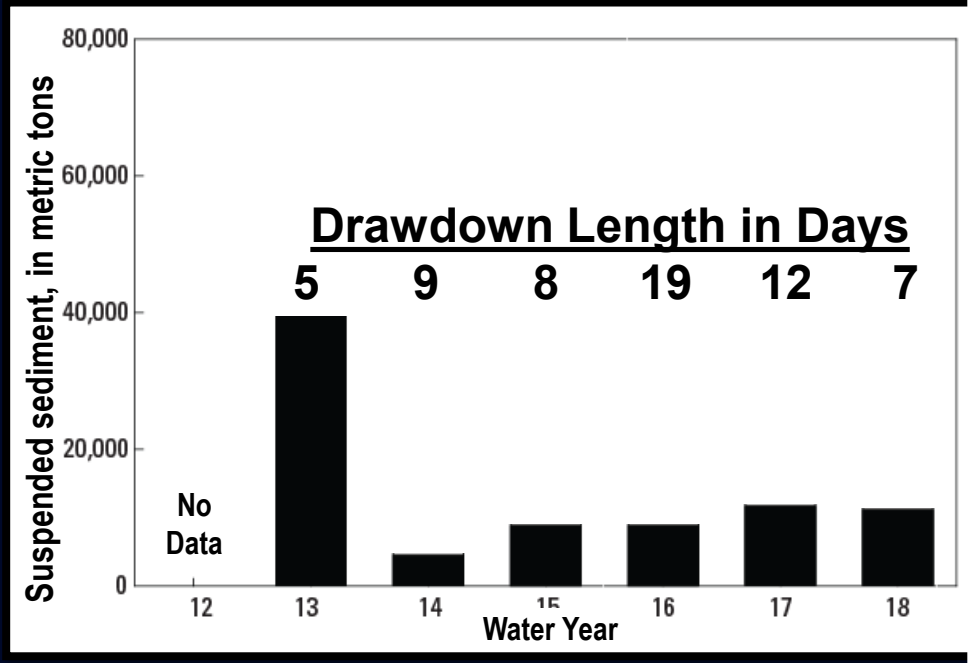
Increasing sediment export

- Longer duration near streambed
- Increases travel time for coarse sediment through the reservoir
- Increasing potential for other factors to become important (flows, storms)

USGS

Provisional data. Subject to revision.

Multiple Factors Influence Geomorphic Responses to Streambed Drawdowns



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Data for Water Years 13-16 from Schenk and Bragg, 2014, 2015; NWIS database.
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  - Time of year
  - Rate of pool change
  - **Regulated flows**

Example Considerations in for Downstream Morphologic Trends

Framework for Change WY12-18

- Off-channel areas evolve by fine sediment accumulation
- Accumulate until reaching a threshold
- Vegetation helps stabilize deposits

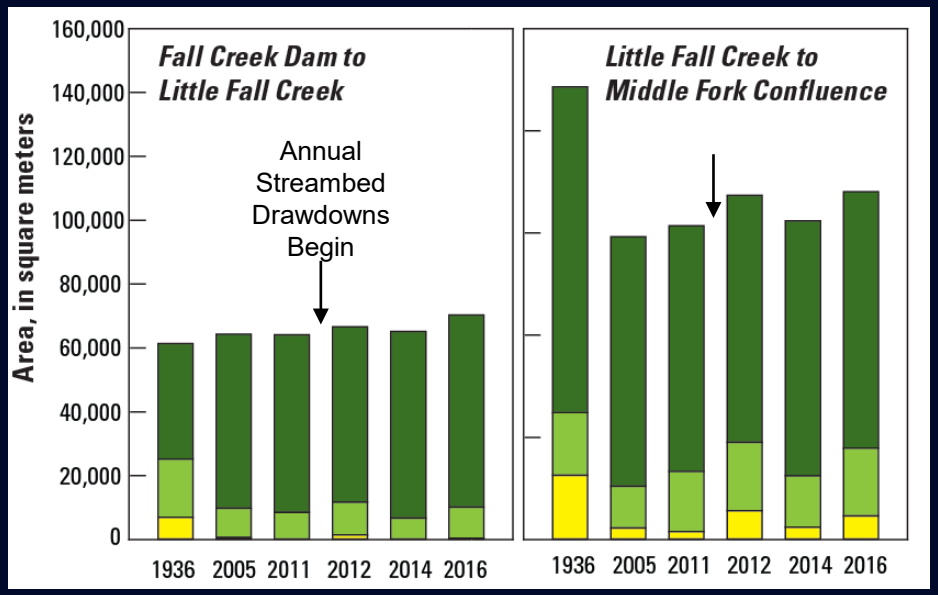
Decadal Variability

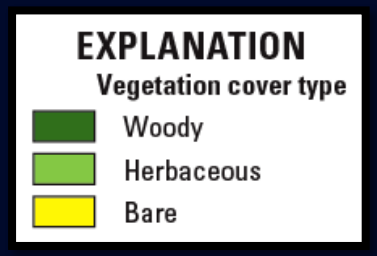
- Reservoir sediment export >0
- Most flows create depositional zones
- Accumulation of reach-scale changes
- Changes will reflect sediment export

USGS

Provisional data. Subject to revision.

Multiple Factors Influence Geomorphic Responses to Streambed Drawdowns





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USGS

Provisional data. Subject to revision.

Sediment Export Variability and Implications for Monitoring

Reservoir erosion and downstream geomorphic changes will vary over time. Examples of key questions and approaches:

Question: Is sediment export changing over time?

Approach: Turbidity with suspended sediment monitoring downstream

Frequency: Seasonal or full year observations overlapping streambed drawdowns

Indicates: Changes in reservoir export but not underlying mechanisms

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Sediment Export Variability and Implications for Monitoring

Reservoir erosion and downstream geomorphic changes will vary over time. Examples of key questions and approaches:

Question: How are downstream responses changing over time? How do responses relate to potential concerns?

Approach: Repeat geomorphic mapping or lidar change analyses along Fall Creek and the Middle Fork Willamette River

Frequency: Decadal-scale monitoring downstream of the dam

Indicates: Whether long-term impacts to channel morphology are substantial but not if reservoir sediment export is changing

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Summary

Reservoir erosion during streambed drawdowns focused in lower reservoir in thickest unconsolidated deposits

Downstream sediment monitoring has shown suspended loads have generally decreased between WY12 and 18

Downstream geomorphic impacts locally can be large, but cumulative impacts are not detectable yet at the reach scale

Multiple factors influence magnitude and type of geomorphic responses to streambed drawdowns, both upstream and downstream of Fall Creek Dam

Future changes in sediment export from the dam could be monitored with a variety of approaches but each answer different questions at different timescales

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Contact Information

Fall Creek Geomorphology Study
Mackenzie Keith
Hydrologist, USGS
mkeith@usgs.gov

Fall Creek Sediment Monitoring Study
Liam Schenk
Hydrologist, USGS
lschenk@usgs.gov

Key References and Datasets

- Keith, M.K., 2019, Surficial Particle Count and Clay Horizon Marker Data for Fall Creek and the Middle Fork Willamette River, Oregon in 2015-2017: U.S. Geological Survey Data Release, https://doi.org/10.5066/P9MGNDHN.
- Keith, M.K., and Gordon, G.W., 2019, Fall Creek and Middle Fork Willamette Geomorphic Mapping Geodatabase: U.S. Geological Survey Data Release, https://doi.org/10.5066/P9THIZD6.
- Keith, M.K., and Mangano, J.F., in press, Structure-from-motion datasets of Fall Creek Lake, Oregon, acquired during annual drawdown to streambed November 2016: U.S. Geological Survey Data Release.
- Keith, M.K. and Stratton, L.E., in review, Geomorphic Mapping of Fall Creek Lake, Oregon, 2016: U.S. Geological Survey Data Release.
- Schenk, L.N. 2018. “Six years of sediment and dissolved oxygen monitoring for the Fall Creek drawdown: Observations, insights, and future directions,” Willamette Fisheries Science Review presentation to the U.S. Army Corps of Engineers, February 2018, Corvallis, Oregon, http://pweb.crohms.org/tmt/documents/FPOM/2010/Willamette_Coordination/WFSR/.
- Schenk, L.N., and Bragg, H.M., 2014, Assessment of suspended-sediment transport, bedload, and dissolved oxygen during a short-term drawdown of Fall Creek Lake, Oregon, winter 2012–13: U.S. Geological Survey Open-File Report 2014–1114, 80 p.
- Schenk, L.N., and Bragg, H.M., 2015, Suspended-sediment concentrations and loads during an operational drawdown of Fall Creek Lake, Oregon: U.S. Geological Survey Data Release, 15 p.
- U.S. Geological Survey, 2019, USGS 14151000 Fall Creek below Winberry Creek, near Fall Creek, Oregon: USGS National Water Information System, https://waterdata.usgs.gov/nwis/inventory/?site_no=14151000&agency_cd=USGS.

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Questions?

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Extra Slides

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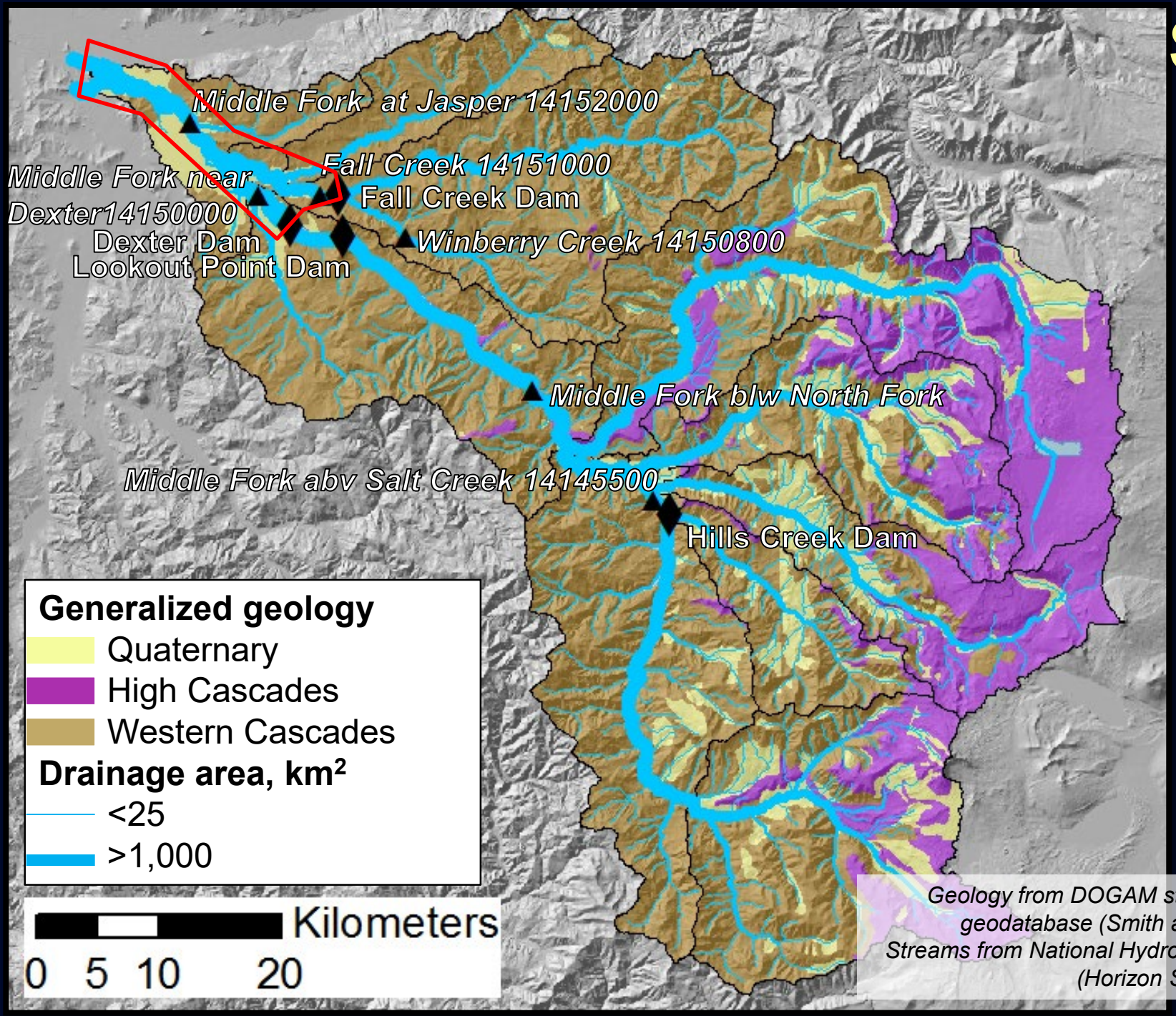
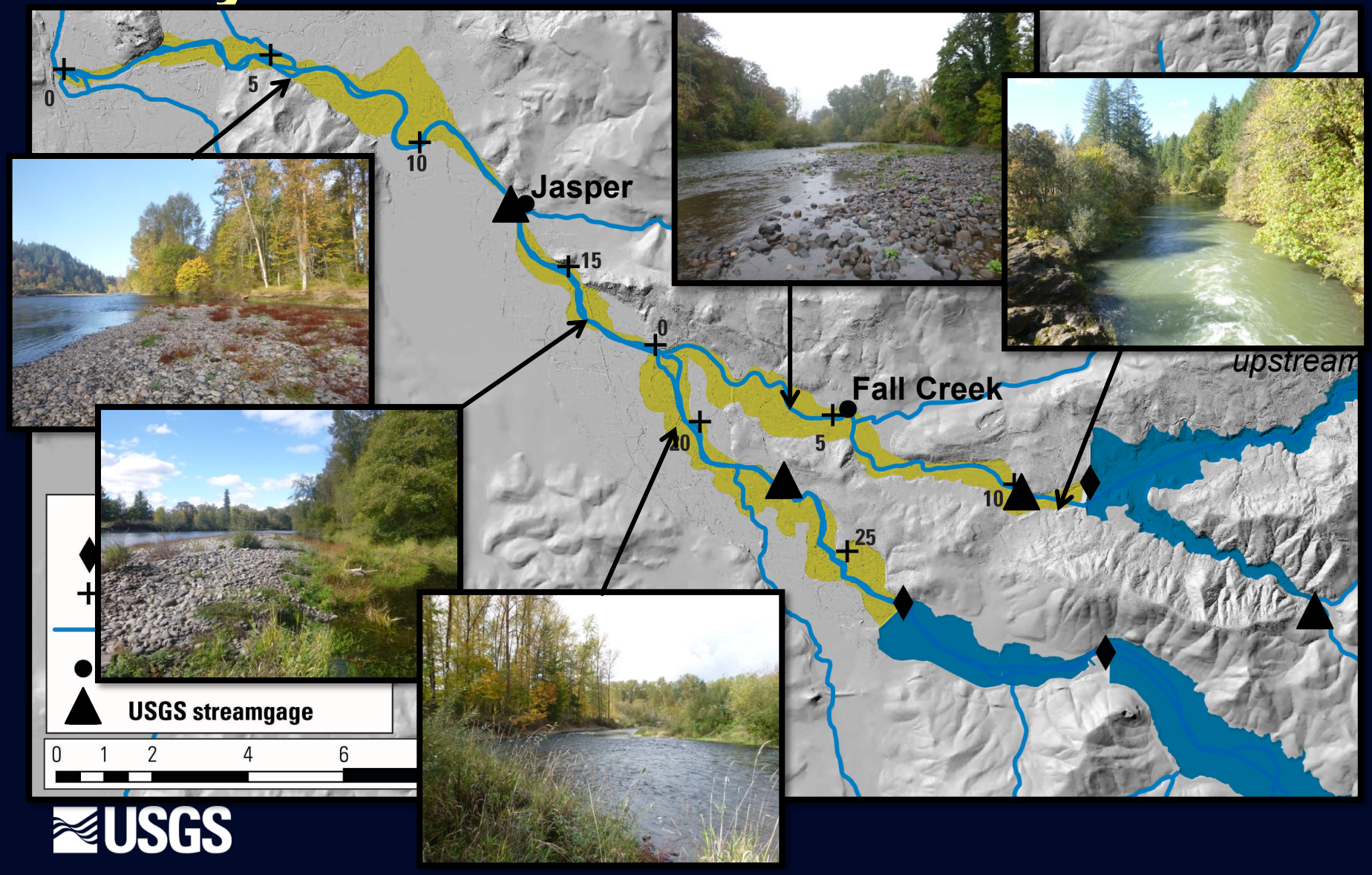
Study Area


Middle Fork at Jasper 14152000
Fall Creek 14151000
Fall Creek Dam
Middle Fork near Dexter14150000
Dexter Dam
Lookout Point Dam
Winberry Creek 14150800
Middle Fork blw North Fork
Middle Fork abv Salt Creek 14145500
Hills Creek Dam
Generalized geology
Quaternary
High Cascades
Western Cascades
Drainage area, km²
<25
>1,000
Kilometers
0 5 10 20
Geology from DOGAM state compilation geodatabase (Smith and Roe, 2015).
Streams from National Hydrography Dataset (Horizon Systems, 2012).

Study Area


0
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Jasper
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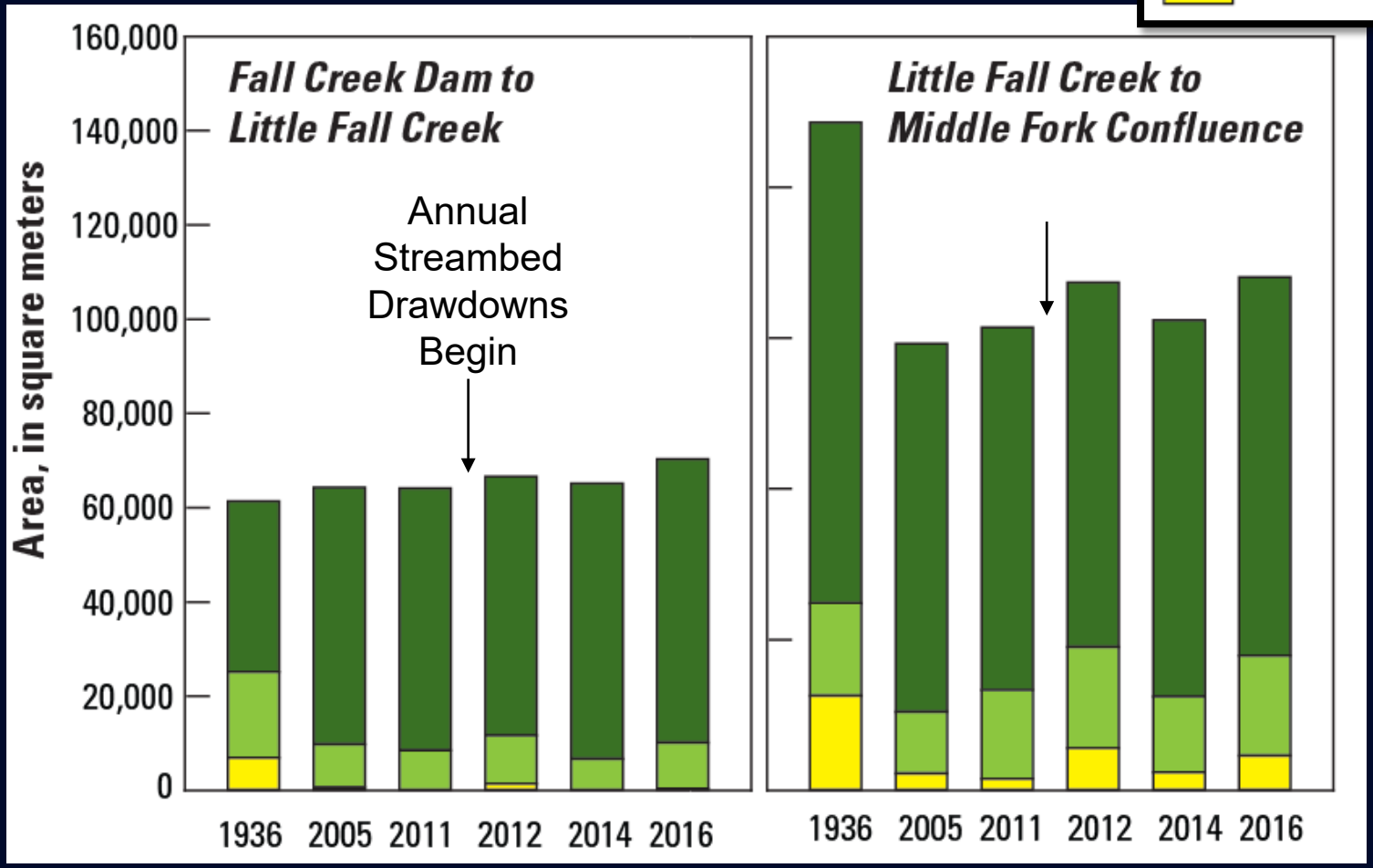
Reach-scale Changes in Bar Landforms

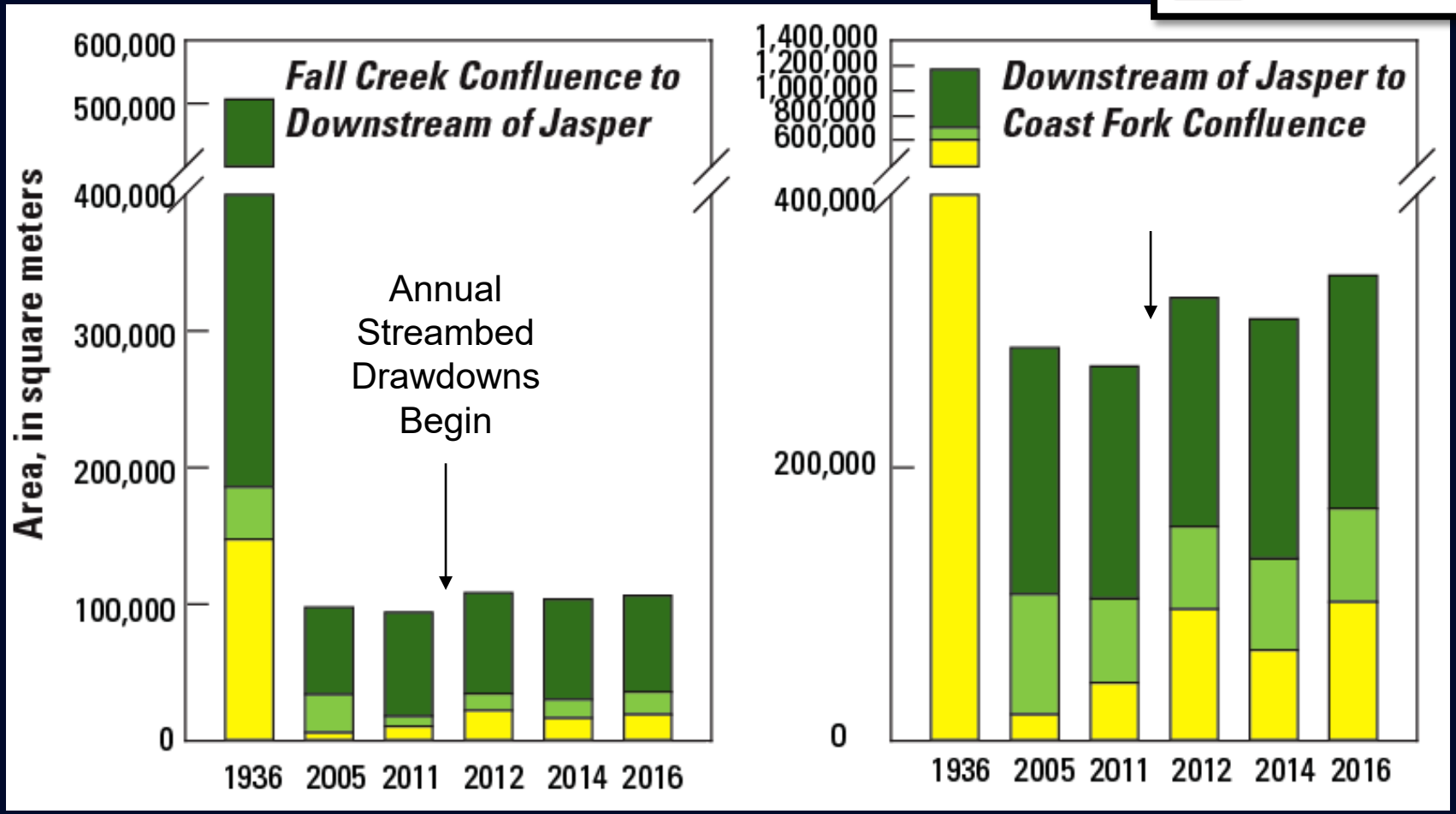


USGS

Changes in Bare Sediment and Vegetated Bars within the Fall Creek Active Channel

Provisional data. Subject to revision. Repeat geomorphic mapping data from aerial photographs.

Reach-scale Changes in Bar Landforms



USGS

Changes in Bare Sediment and Vegetated Bars within the Middle Fork Active Channel

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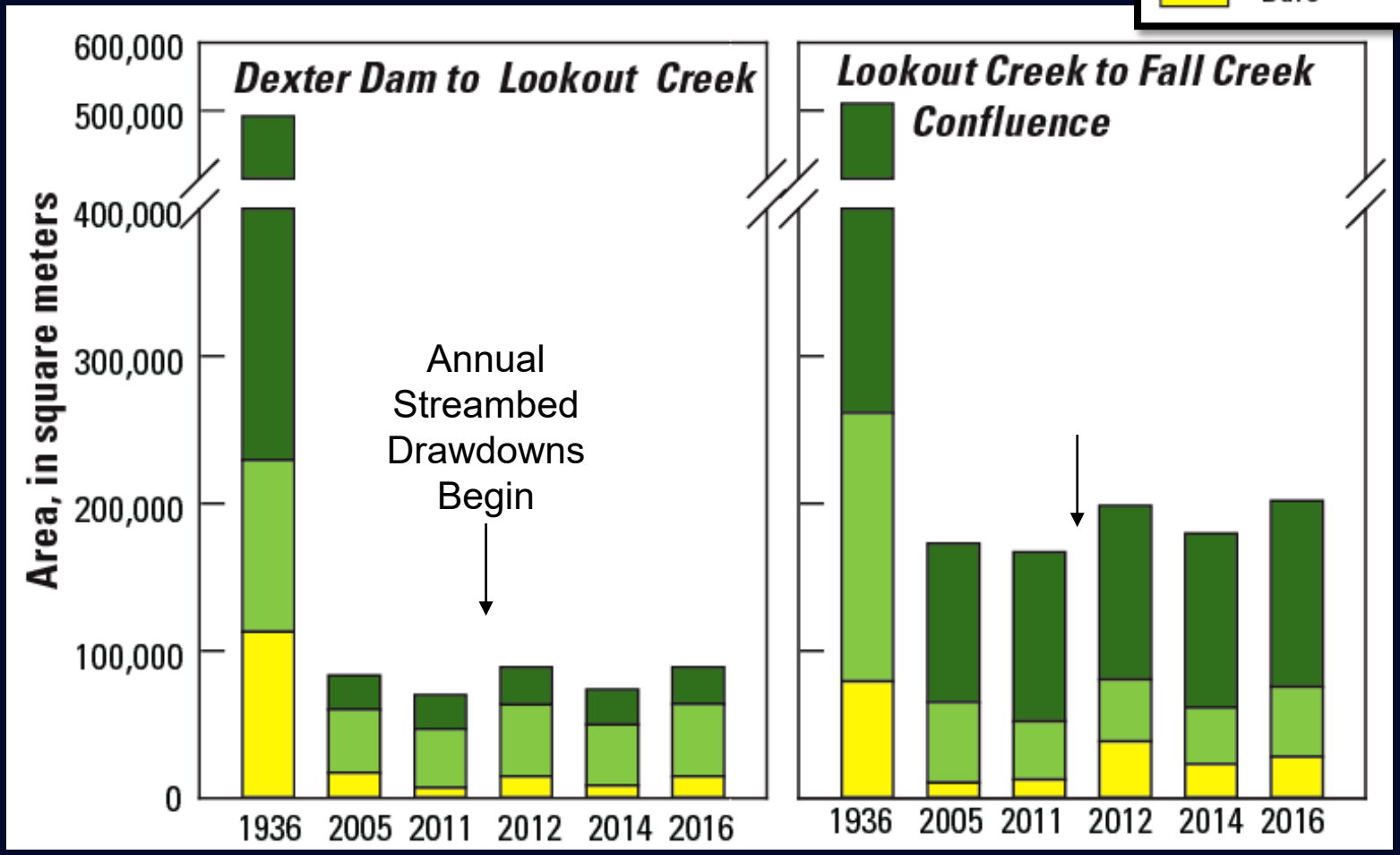
Reach-scale Changes in Bar Landforms



USGS

Changes in Bare Sediment and Vegetated Bars within the Middle Fork Active Channel

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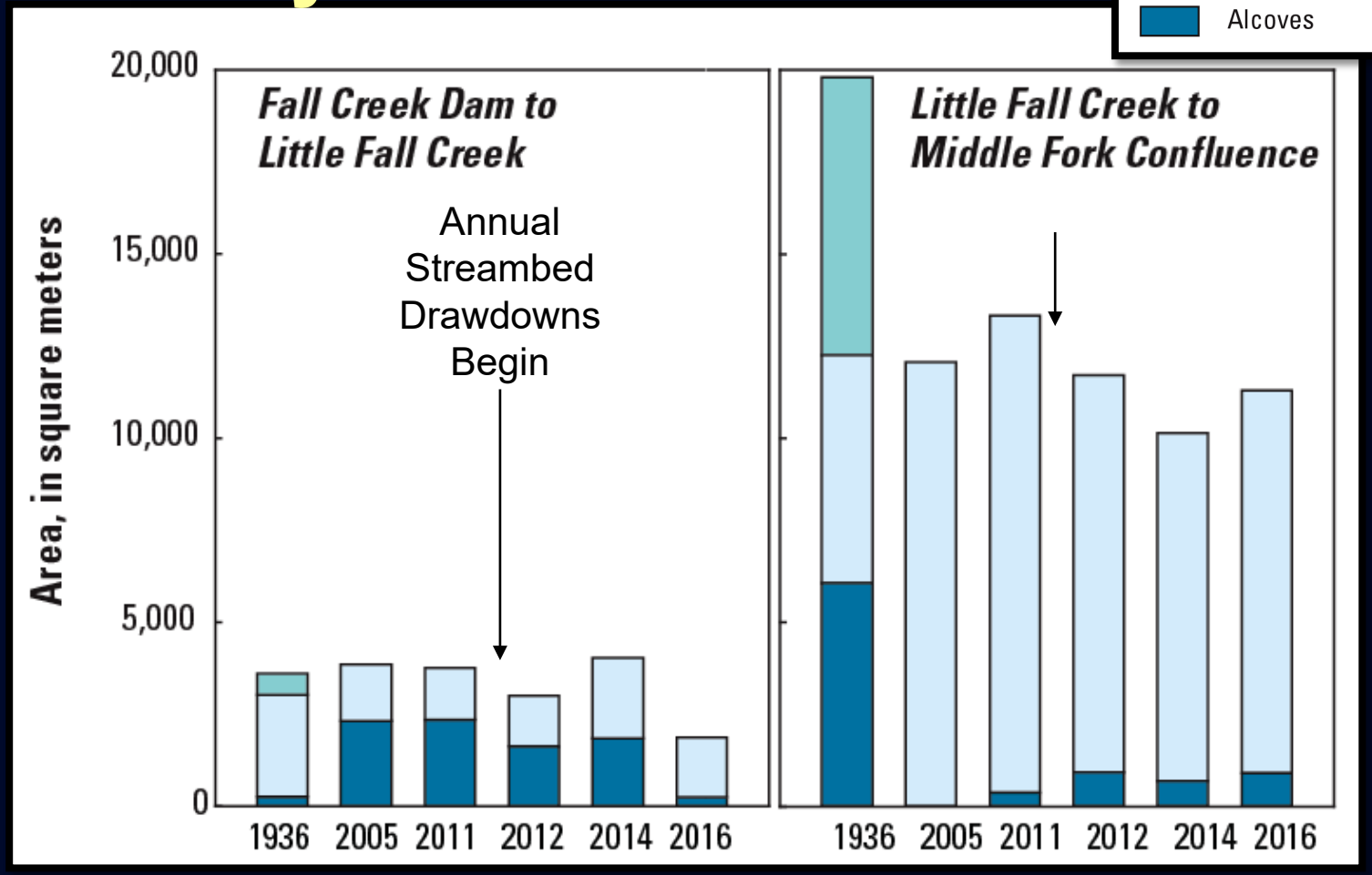
Reach-scale Changes in Secondary Water Features

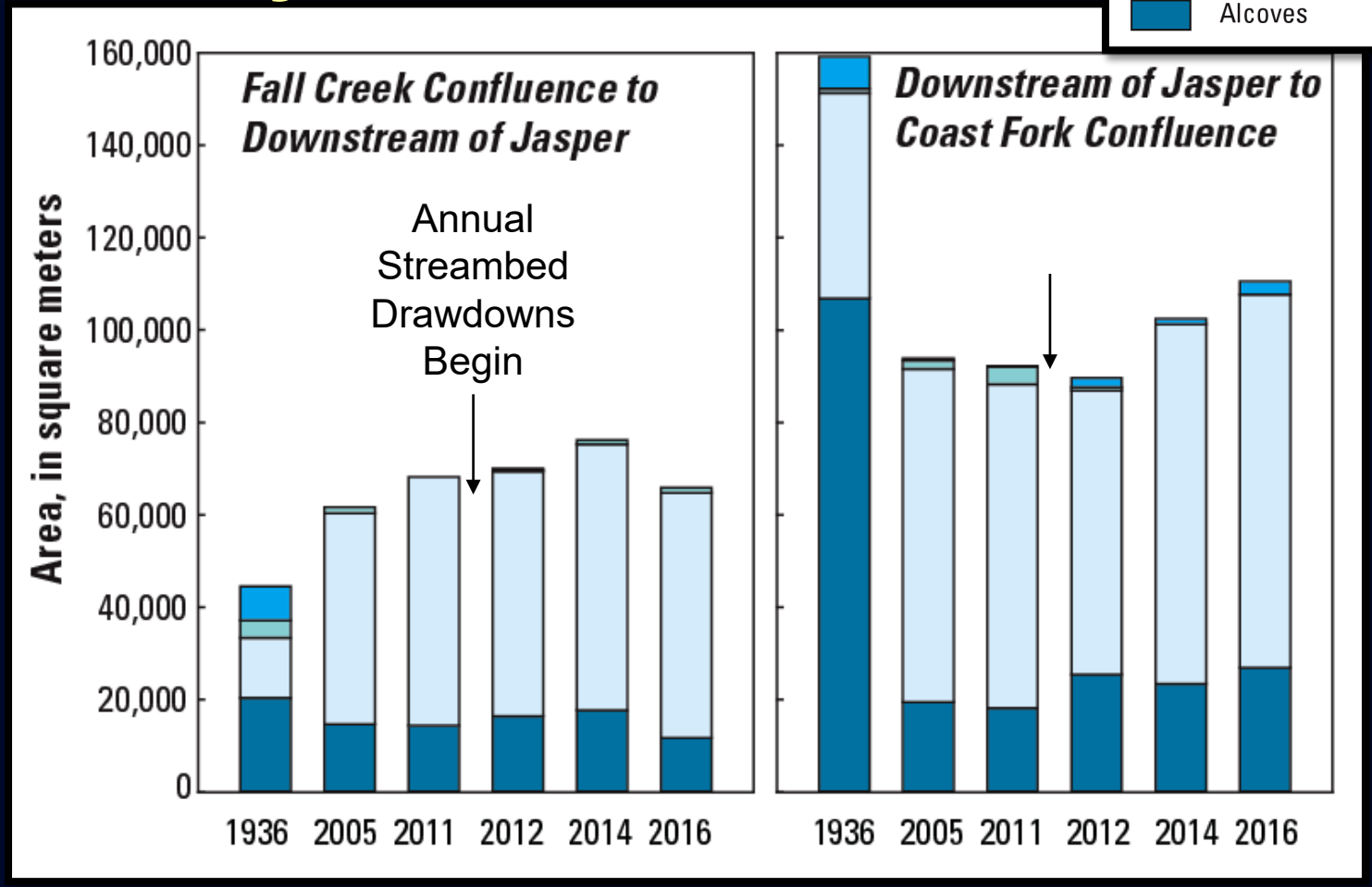


USGS

Changes in Secondary Water Landforms Fall Creek within the Active Channel

Provisional data. Subject to revision. Repeat geomorphic mapping data from aerial photographs.

Reach-scale Changes in Secondary Water Features

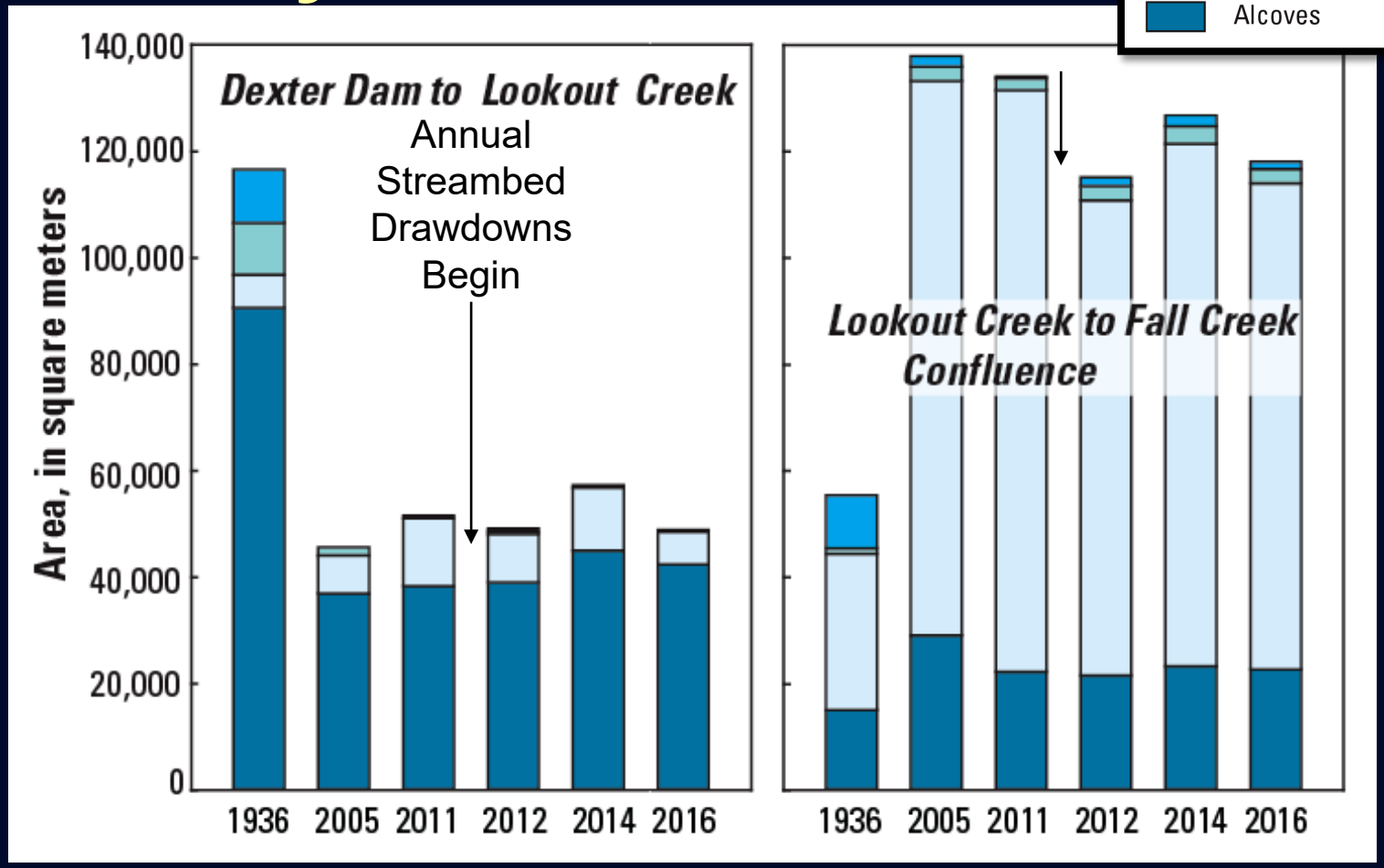


USGS

Changes in Secondary Water Landforms within the Middle Fork Active Channel

Provisional data. Subject to revision. Repeat geomorphic mapping data from aerial photographs.

Reach-scale Changes in Secondary Water Features

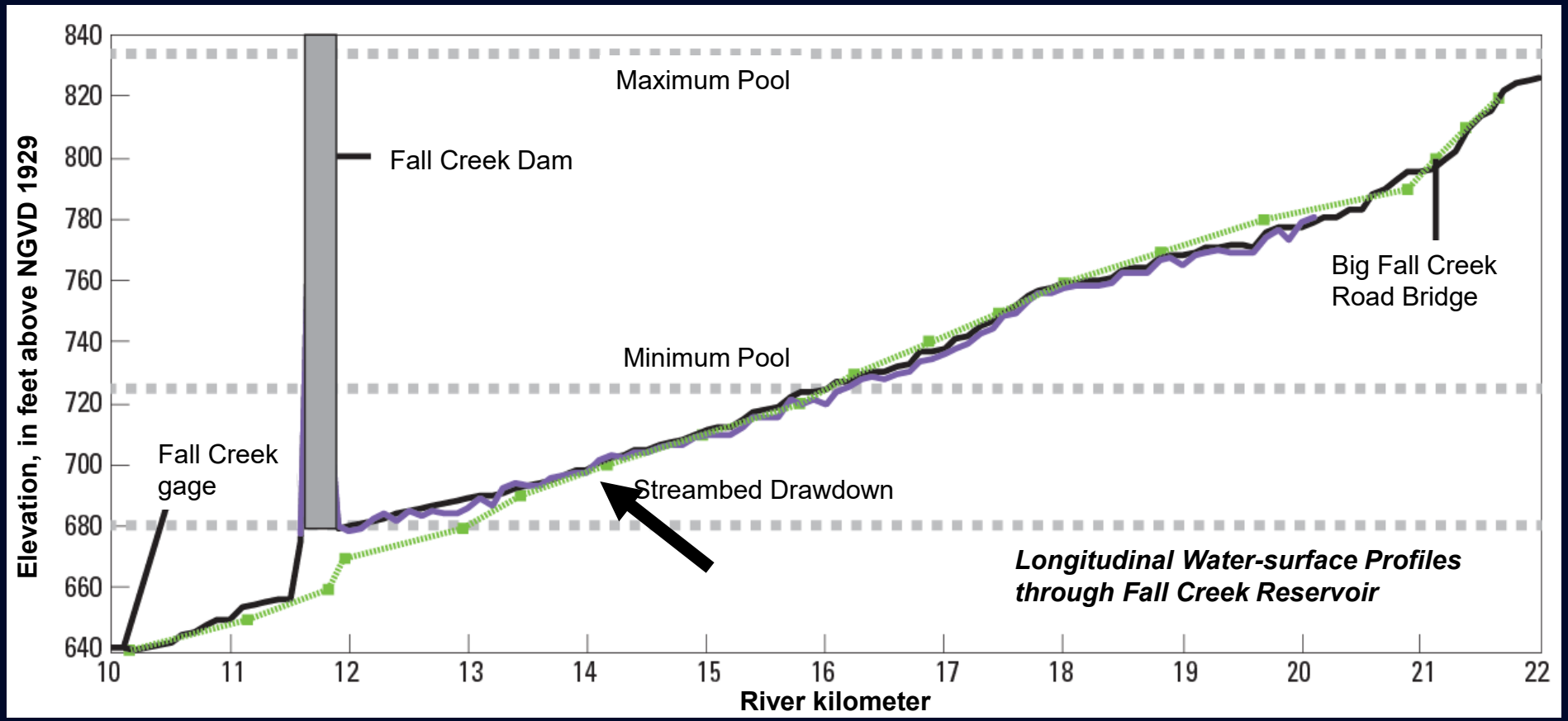


USGS

Changes in Secondary Water Landforms within the Middle Fork Active Channel

Provisional data. Subject to revision. Repeat geomorphic mapping data from aerial photographs.

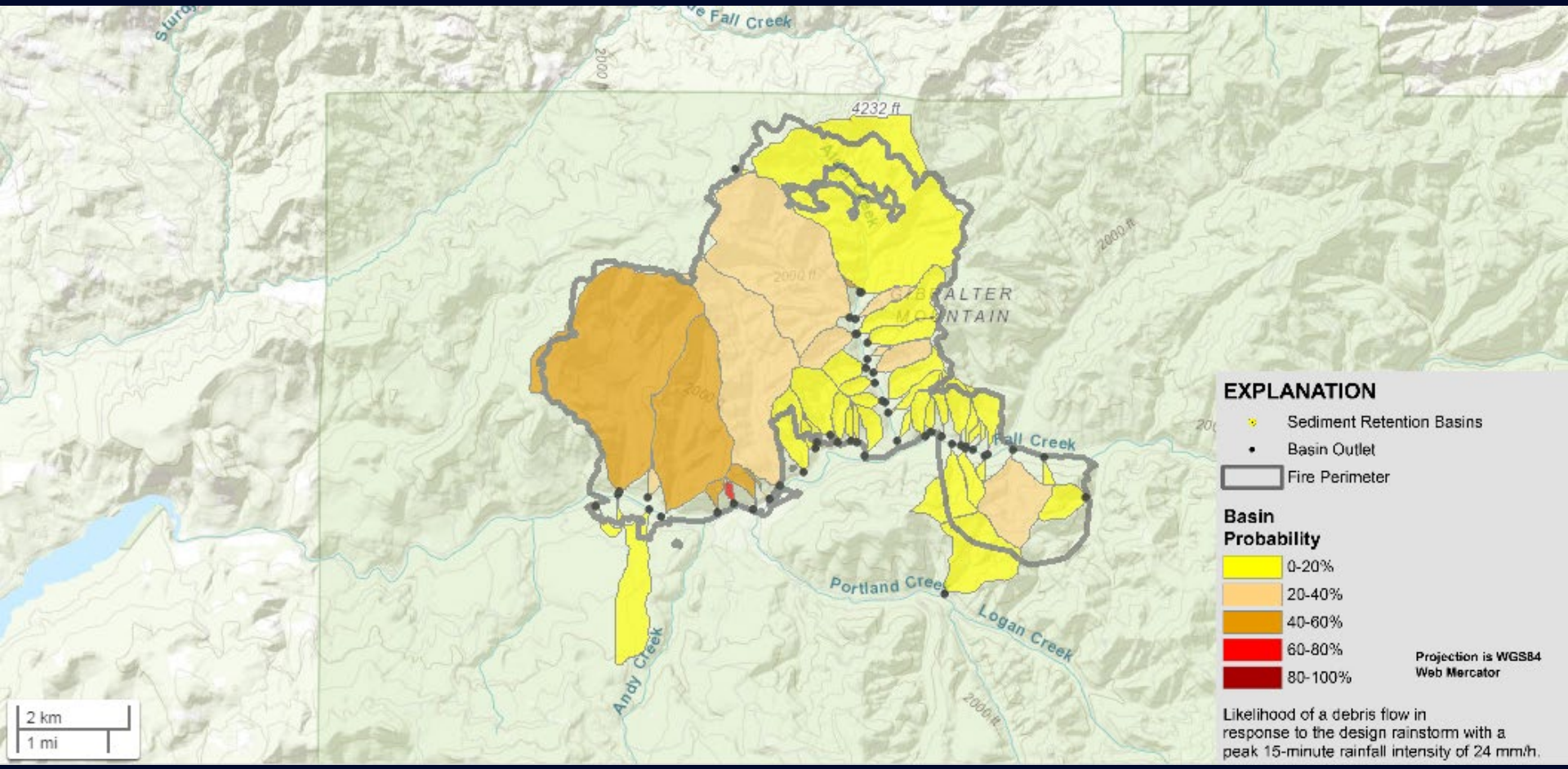
Patterns of Long-term Reservoir Sedimentation and Recent Erosion



USGS

Provisional data. Subject to revision. Longitudinal water-surface profiles from 1965 USACE maps, 2012 lidar data, and 2016 structure-from-motion data collected for this study.

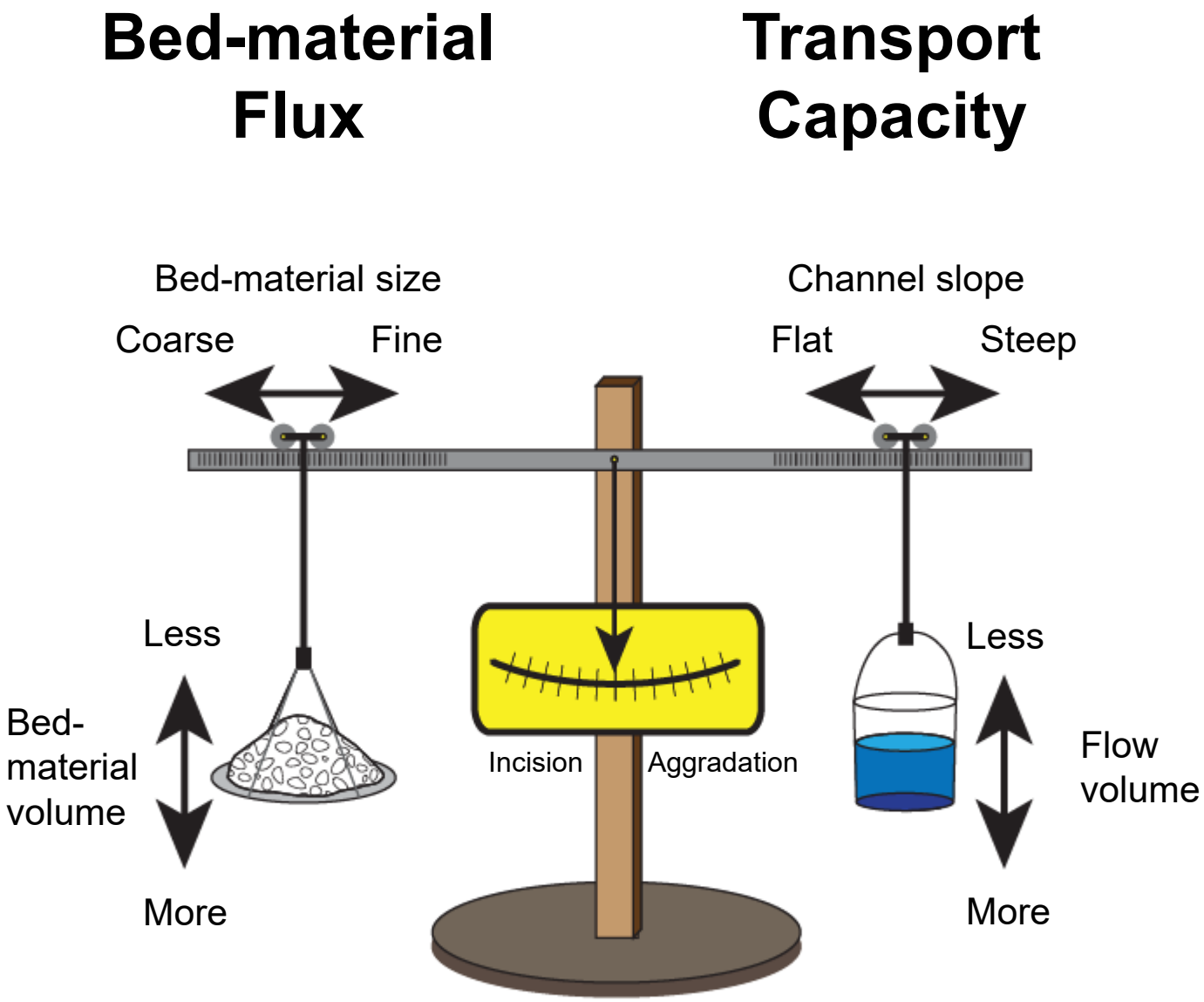
Jones Fire, 2017



USGS

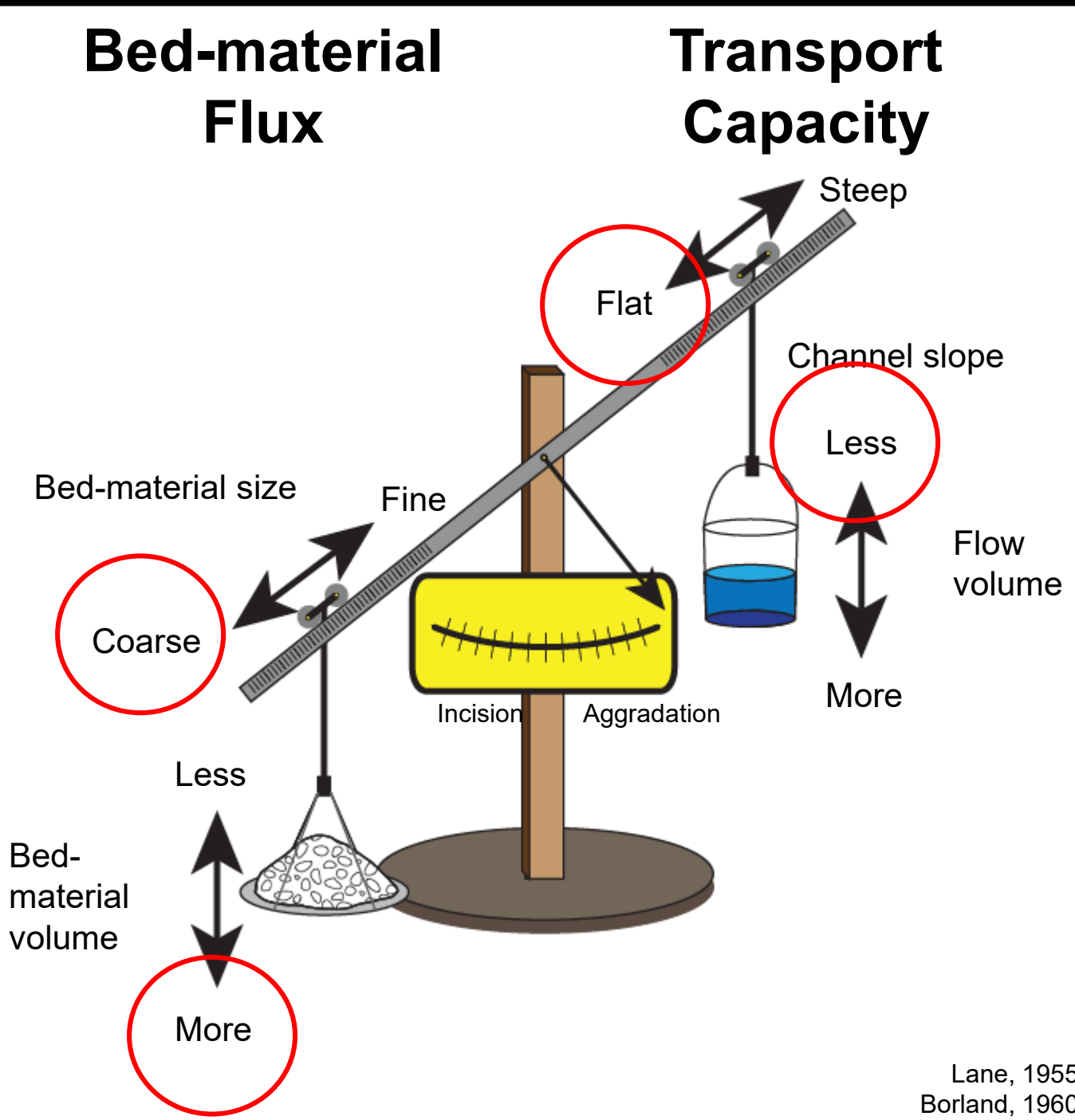
Map from preliminary hazard assessment of the Jones Fire (Willamette National Forest, OR) generated by the USGS Landslides Hazard Program. https://landslides.usgs.gov/hazards/postfire_debrisflow/detail.php?objectid=123

Lane-Borland Balance



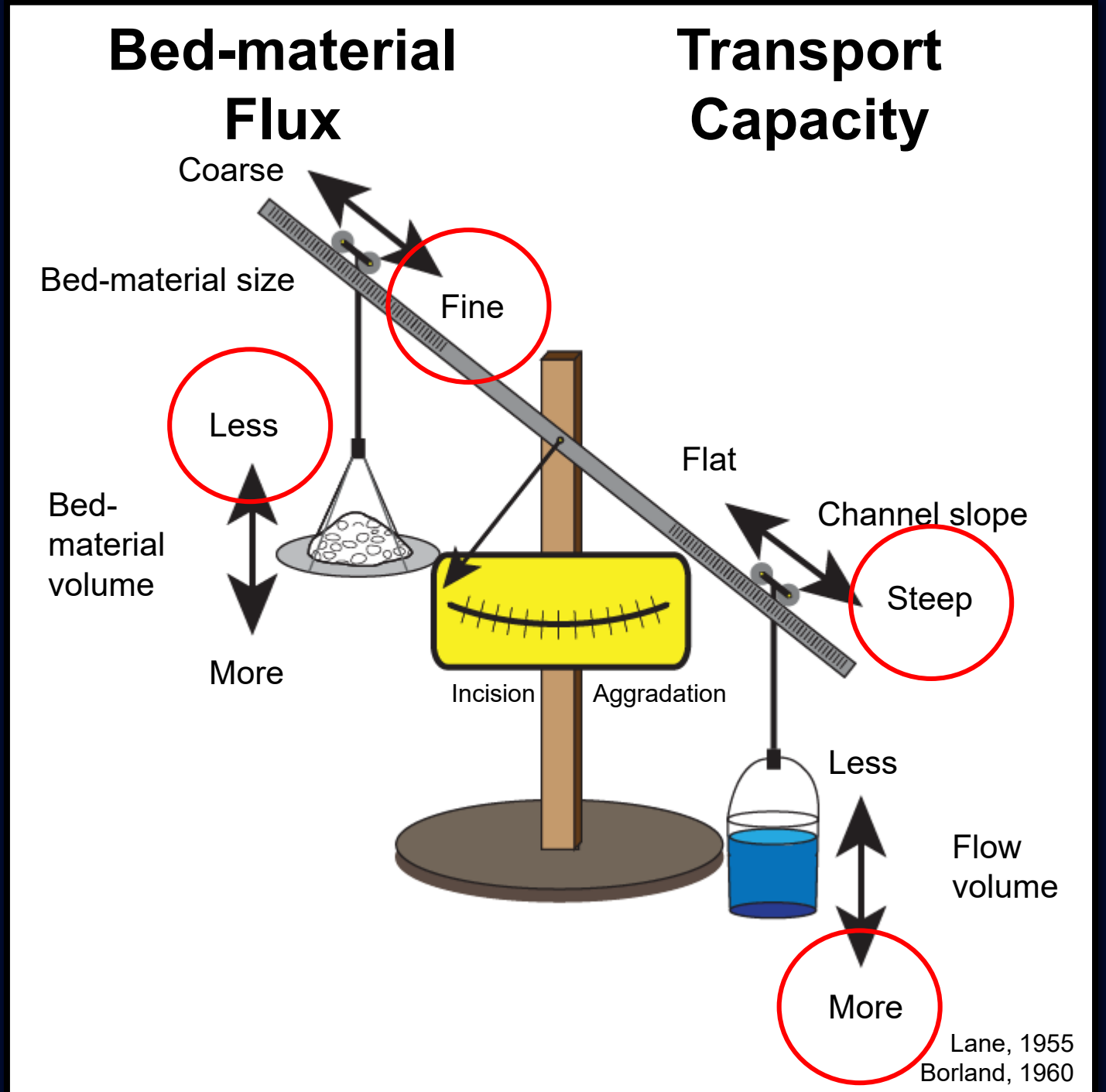
Lane, 1955
Borland, 1960

Lane-Borland Balance



USGS

Lane-Borland Balance



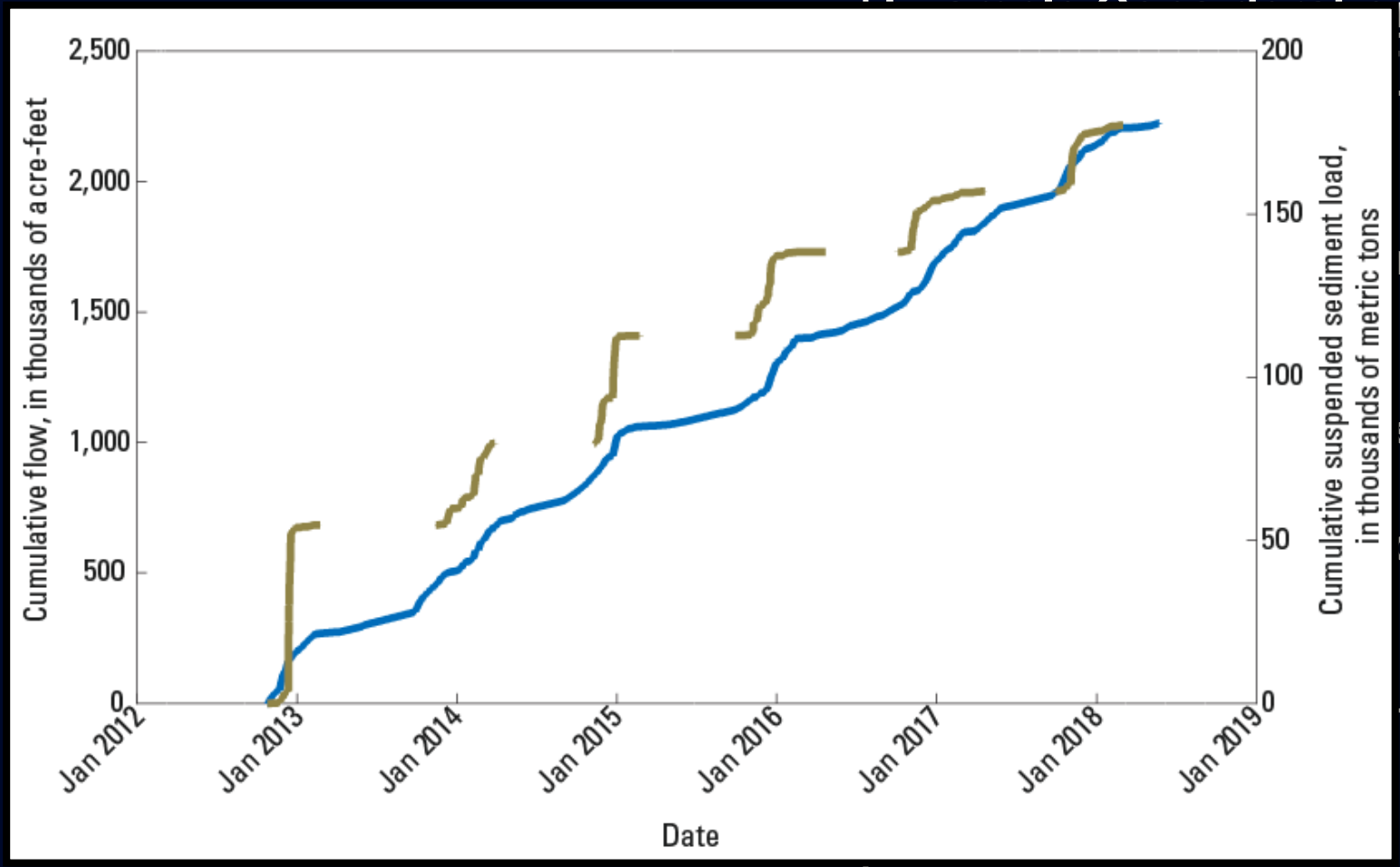
USGS

Multiple Factors Influence Geomorphic Responses to Streambed Drawdowns

Example Factors	Example Considerations in Reservoir Inflow and Through-flow
Sediment yield Reservoir morphology Reservoir sediment deposit magnitude, geometry, character **Reservoir Inflow** Downstream channel morphology Precipitation and temperature during drawdown operations Dam infrastructure Dam operations ▪ Duration ▪ Time of year ▪ Rate of pool change ▪ **Regulated flows**	**Decreasing/similar sediment export** ▪ Lower flows ▪ Move less sediment ▪ Move much less coarse sediment **Increasing sediment export** ▪ Higher flows ▪ Move more sediment ▪ Move more coarse sediment

Provisional data. Subject to revision.

Multiple Factors Influence Geomorphic Responses to Streambed Drawdowns



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USGS

Provisional data. Subject to revision.

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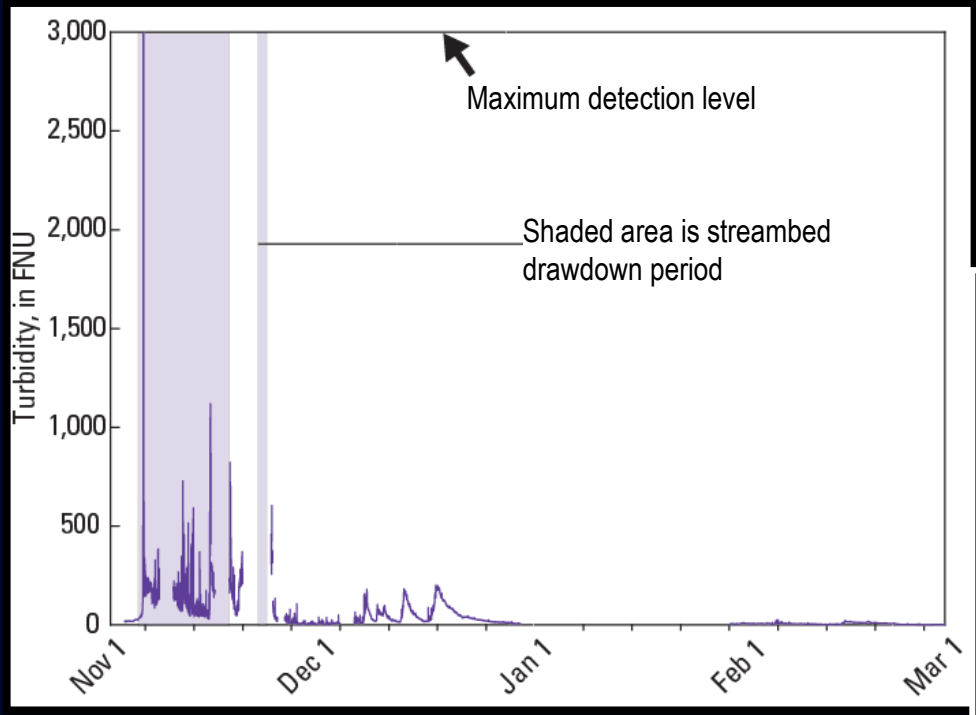

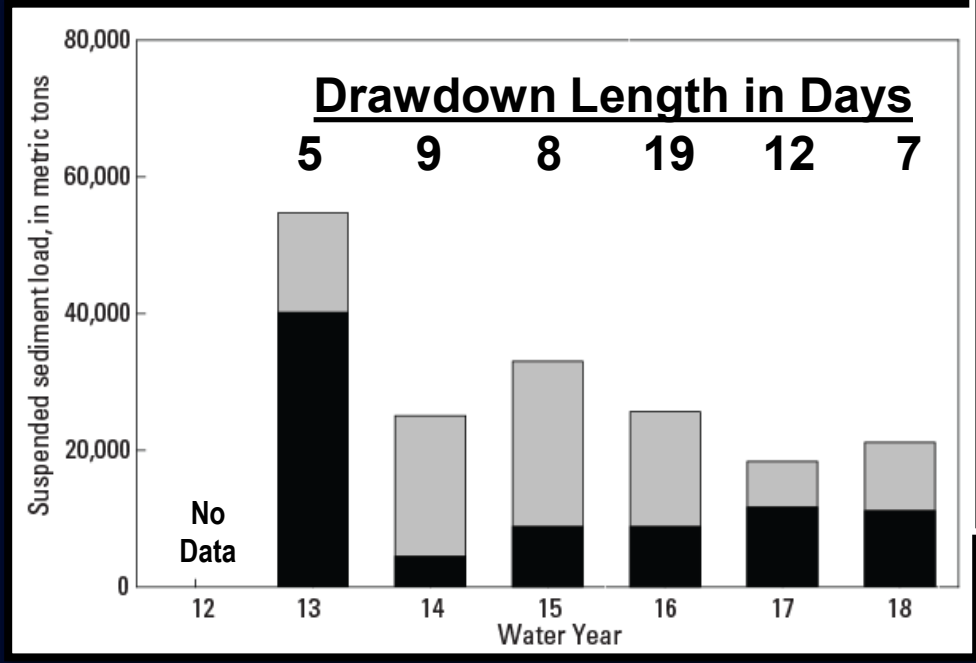

Example Considerations in Streambed Drawdown Duration

Decreasing/similar sediment export

- Shorter duration near streambed
- Move less sediment overall
- Move newly deposited sediment near dam

Increasing sediment export

- Longer duration near streambed
- Increases travel time for coarse sediment through the reservoir
- Increasing potential for other factors to become important (flows, storms)

Provisional data. Subject to revision.

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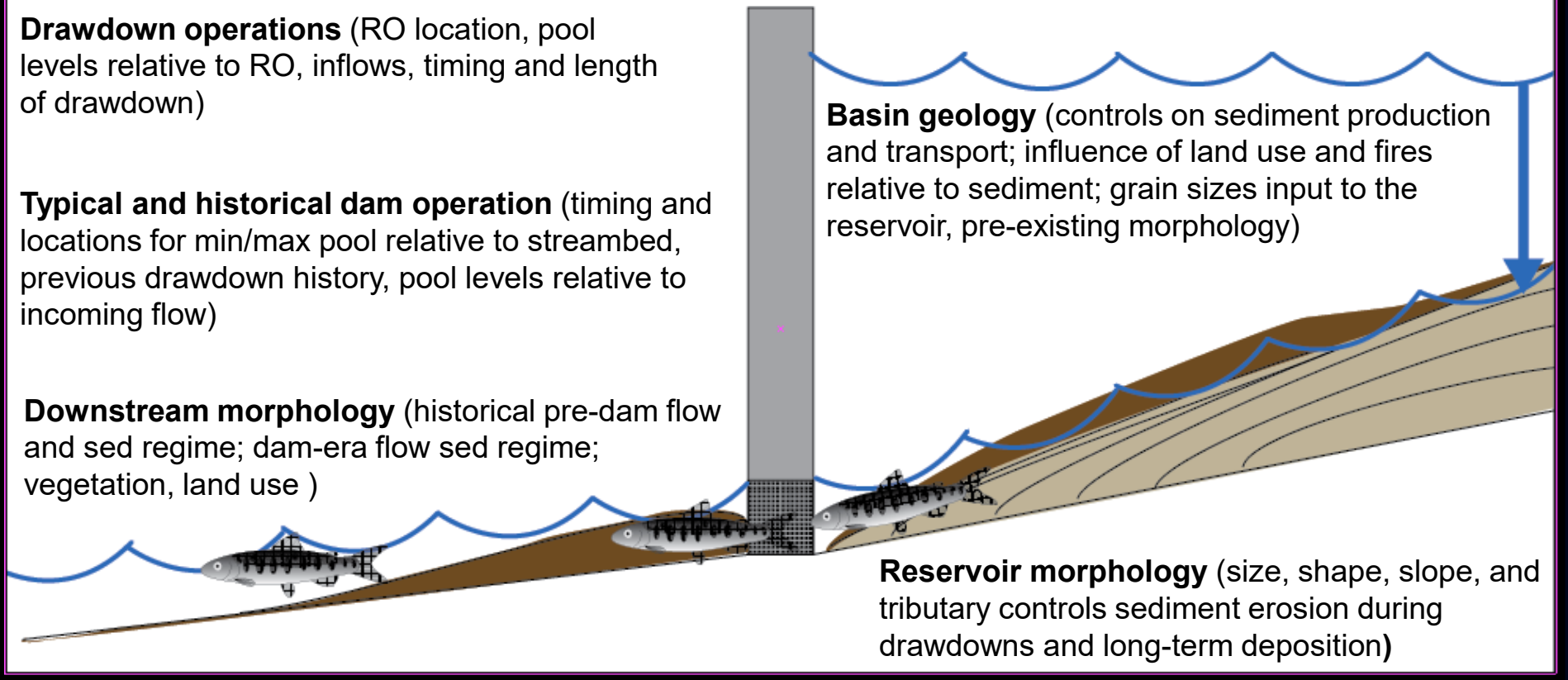
Drawdown Operations

Drawdown operations (RO location, pool levels relative to RO, inflows, timing and length of drawdown)

Typical and historical dam operation (timing and locations for min/max pool relative to streambed, previous drawdown history, pool levels relative to incoming flow)

Downstream morphology (historical pre-dam flow and sed regime; dam-era flow sed regime; vegetation, land use)



Basin geology (controls on sediment production and transport; influence of land use and fires relative to sediment; grain sizes input to the reservoir, pre-existing morphology)

Reservoir morphology (size, shape, slope, and tributary controls sediment erosion during drawdowns and long-term deposition**)**

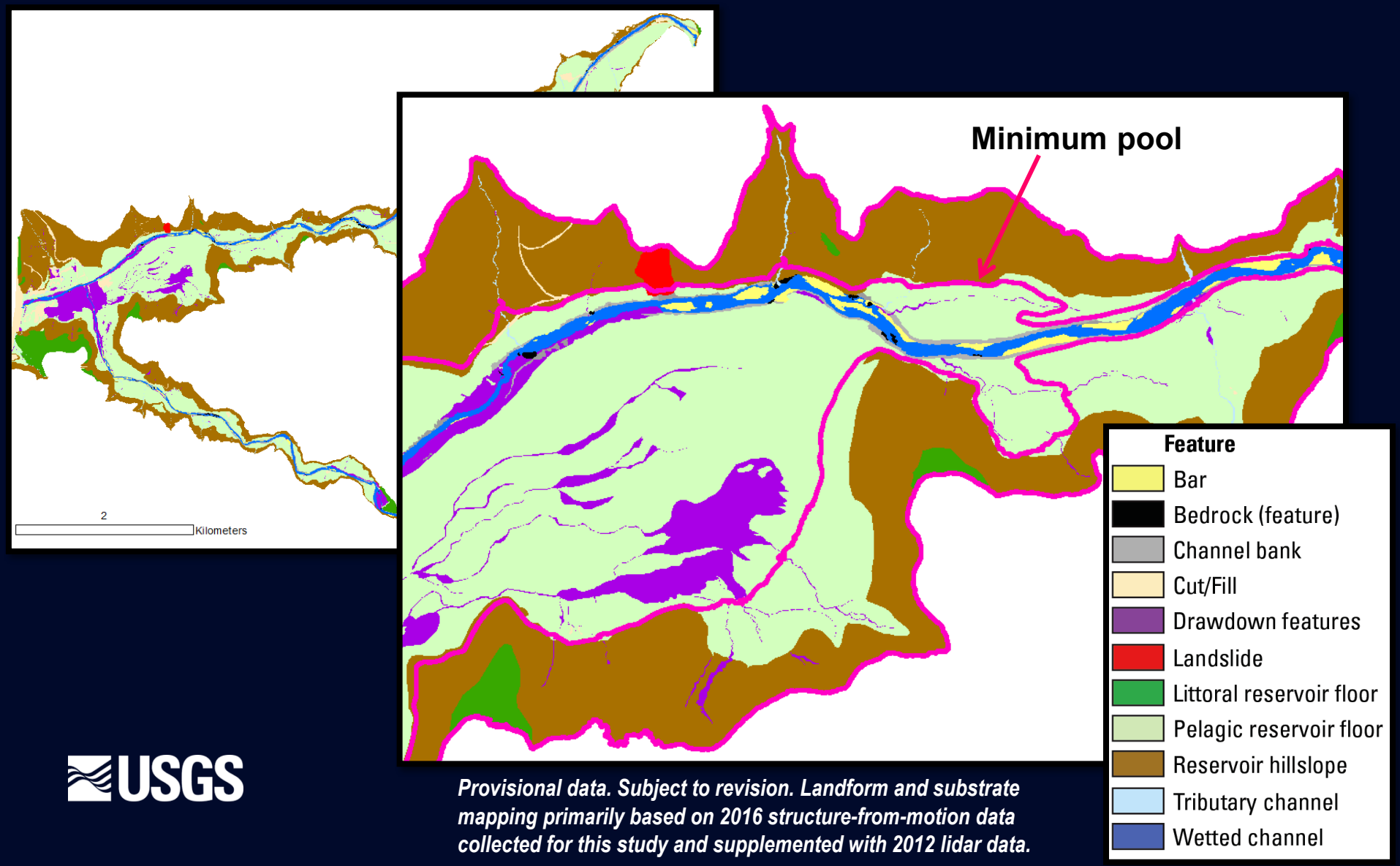
Downstream Concerns (habitat alteration, invasive aquatics, redds, drinking water, turbidity, dissolved oxygen, balance sediment and flows)

Operational Concerns (flood control, hydropower, temperature, recreation)

Reservoir Concerns (fish passage, invasives, HABs, sediment management, contaminants)

USGS

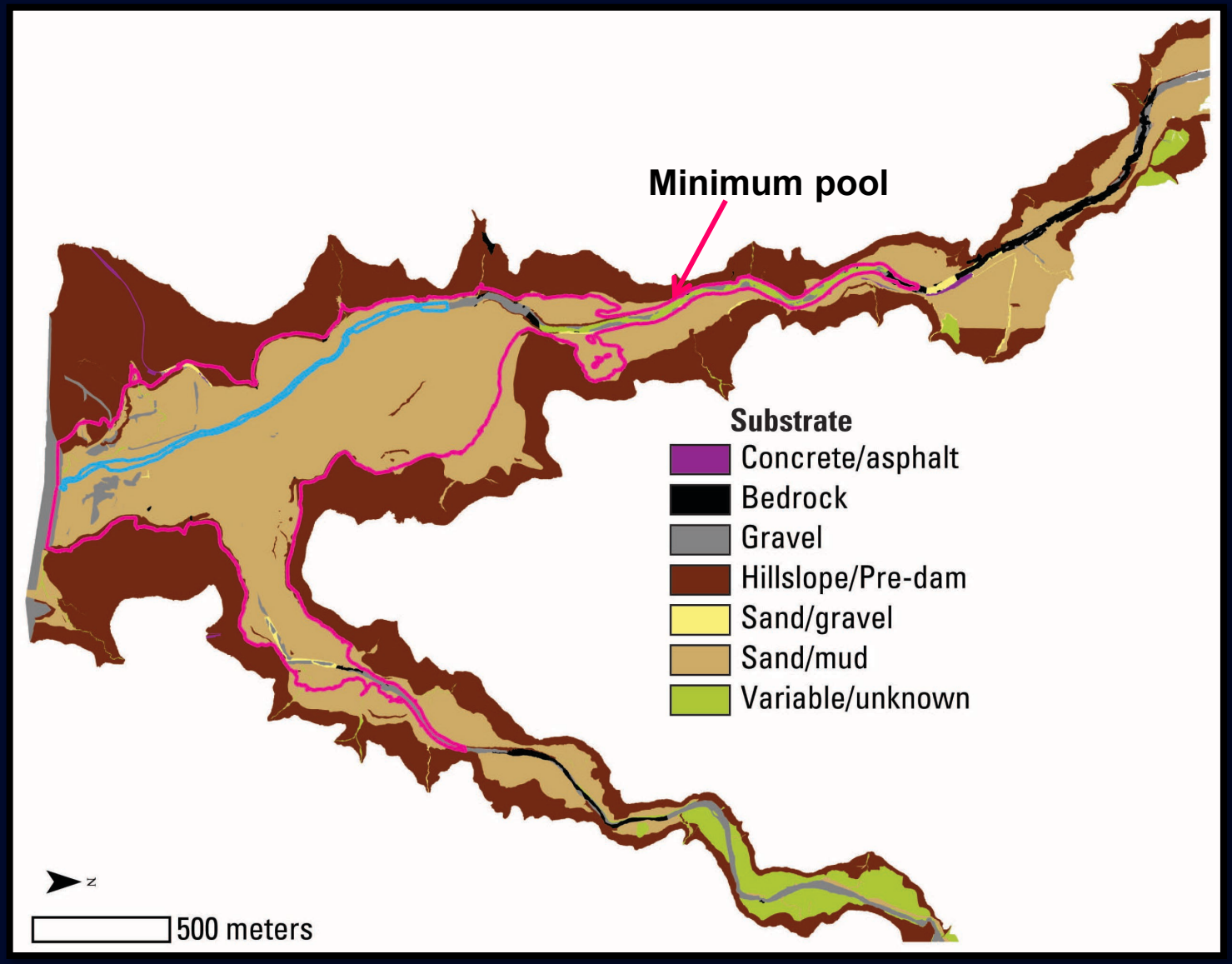
Reservoir Landform Mapping



USGS

Provisional data. Subject to revision. Landform and substrate mapping primarily based on 2016 structure-from-motion data collected for this study and supplemented with 2012 lidar data.

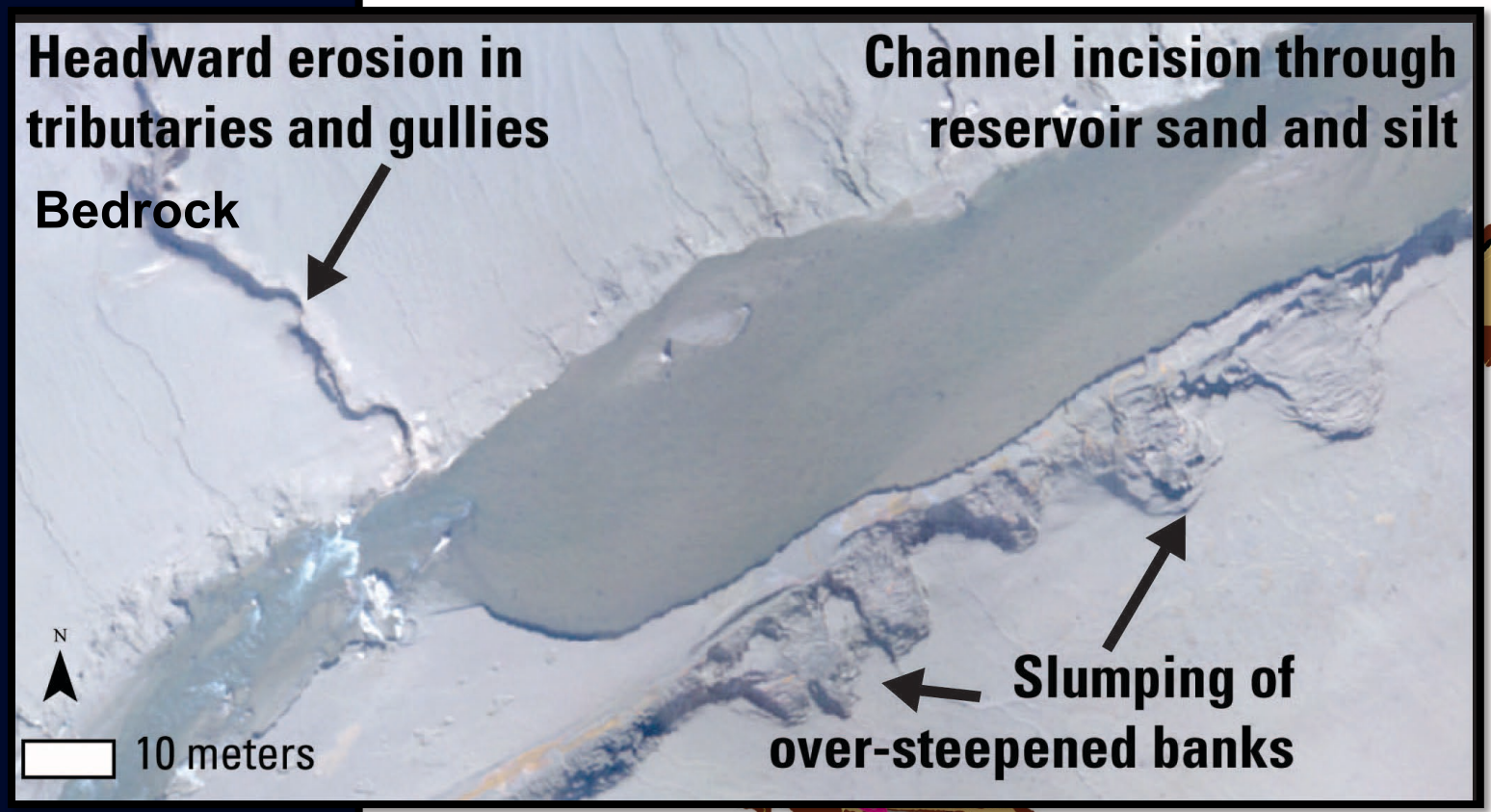
Reservoir Substrate Mapping



Provisional data. Subject to revision. Landform and substrate mapping primarily based on 2016 structure-from-motion data collected for this study and supplemented with 2012 lidar data.

USGS

Reservoir Erosion Mechanisms



USGS

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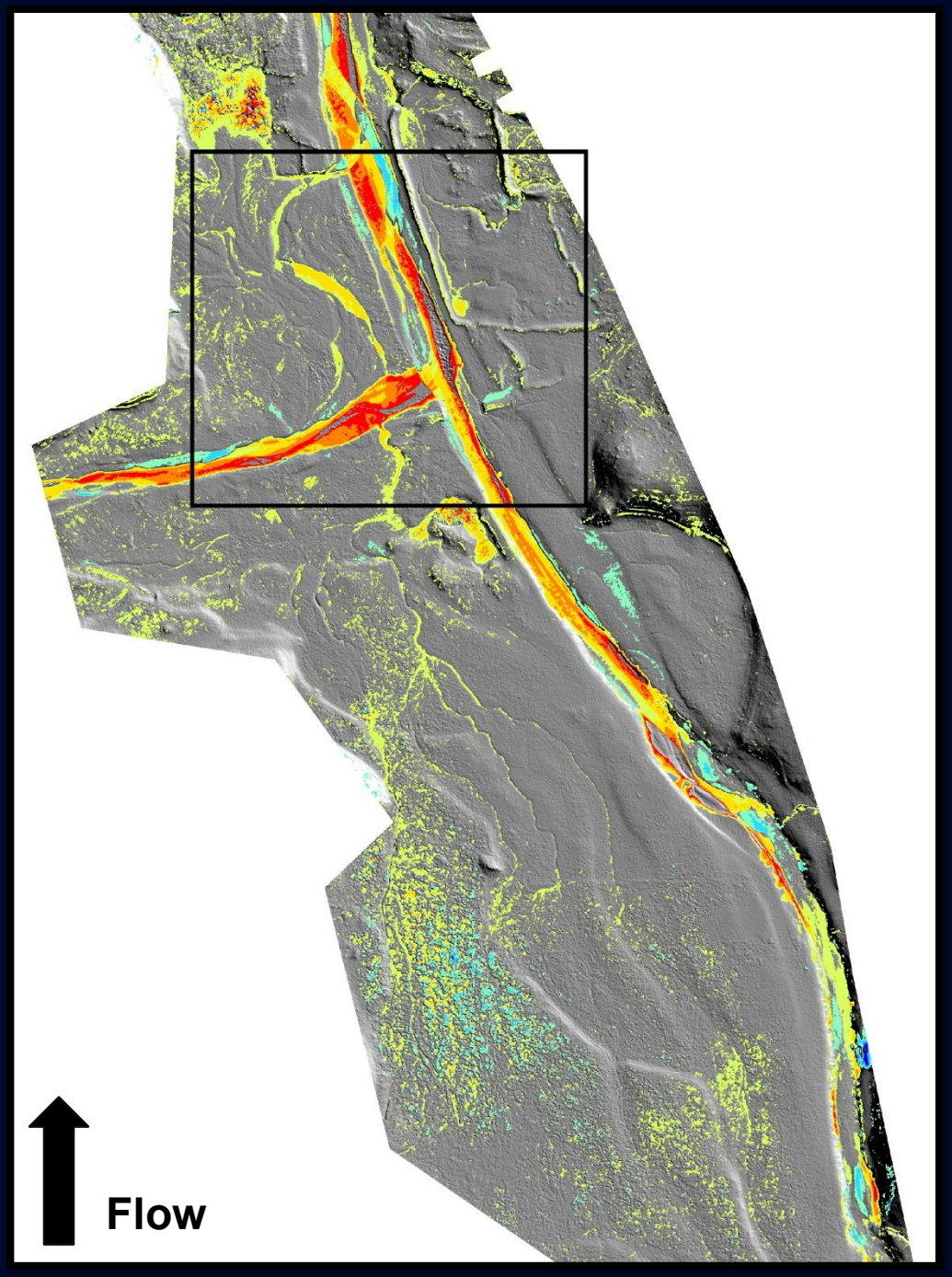
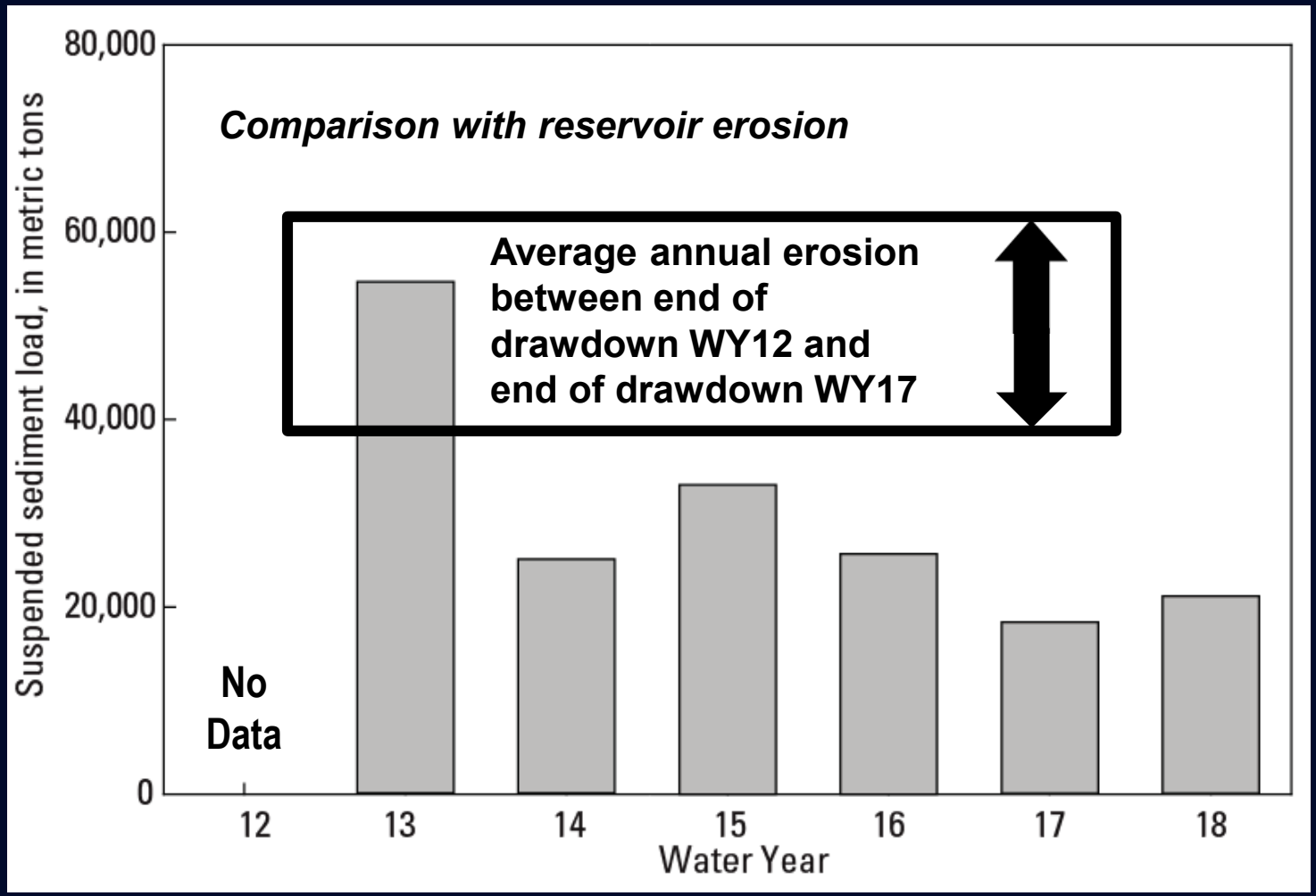
Reservoir Erosion



Provisional data. Subject to revision. Change analyses from comparison of 2016 structure-from-motion data collected for this study with 2012 lidar data.

USGS

Sediment Gaging: Computed Suspended Sediment Loads



USGS

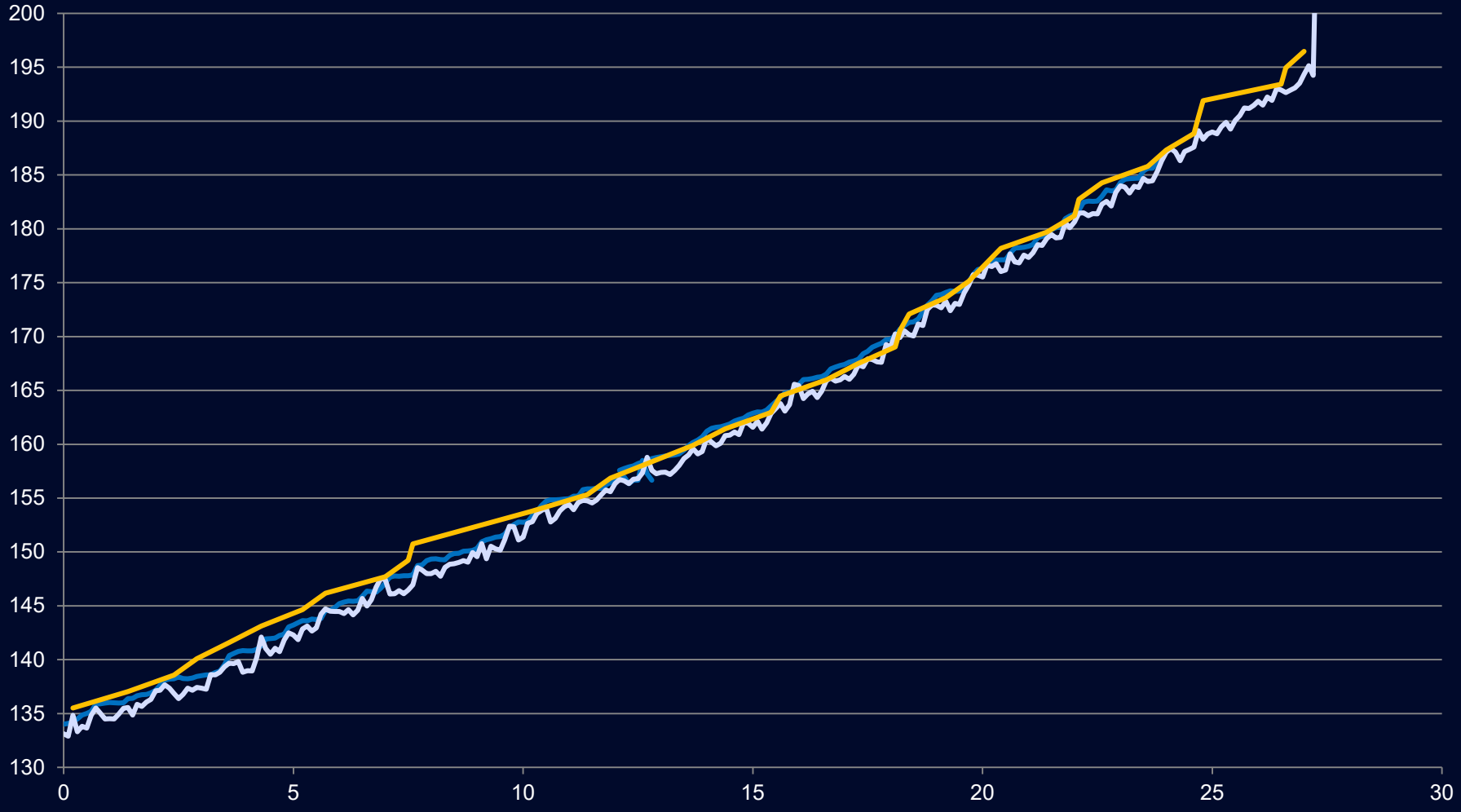
Data for Water Years 13-16 from Schenk and Bragg, 2014, 2015; NWIS database. Data for Water Years 17-18 provisional. Subject to revision. Loads computed from turbidity-suspended sediment concentration relations spanning the streambed drawdown. Data collected for partial water years. Average annual erosion from reservoir change detection analyses.

WY2014

Photo credit: L. Schenk, USGS, 2013 (WY 2014)

USGS

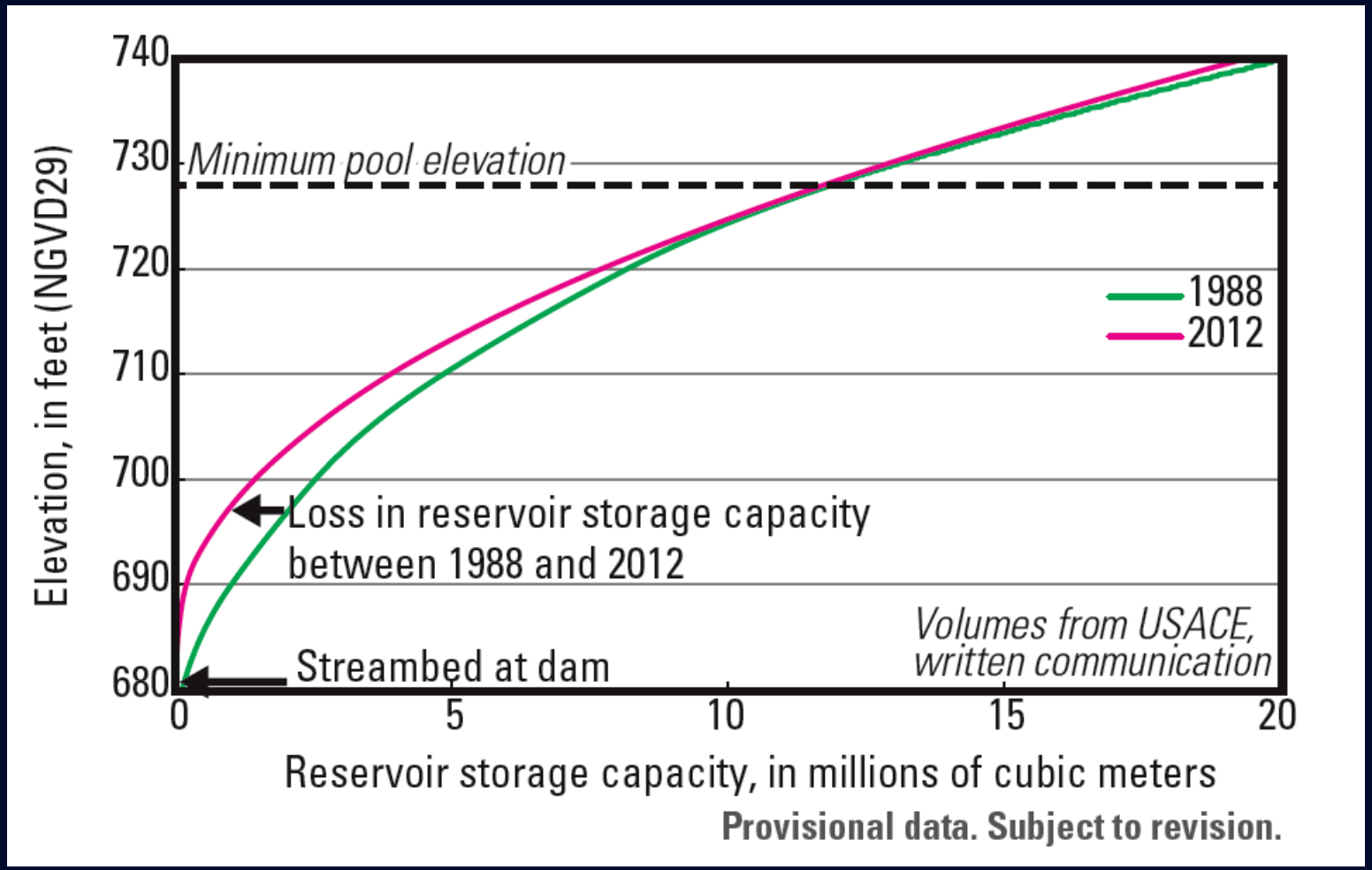
Historical Context



USGS

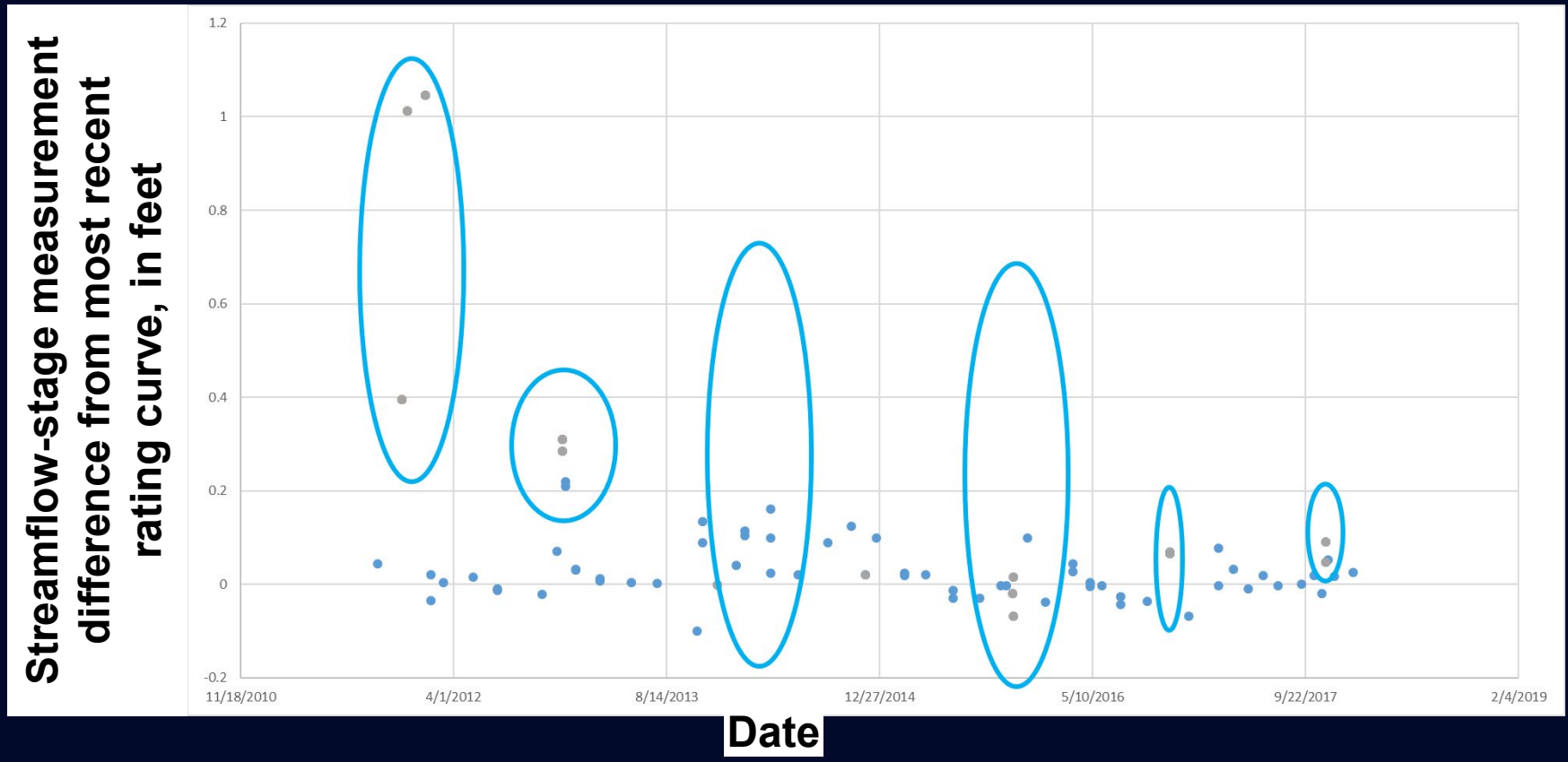
Provisional data. Subject to revision. Data from historical USGS Plan and Profile maps (1926), topographic lidar (2012), and topo-bathymetric lidar (2015).

Fall Creek Lake Storage Curves



USGS

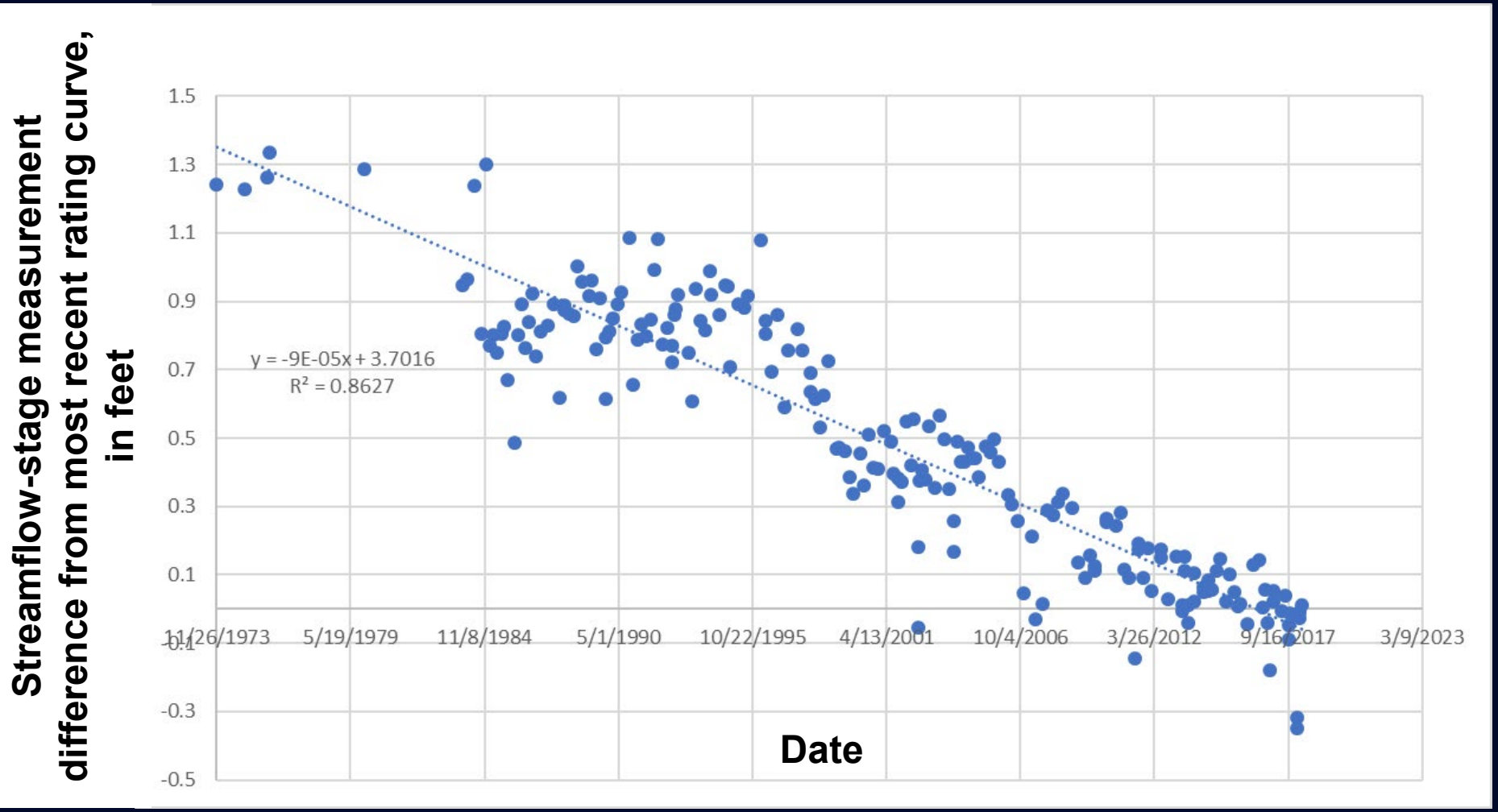
Specific Gage Analysis-Fall Creek



USGS

Provisional data. Subject to revision. Rating and stream data from NWIS.

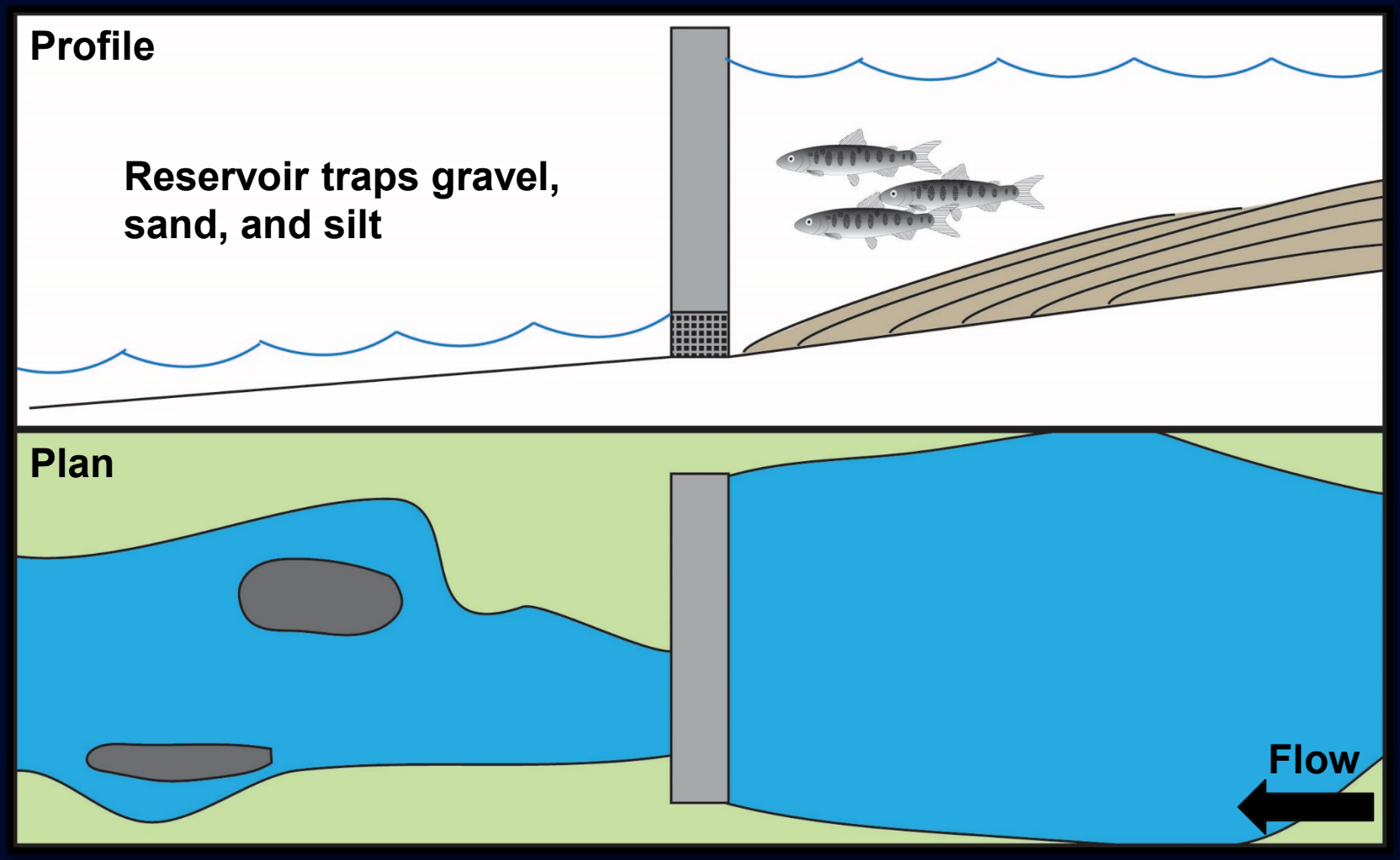
Specific Gage Analysis-Dexter



USGS

Provisional data. Subject to revision. Rating and stream data from NWIS.

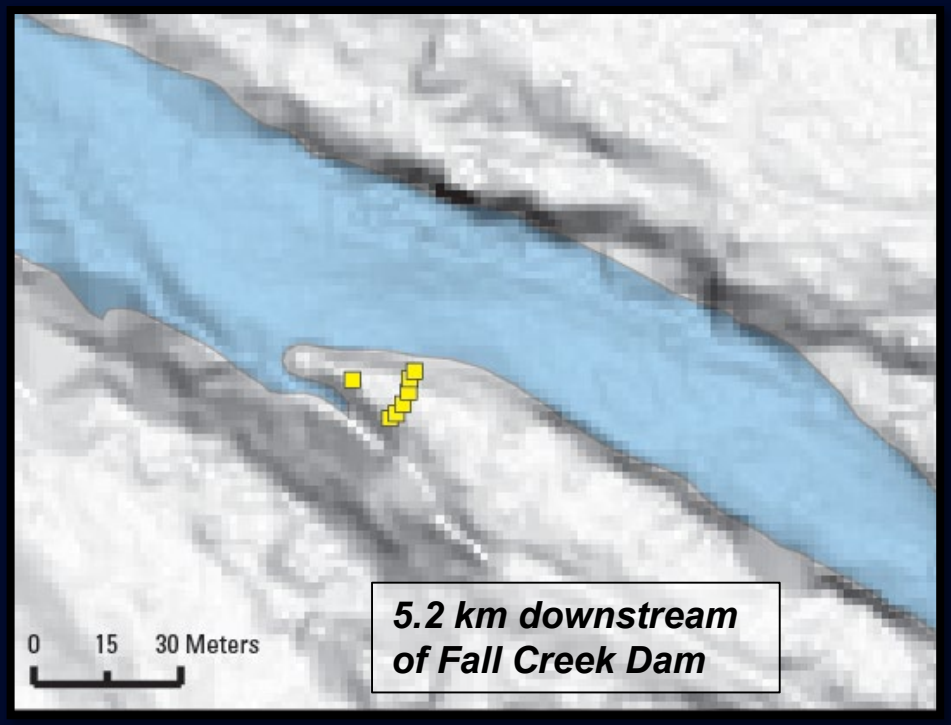
Fall Creek: Coupled Upstream-Downstream Responses WY12-18



USGS

Provisional data. Subject to revision.

Sand and Silt Deposition

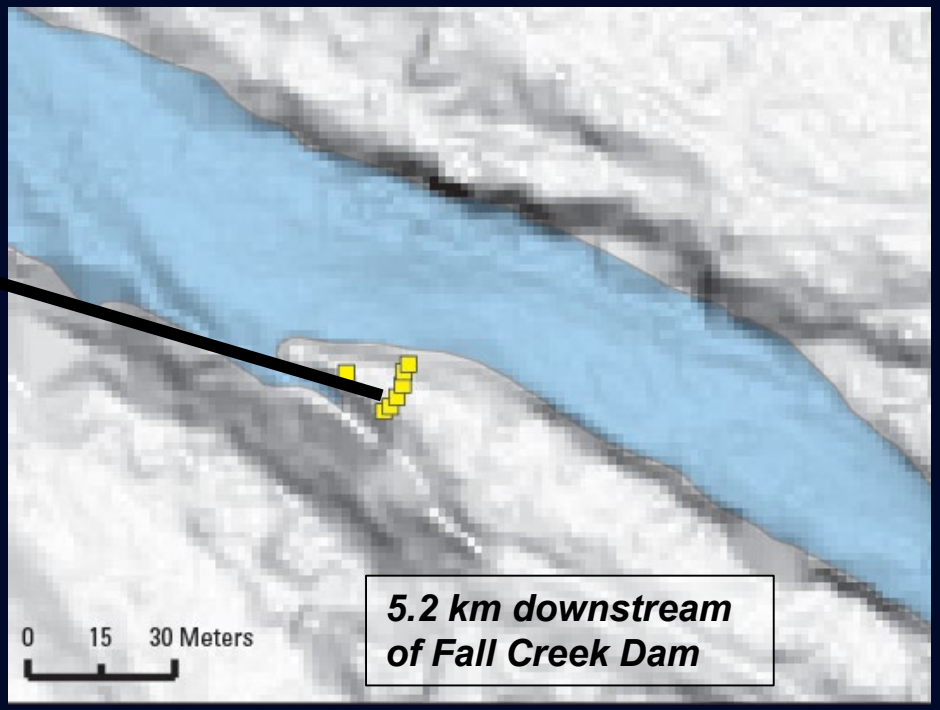


USGS

Provisional data. Subject to revision. Finding from clay-horizon markers, geomorphic change analyses, specific-gage analyses, geomorphic mapping, and particle-size measurements

Sand and Silt Deposition

Photo credit: M. Keith, USGS, March. 2016



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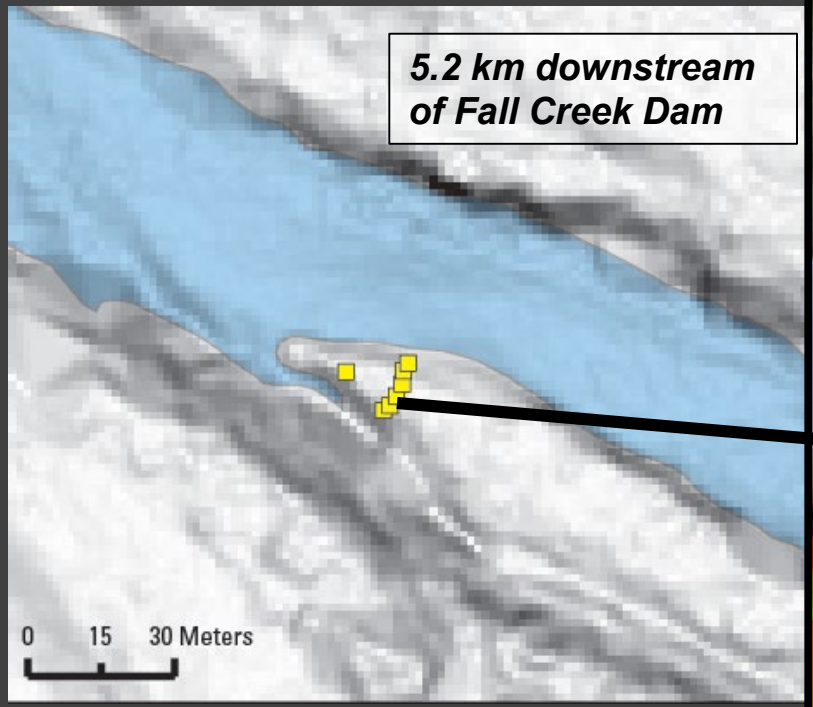
Sand and Silt Deposition



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USGS