River Science (Hydrology & Fluvial Geomorphology)

for Non-Engineers

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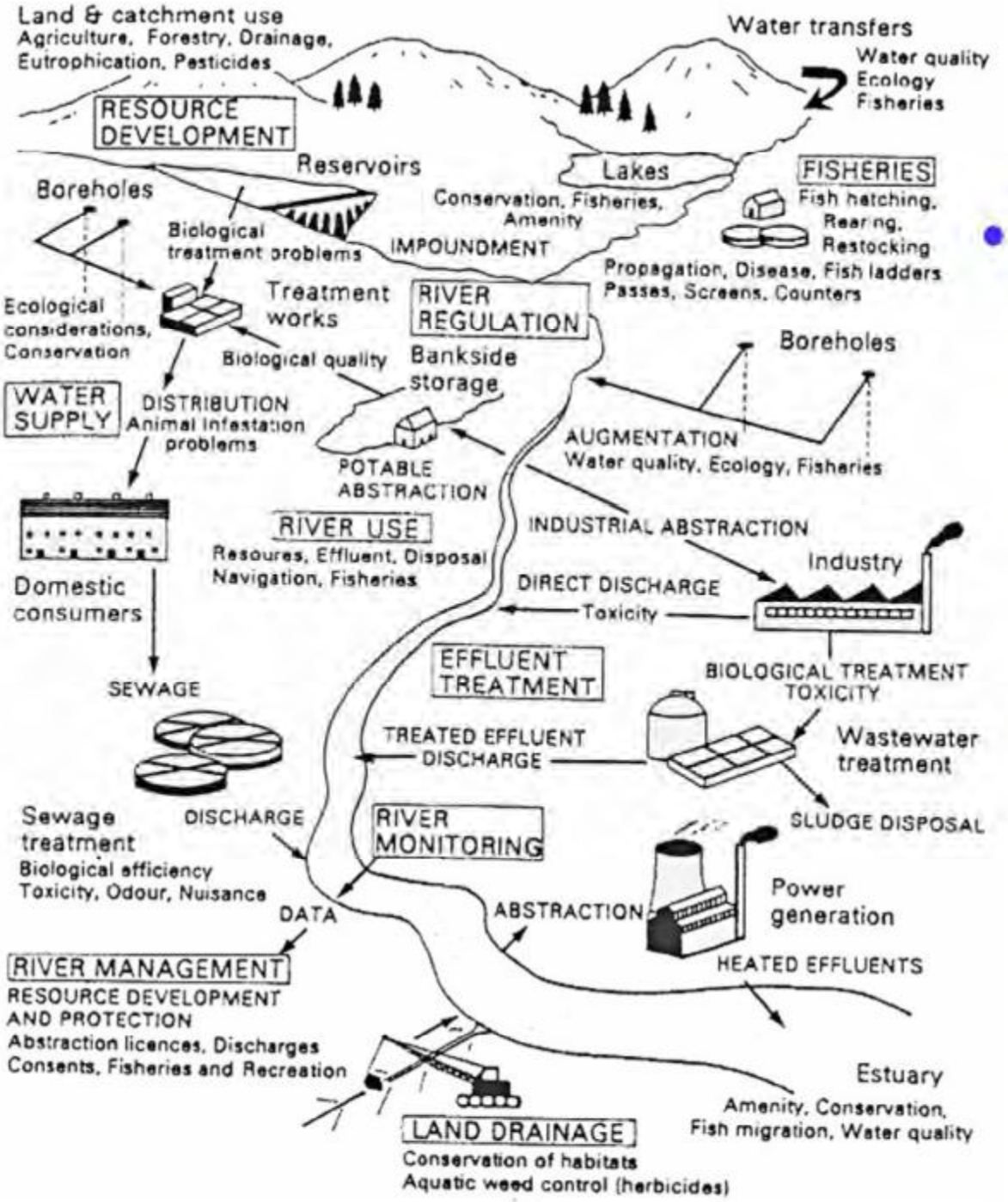
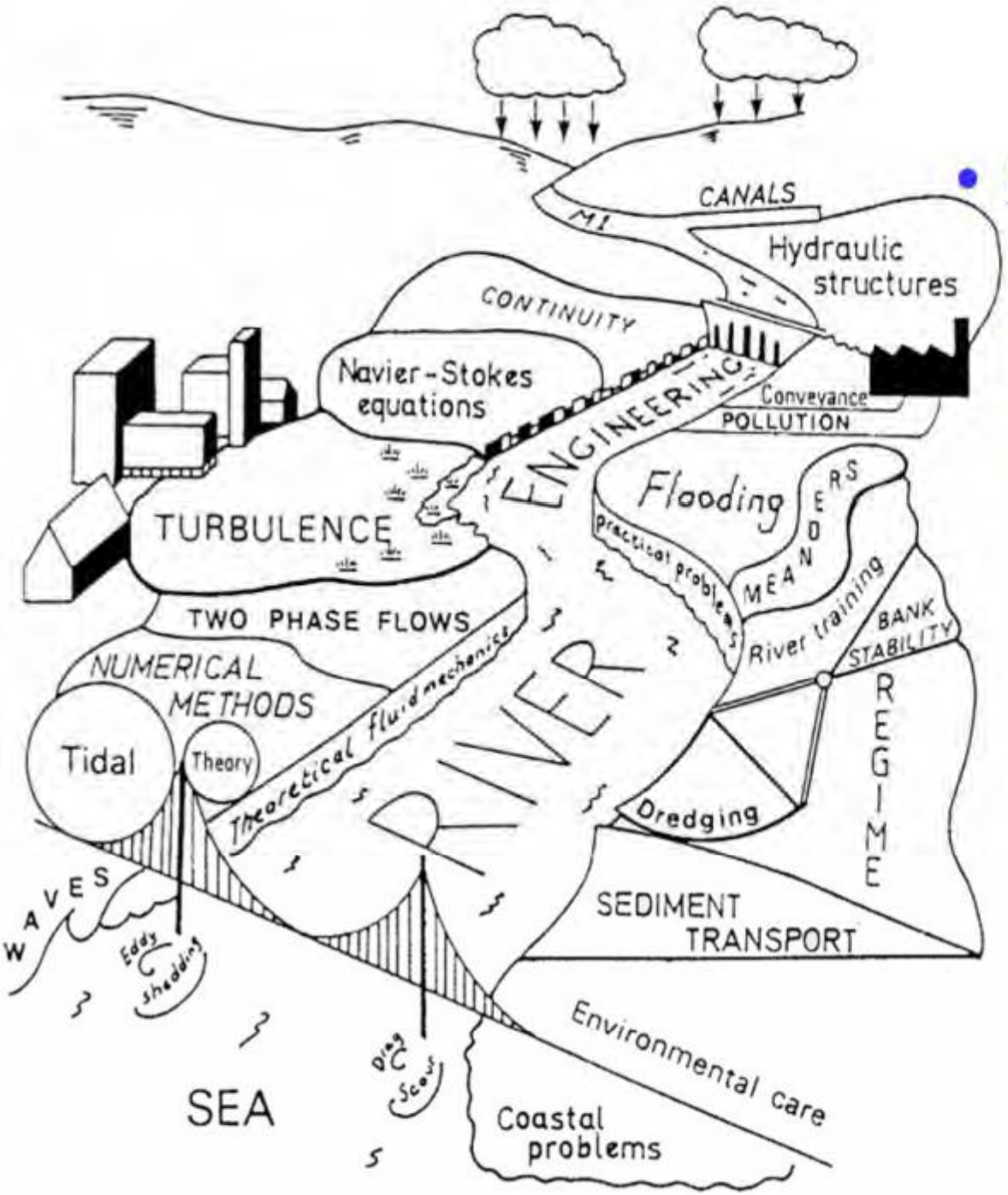
Why Non-Engineers??

- Not all NRCS conservation professionals are trained in these fairly specialized disciplines.
- *No intention to alienate anybody*—in fact many engineers commonly encounter these concepts in college.
- Present fundamental concepts and resources for conservation planners

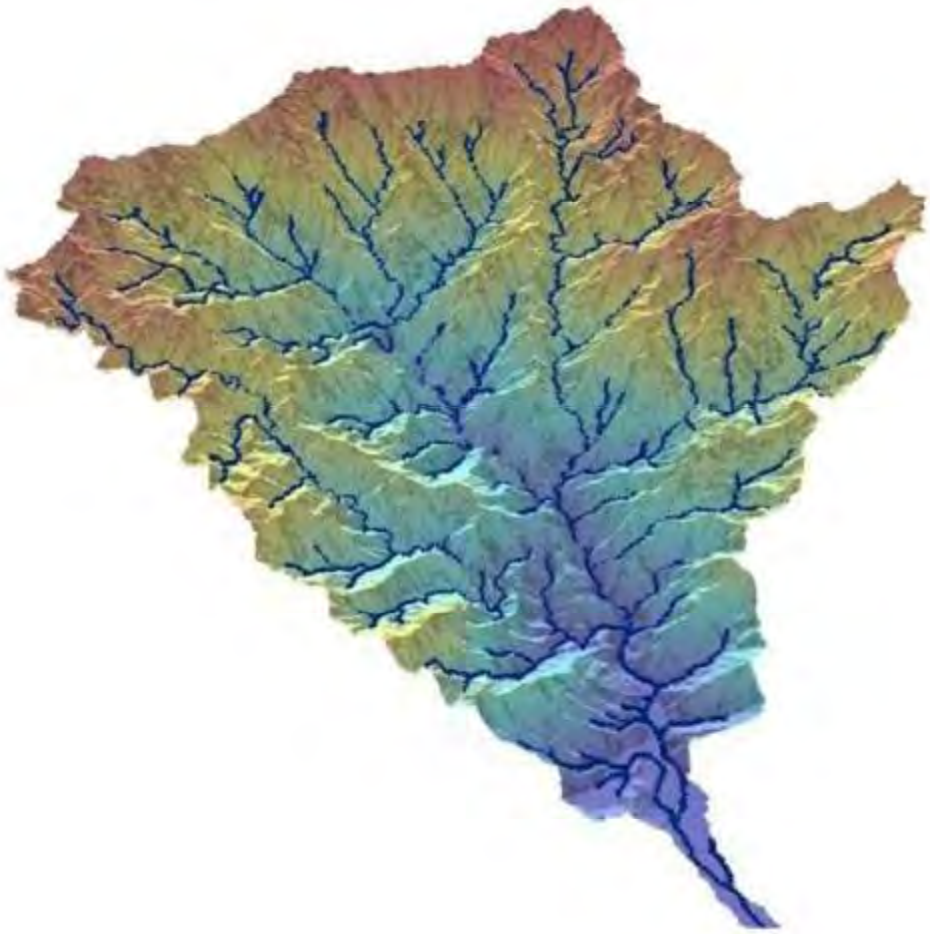


- Land Planner
  - Activities and processes linked through economics and human actions
    - Irrigation
    - Agriculture
    - Industry
    - Water Supply



- **Engineer**
  - Adjacent sets of isolated, independent processes and problems
    - Bank Erosion
    - Water Treatment
    - Flood Prevention
    - Navigability

- **Biologist**
  - Chemical, biological, and physical processes
  - Rivers and floodplains provide habitat for wildlife and vegetation
  - Biological communities respond to habitat gradients
  - Degrade habitat and you degrade aquatic populations



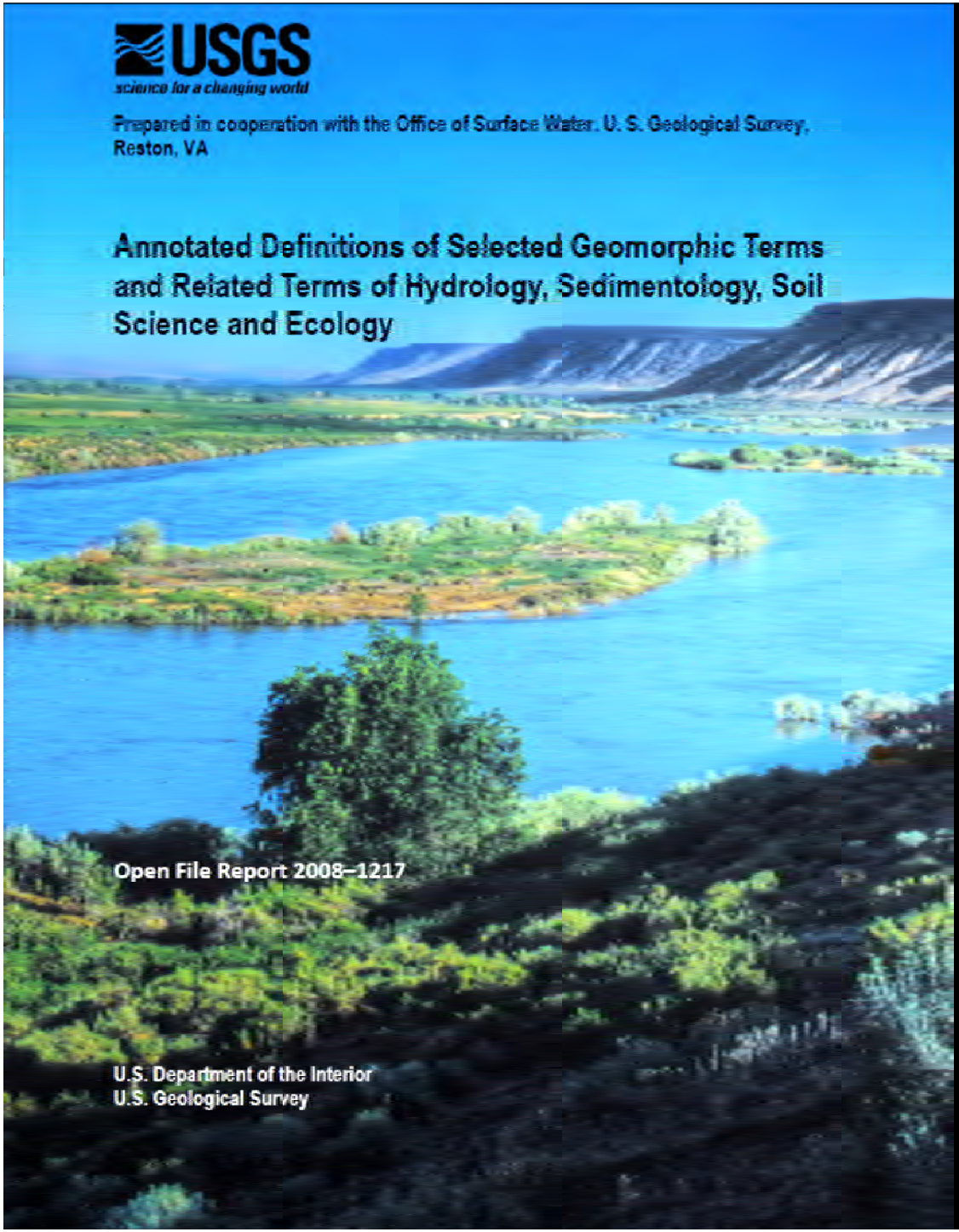
Graphic: D. Montgomery, UW

- Geomorphologist
  - Drainage basins are landscape systems that produce and transport runoff and watershed materials
  - Channels and floodplains respond to transport, storage, and routing processes
  - Every river has a history

Common Goals

- Reduce erosion and conserve soil
- Improve water quality/quantity
- Increase and enhance wildlife habitat
- Preserve streambank function
- Create functional stream corridors

Common Terms



- **Resource**

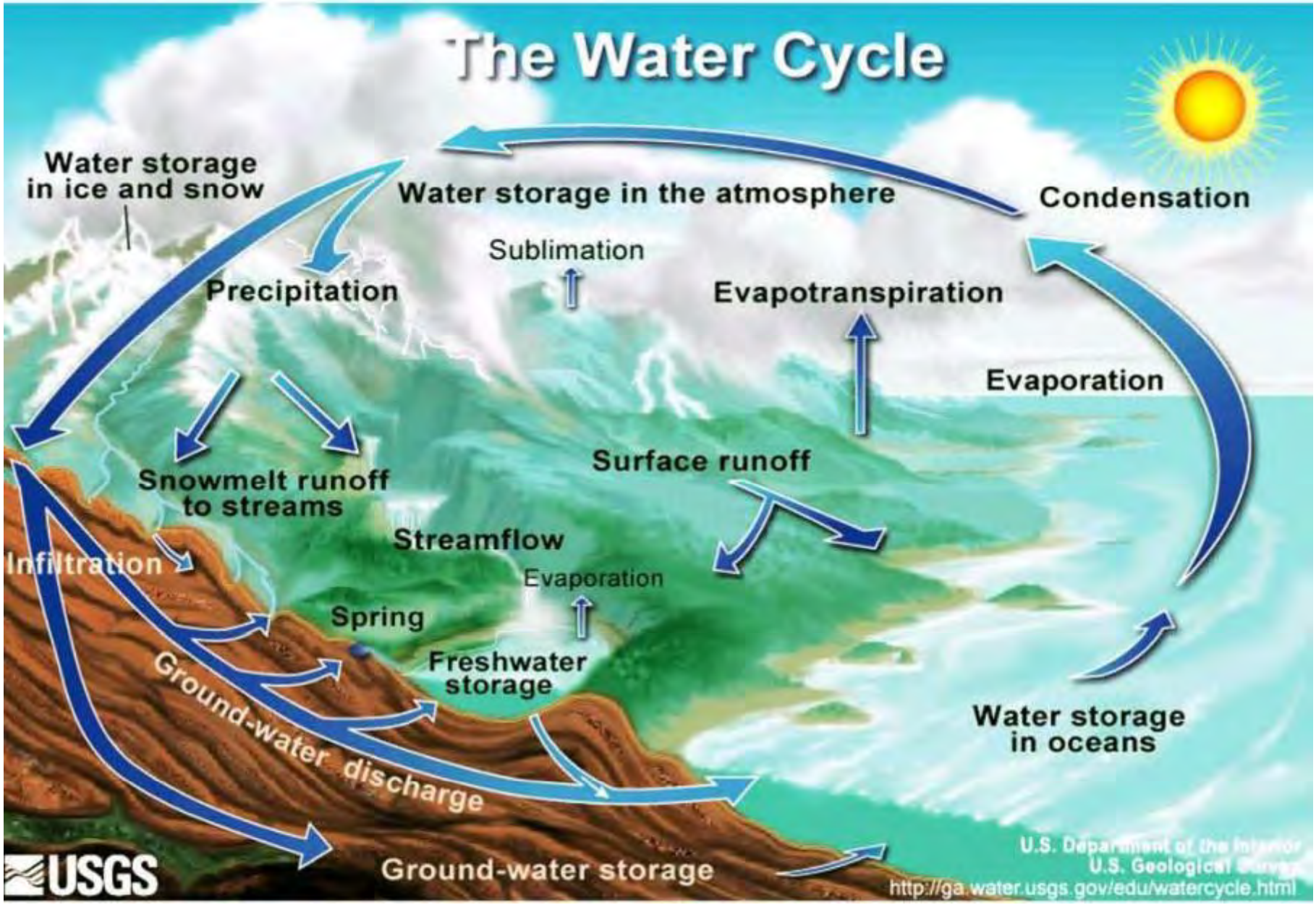
– Download for this Webinar will include a list of resources—with links—for later use.

– If links are broken, contact me and I'll send you a digital or printed copy!

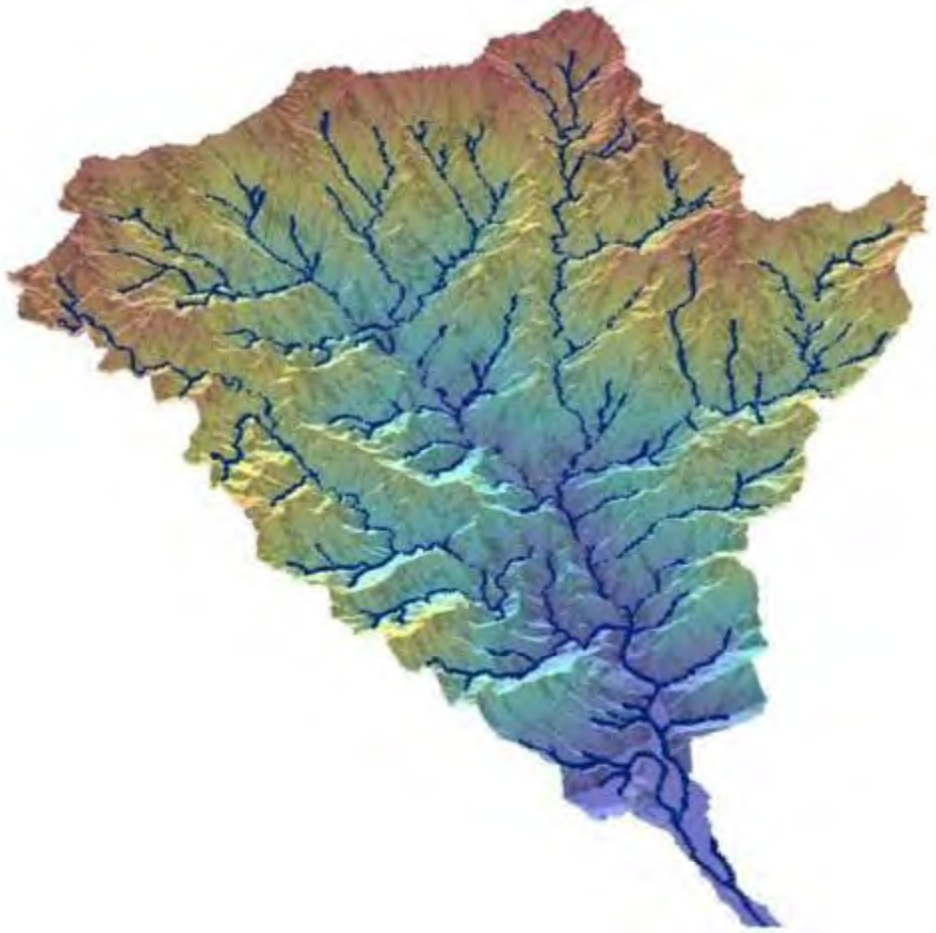
Definition

- Hydrology: Earth science concerned with the origin, circulation, distribution, and properties of water.
- Key elements:
  - measurement of fluxes of water (as streamflow, ground-water discharge, etc.)
  - manners by which the fluxes affect the landscape (erosion, plant growth, etc.).

The Hydrologic Cycle



Drainage Basins

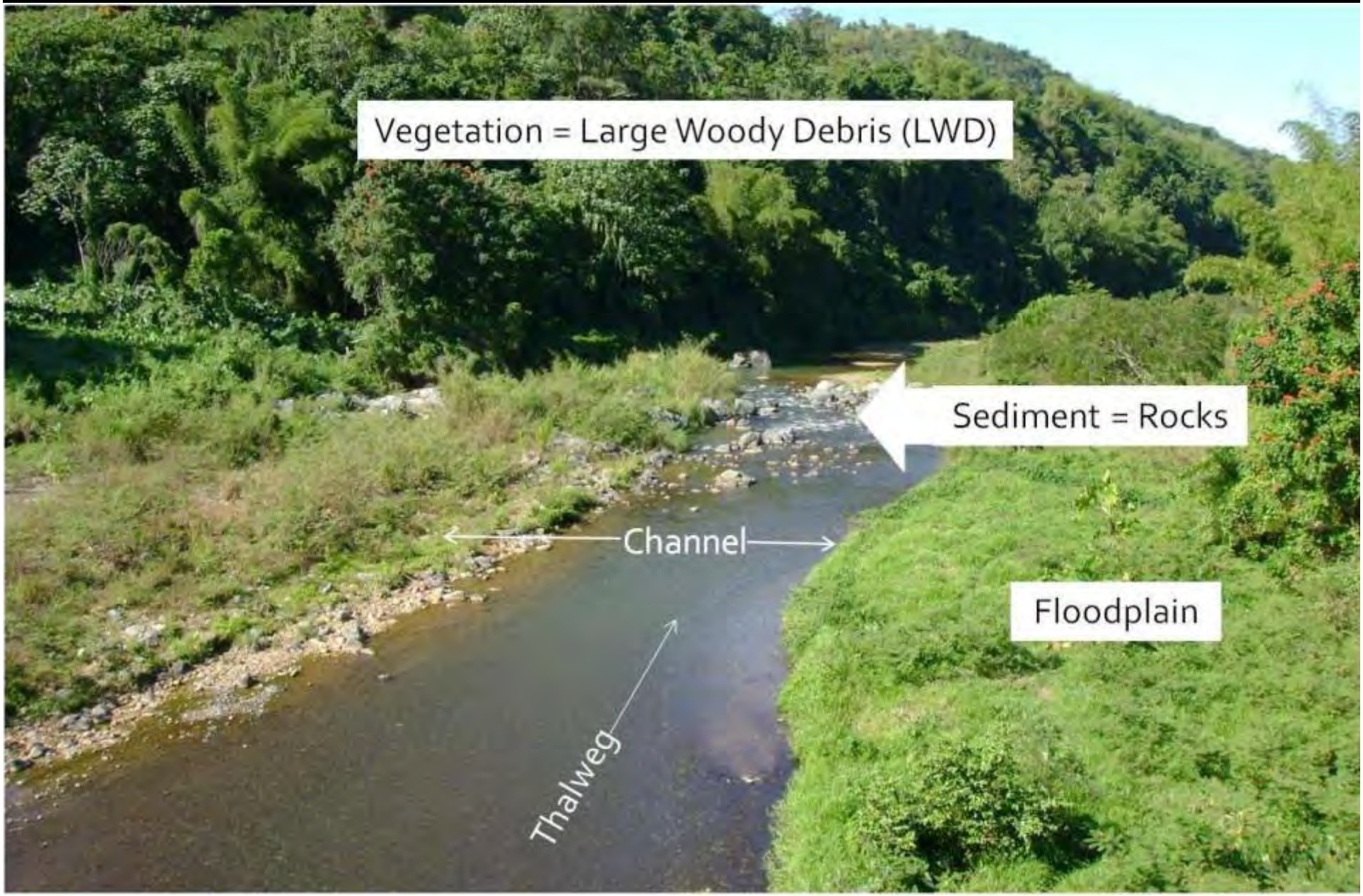


Graphic: D. Montgomery, UW

Material moves downhill under the influence of gravity

River Systems

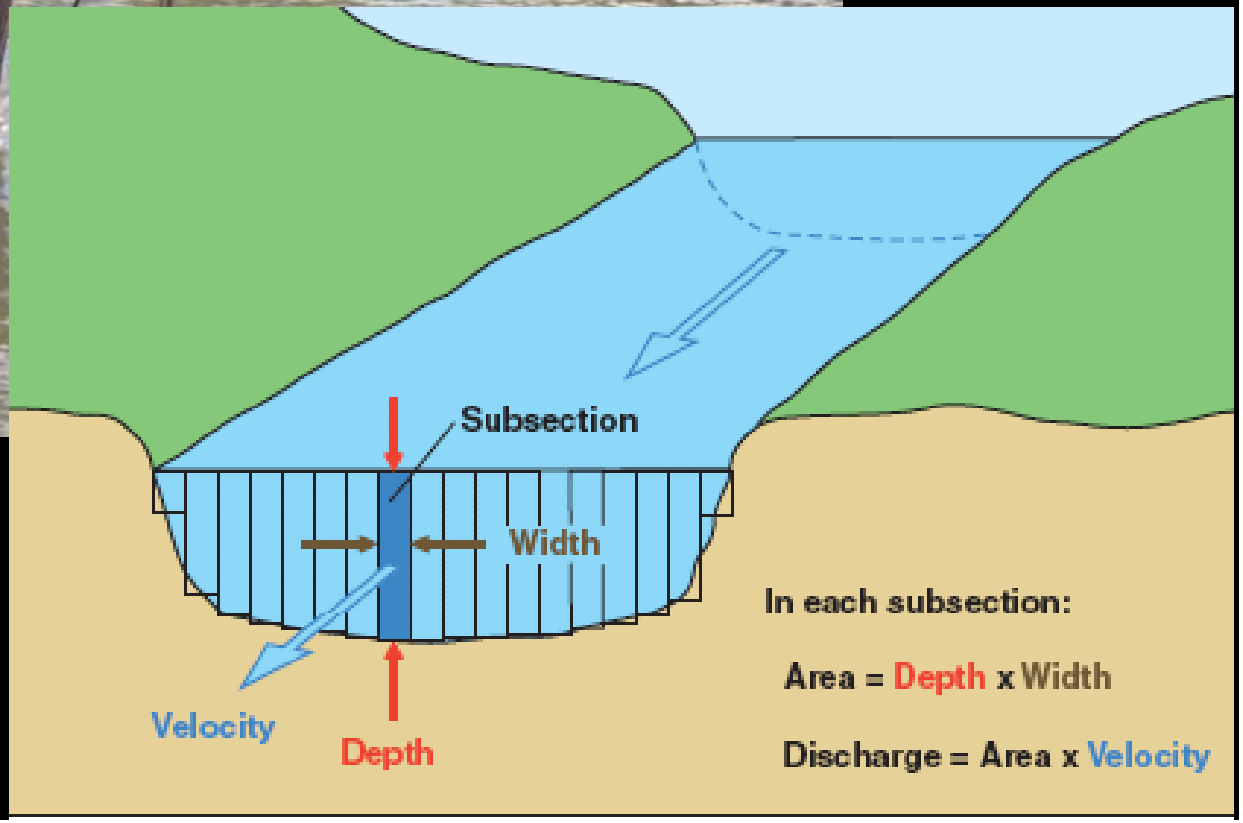
Basic River Anatomy



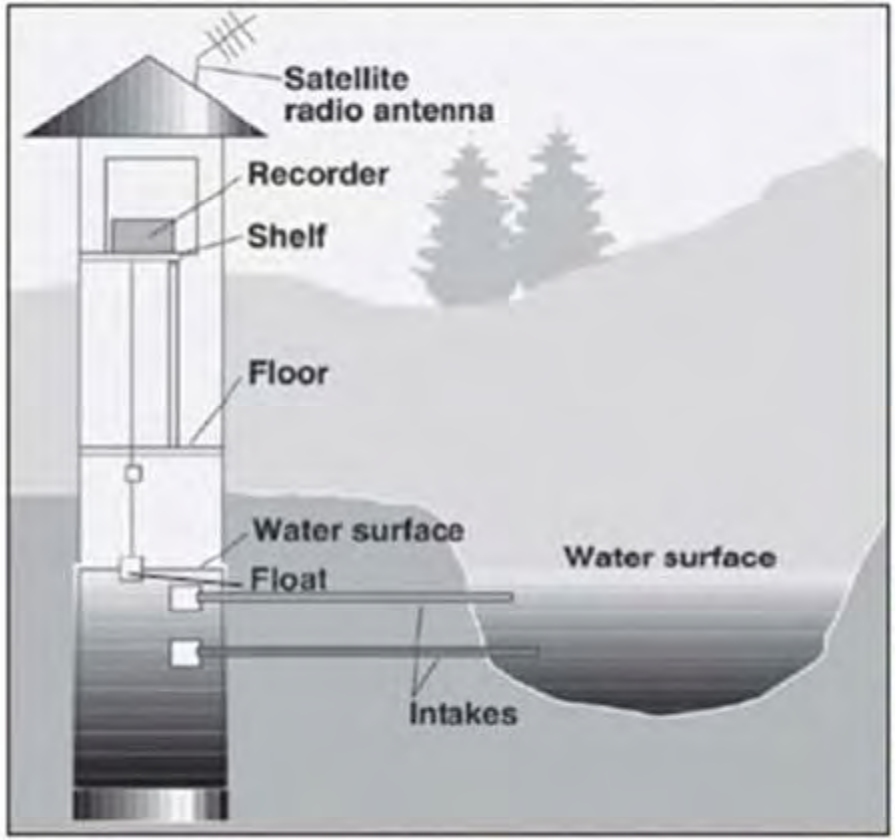
Measuring Streamflow

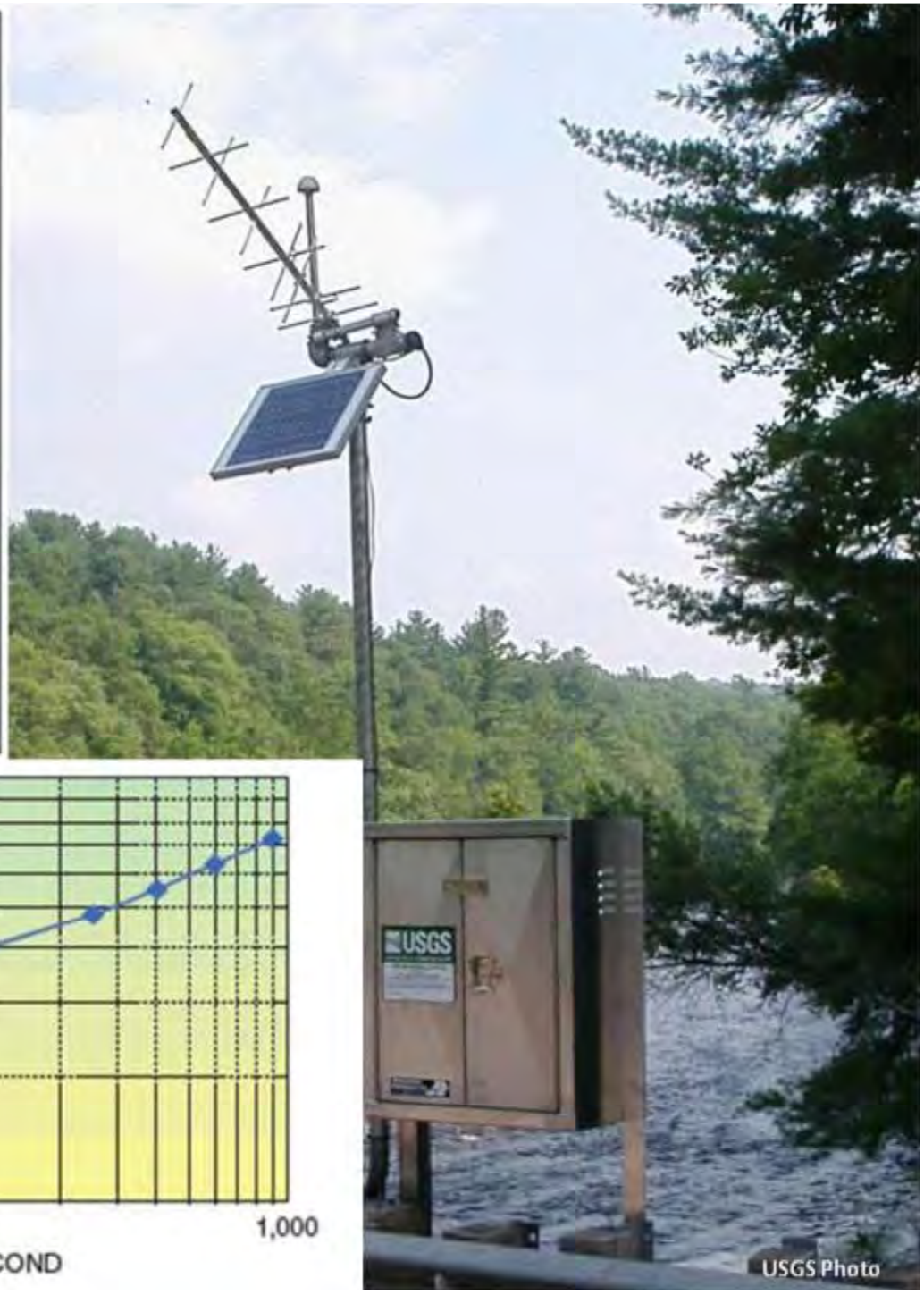
Measuring Streamflow

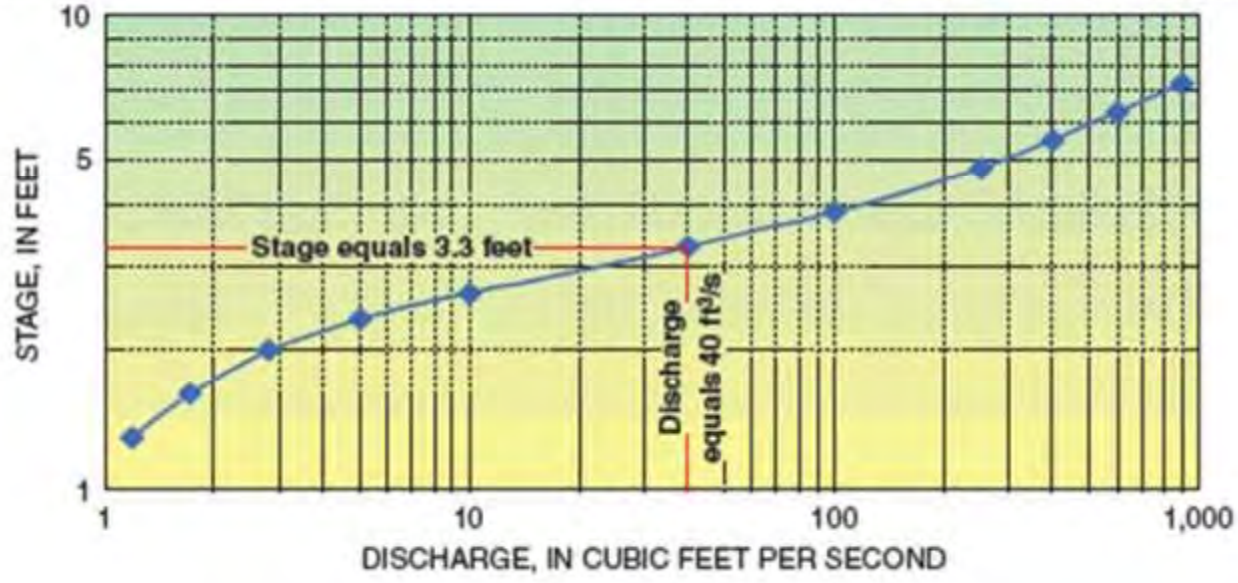
Unit = Cubic feet or meters per second (cfs or cms)



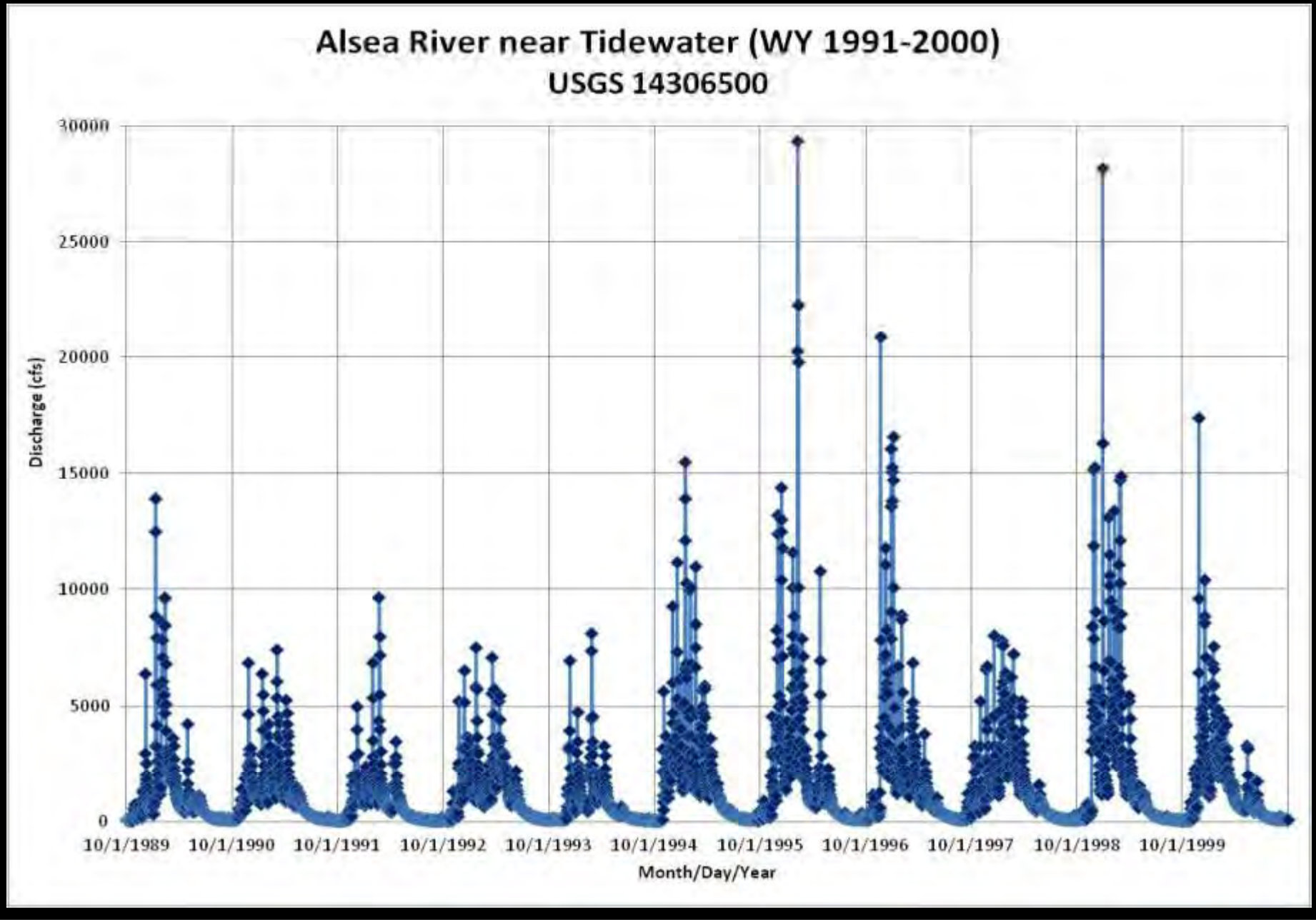
Measuring Streamflow


Satellite
radio antenna
Recorder
Shelf
Floor
Water surface
Float
Water surface
Intakes

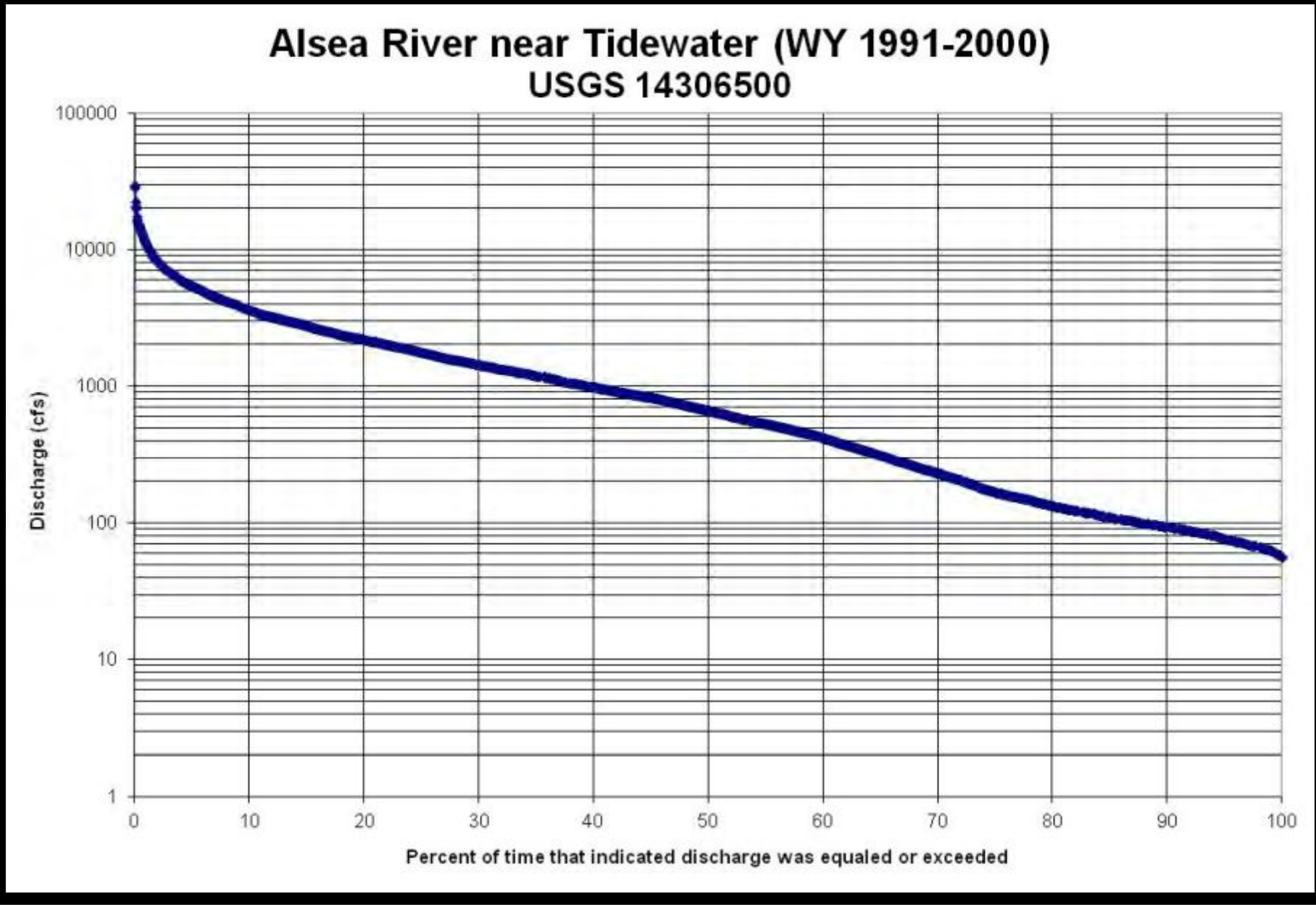

USGS
USGS Photo


10
5
1
STAGE, IN FEET
Stage equals 3.3 feet
Discharge equals 40 ft³/s
1
10
100
1,000
DISCHARGE, IN CUBIC FEET PER SECOND

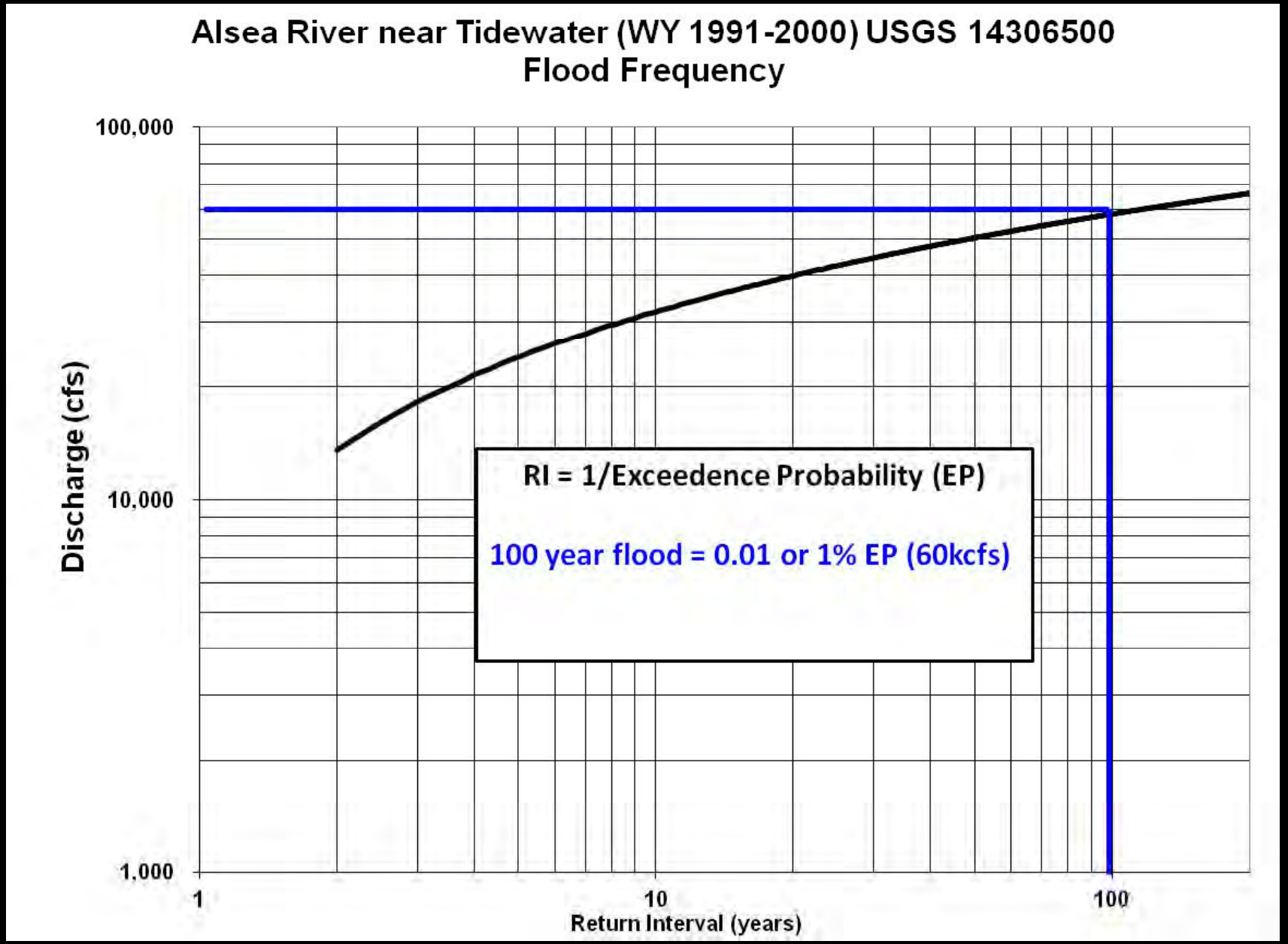
Hydrograph


Alsea River near Tidewater (WY 1991-2000)
USGS 14306500
Discharge (cfs)
30000
25000
20000
15000
10000
5000
0
10/1/1989
10/1/1990
10/1/1991
10/1/1992
10/1/1993
10/1/1994
10/1/1995
10/1/1996
10/1/1997
10/1/1998
10/1/1999
Month/Day/Year

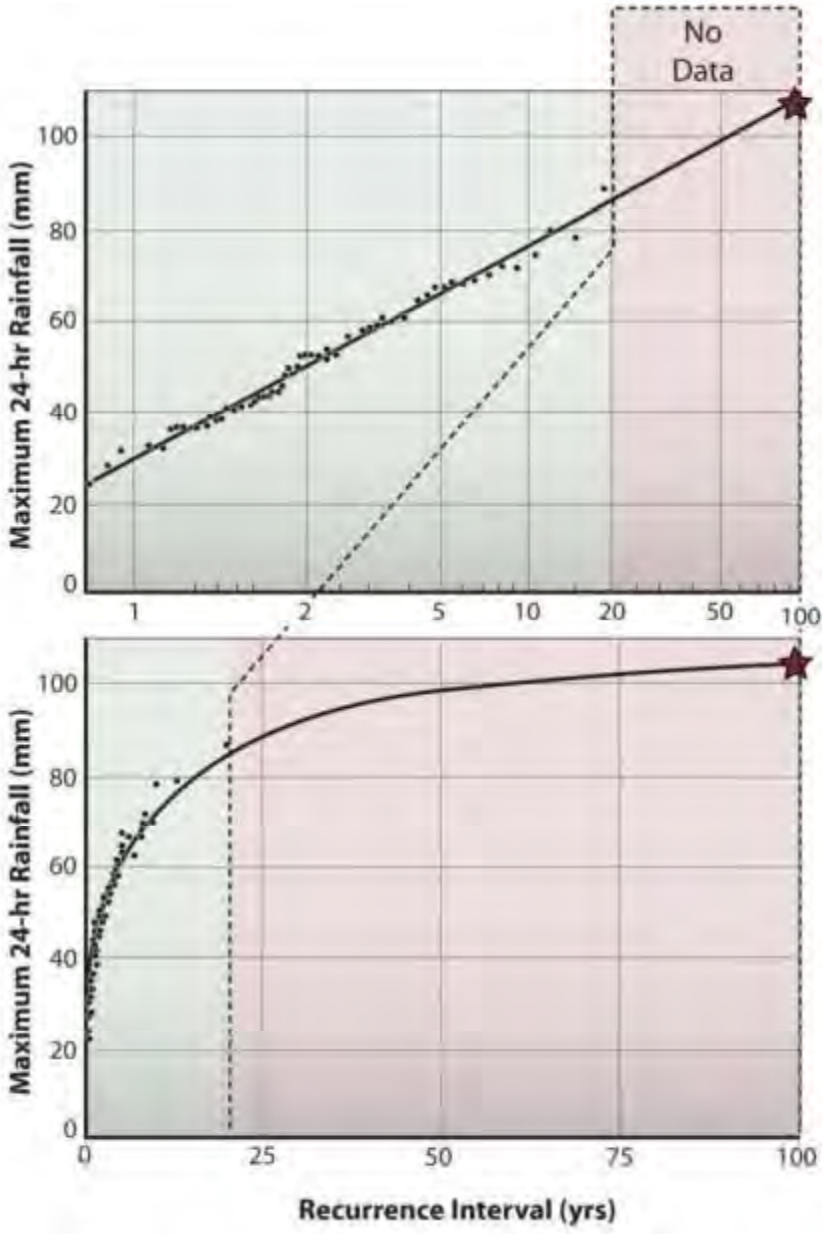
Flow Duration Curve



Flow Recurrence Intervals



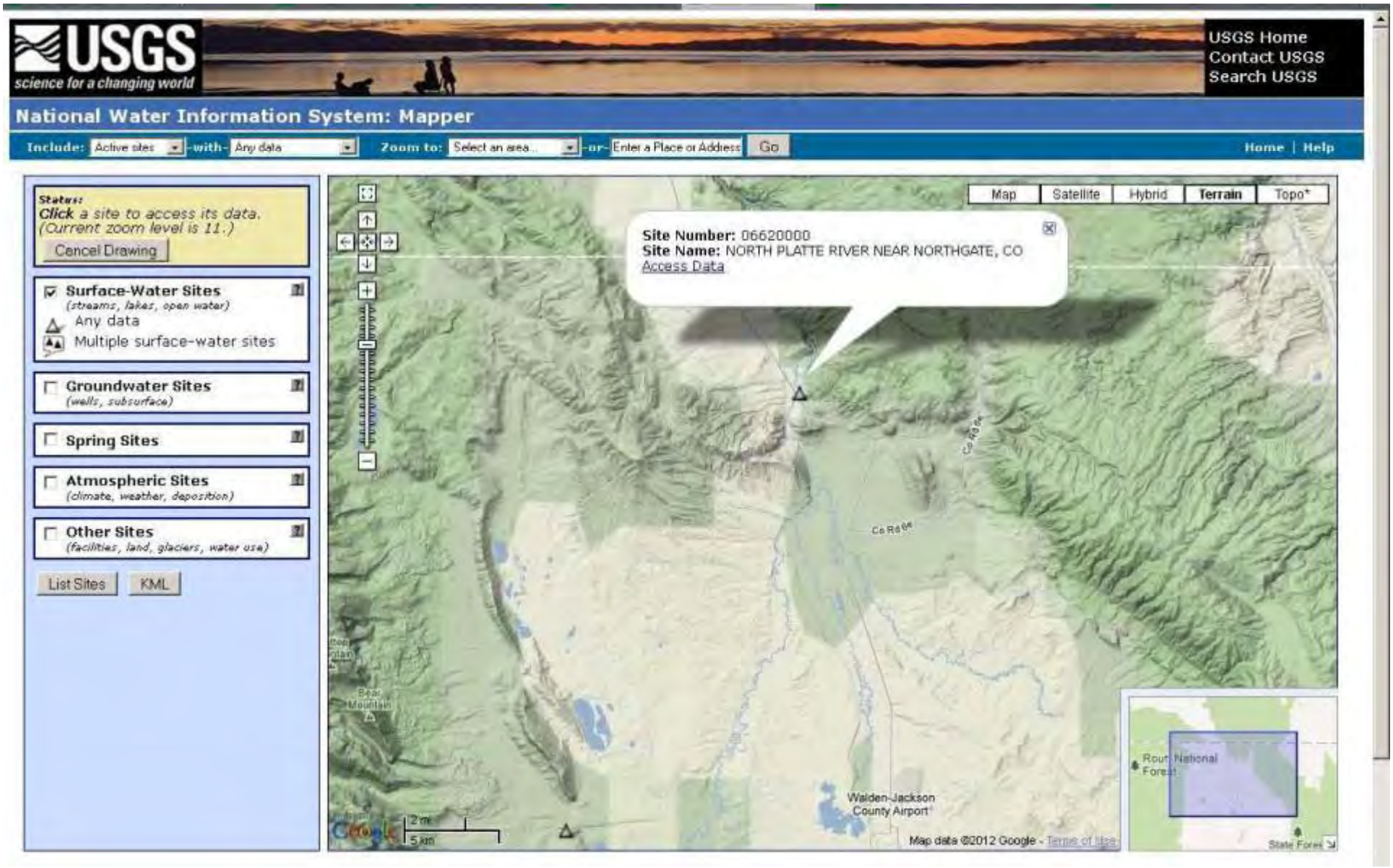
Probability and Prediction



- **Plotting on probability or log axes helps data to fit a straight line. Infers predictive ability.**
- **Same data on a linear plot shows how much extrapolation is needed to infer same 100-yr event.**
- **30-year mortgage in 100-year FEMA floodplain—26% chance of being flooded**

USGS National Water Information System

USGS National Water Information System



USGS National Water Information System

USGS 06620000 NORTH PLATTE RIVER NEAR NORTHGATE, CO

PROVISIONAL DATA SUBJECT TO REVISION

Available data for this site | Time-series: Current/Historical Observations | GO

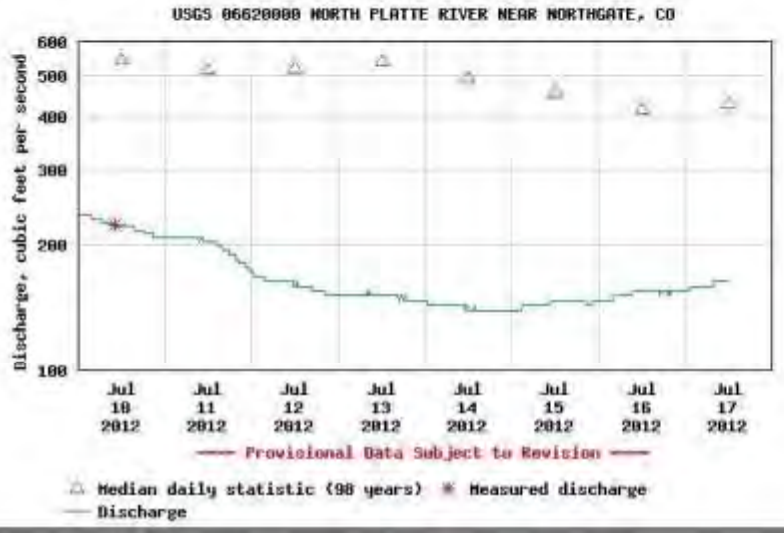
Flood Tracking Charts | Stage | Discharge |
Station operated by the USGS Wyoming Water Science Center Cheyenne Office as part of the National Streamflow Information Program. *Direct all inquiries regarding this station to Wyoming NWISWeb Data Inquiries.*
NEW Gage-height | corrections | Ratings available: | base | shift-adjusted | (About shift-adjusted ratings.)
National Weather Service forecast information for this station may be available here.
USCG boating safety tips -> Leaving USGS
This station managed by the Cheyenne Field Office.

Available Parameters	Available Period
☐ All 3 Available Parameters for this site	
☑ 00060 Discharge	2007-10-01 2012-07-17
☑ 70969 DCP battery voltage	2012-04-15 2012-07-17
☑ 00065 Gage height	2012-03-19 2012-07-17

Output format: ◉ Graph | ○ Graph w/ stats | ○ Graph w/o stats | ○ Table | ○ Tab-separated
Begin date: 2012-07-10
End date: 2012-07-17
GO

Summary of all available data for this site
Instantaneous-data availability statement

Discharge, cubic feet per second
Most recent instantaneous value: 163 07-17-2012 11:45 MDT



USGS National Water Information System

Discharge, cubic feet per second

Most recent instantaneous value: 163 07-17-2012 11:45 MDT

USGS StreamStats

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Welcome to StreamStats

Best viewed in Internet Explorer 5 or above
Screen resolution of 1152x864 or greater, with pop-up blocker disabled

- Home
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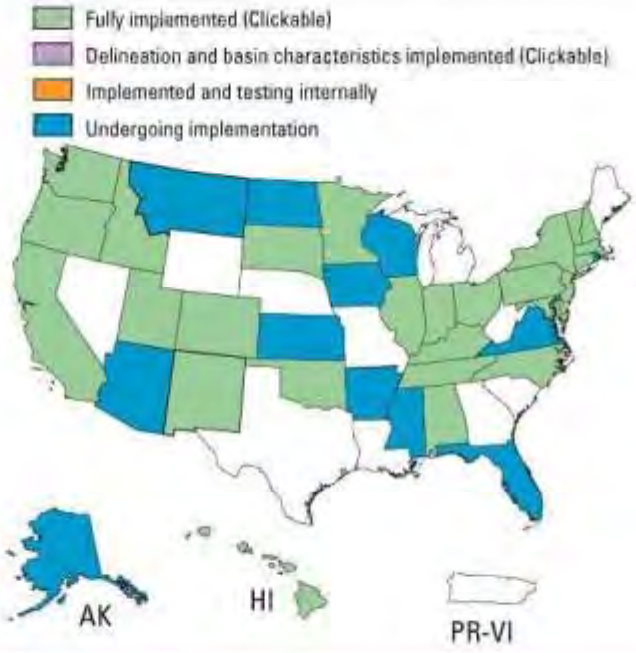
  - Data-Collection Stations
- StreamStats Limitations
- State Applications
- USGS Station Statistics
- User Instructions
- Definitions
  - Basin Characteristics
  - Streamflow Statistics
- StreamStats Fact Sheet
- Frequently Asked Questions
- Available Web Services
- Talks and Other Info
- Internal Links
- Contact StreamStats Team
- Current Streamflow Conditions

State Applications

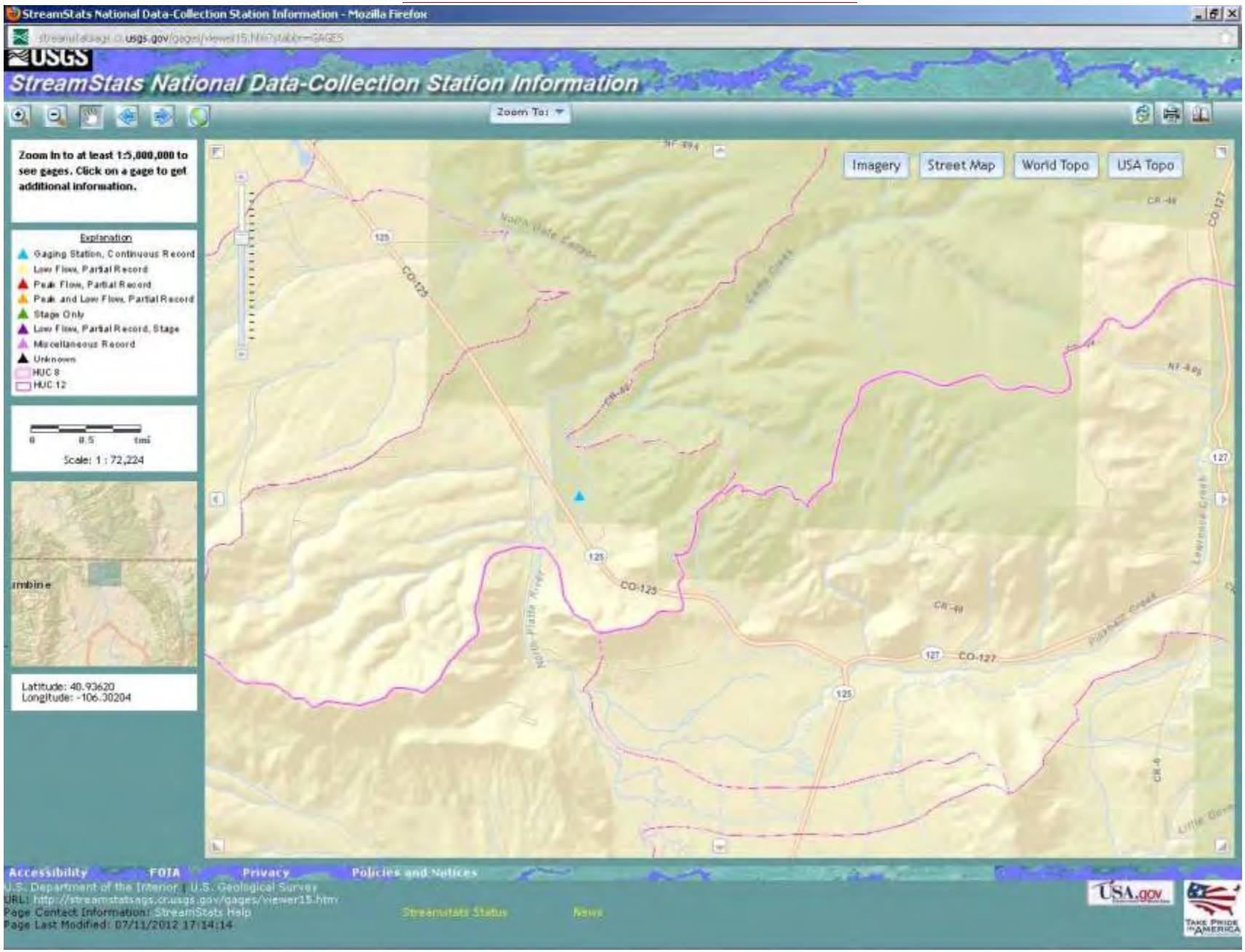
StreamStats Application Status

Choose a State

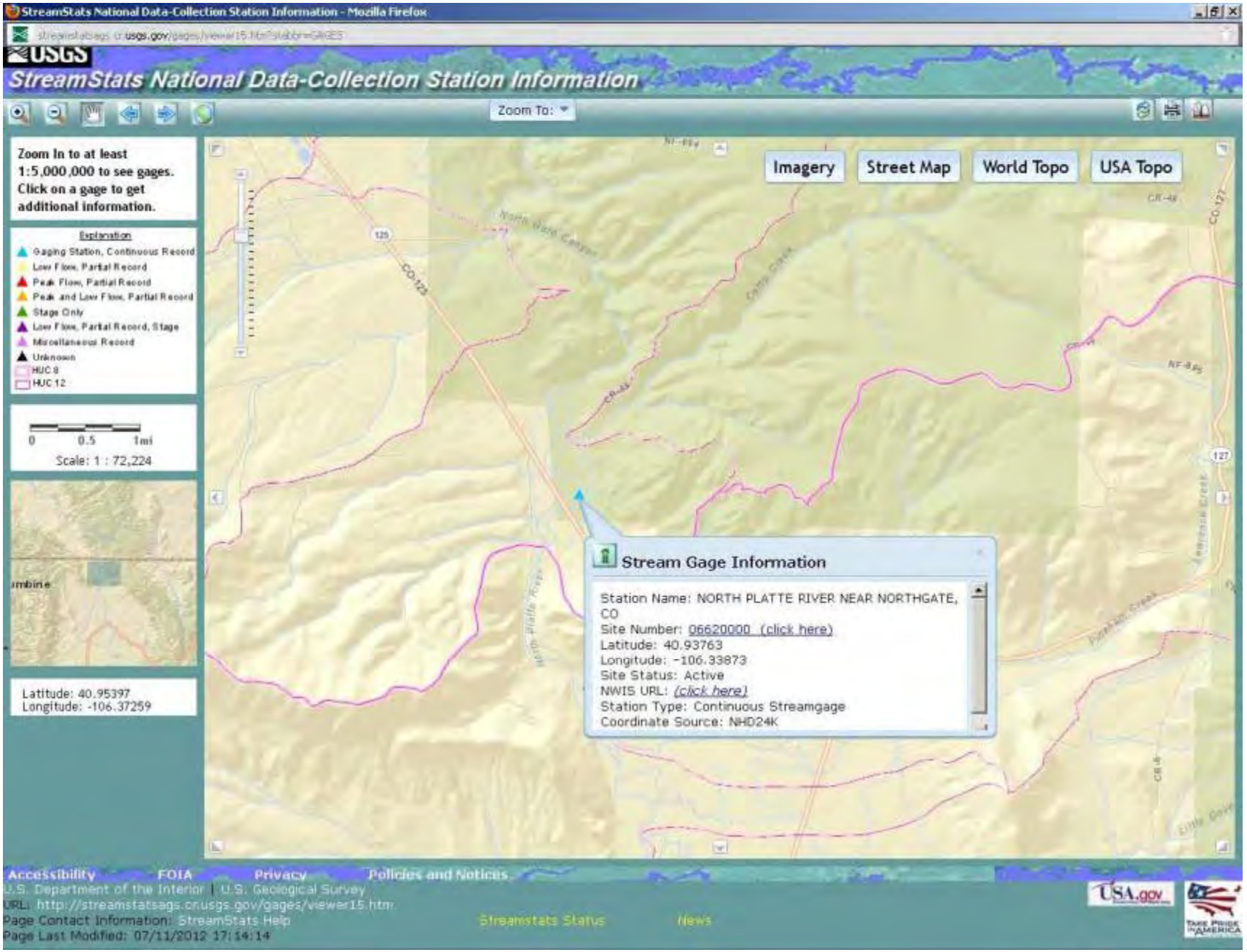
Efforts are underway to make StreamStats operational for many states, with a long-term goal of national coverage. Work needed to implement StreamStats is generally done by the USGS in cooperation with various state and local agencies. The map below indicates states where StreamStats has been implemented, and where work on implementation is currently underway. Green states have fully implemented StreamStats applications, orange states have been completed and are in testing internally, and blue states are undergoing implementation. Users may access the implemented state applications by selecting the state of interest on the map below, or by selecting the name of the state from the list above.



USGS StreamStats



USGS StreamStats



USGS StreamStats

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StreamStats Data Collection Station Report

USGS Station Number 06620000
Station Name NORTH PLATTE RIVER NEAR NORTHGATE, CO

Click here to link to available data on NWIS-Web for this site

Descriptive Information

Station Type	Gaging Station, continuous record
Regulated?	Undefined
Period of Record	
Remarks	
Latitude (degrees NAD83)	40.93747
Longitude (degrees NAD83)	-106.3384
Hydrologic unit code	10180001
Local Basin	-
County	-
MCD	-
Directions to station	

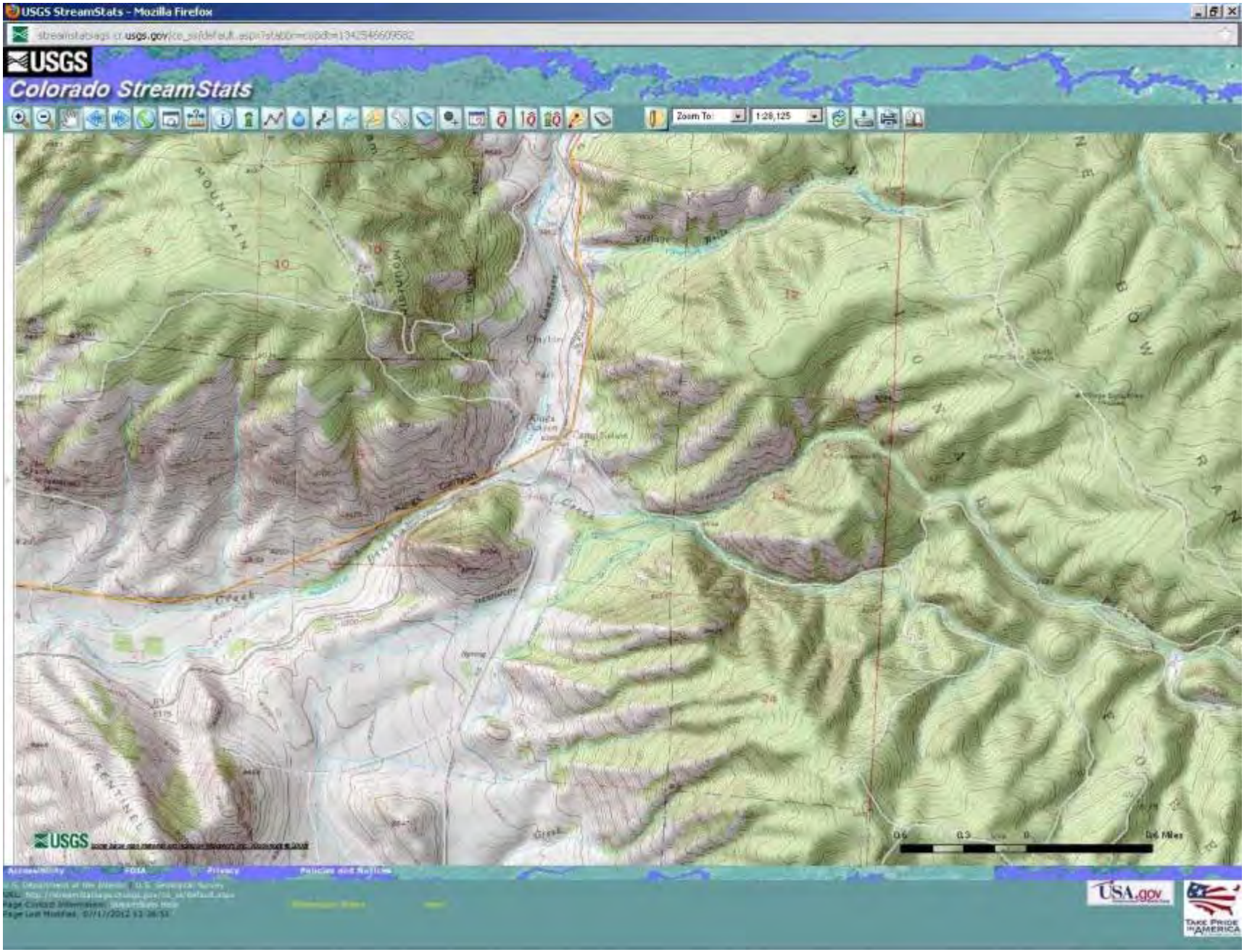
Physical Characteristics

Characteristic Name	Value	Units	Citation Number
Drainage_Area	1431	square miles	30
Latitude_of_Basin_Centroid	40.500	decimal degrees	31
Main_Channel_Length	91.000	miles	31
Mean_Basin_Elevation	8800.00	feet	31
Percent_Forest	40.000	percent	31
Percent_Lakes_and_Ponds	0.0000	percent	31
Percent_Storage	0.0000	percent	31
Stream_Slope_10_and_85_Method	7.0000	feet per mi	31

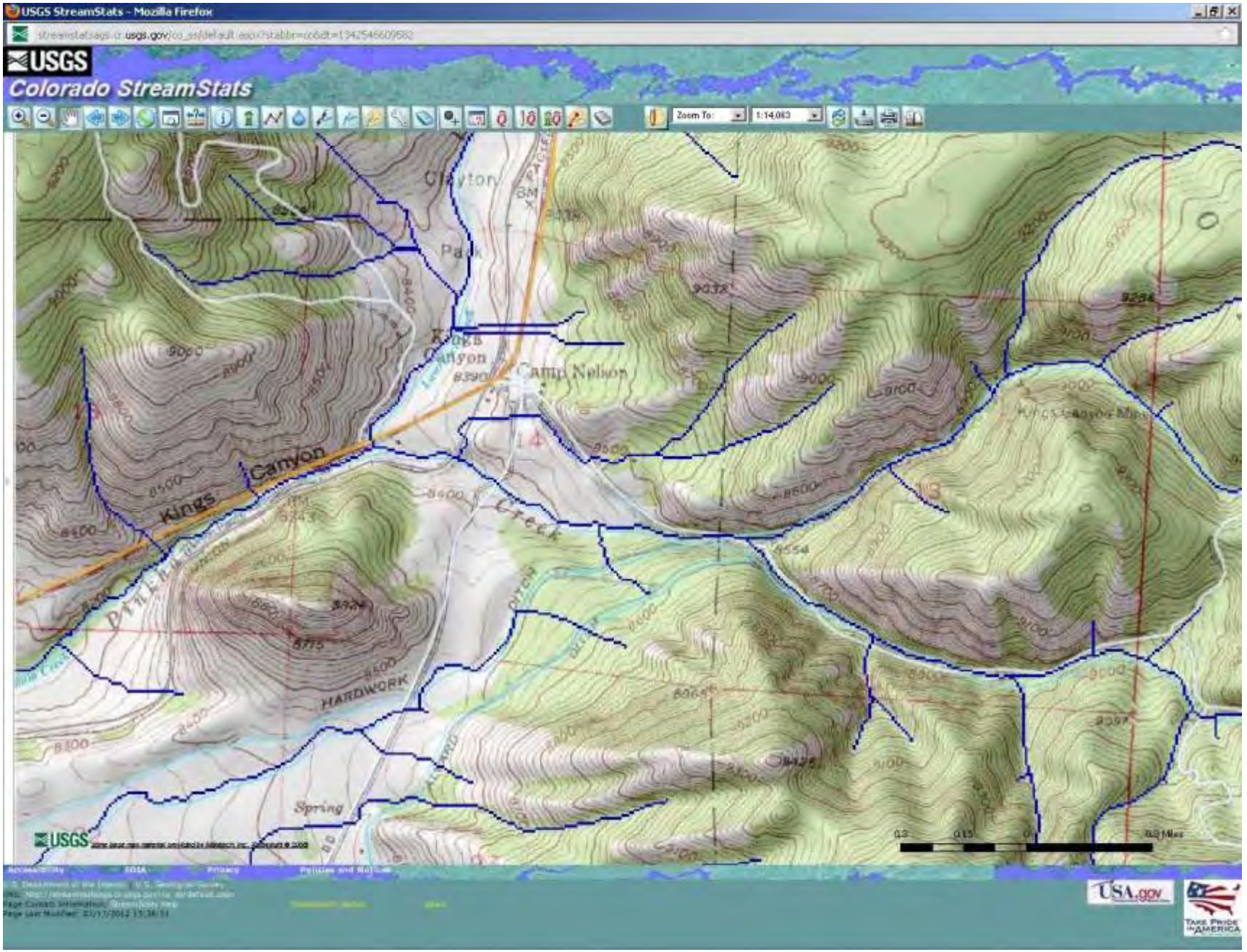
Streamflow Statistics

Statistic Name	Value	Units	Citation Number
Peak-Flow Statistics			
10_Year_Peak_Flood	5330.00	cubic feet per second	31
2_Year_Peak_Flood	3010.00	cubic feet per second	31
25_Year_Peak_Flood	6320.00	cubic feet per second	31
5_Year_Peak_Flood	4460.00	cubic feet per second	31
50_Year_Peak_Flood	6980.00	cubic feet per second	31
Flood-Volume Statistics			
1_Day_2_Year_Maximum	2760.00	cubic feet per second	31
1_Day_50_Year_Maximum	6580.00	cubic feet per second	31
15_Day_2_Year_Maximum	1980.00	cubic feet per second	31
15_Day_50_Year_Maximum	4680.00	cubic feet per second	31
3_Day_2_Year_Maximum	2580.00	cubic feet per second	31

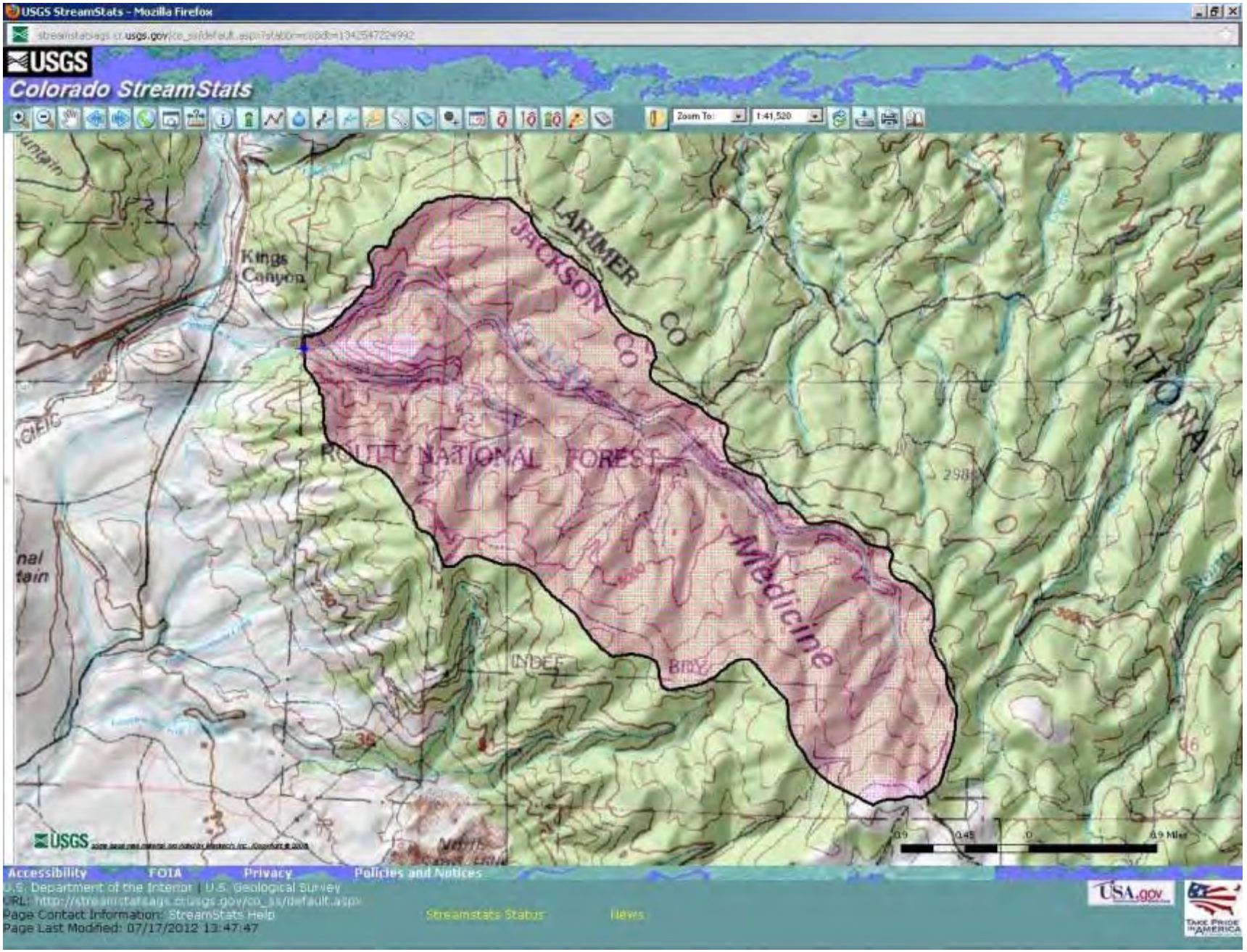
USGS StreamStats



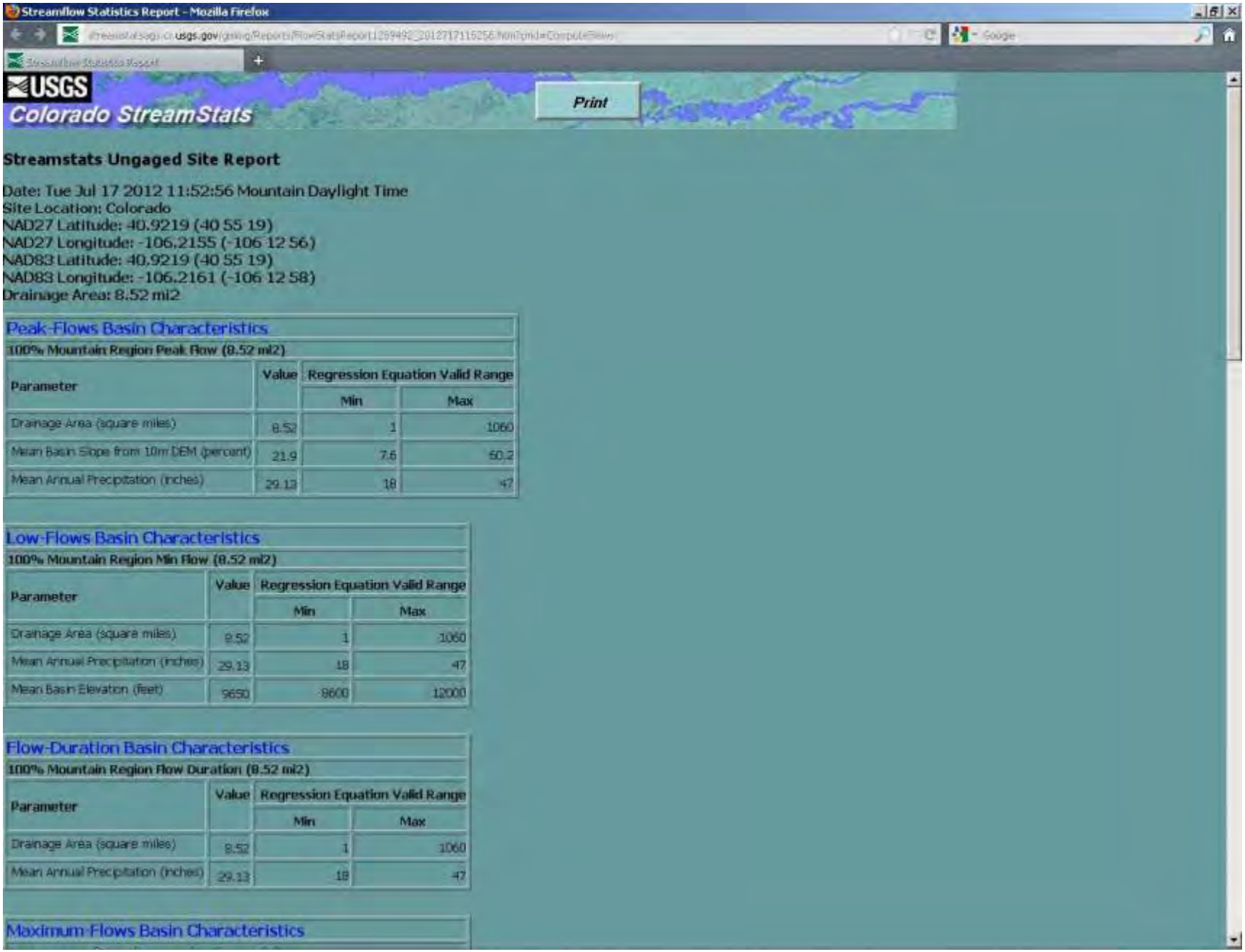
USGS StreamStats



USGS StreamStats

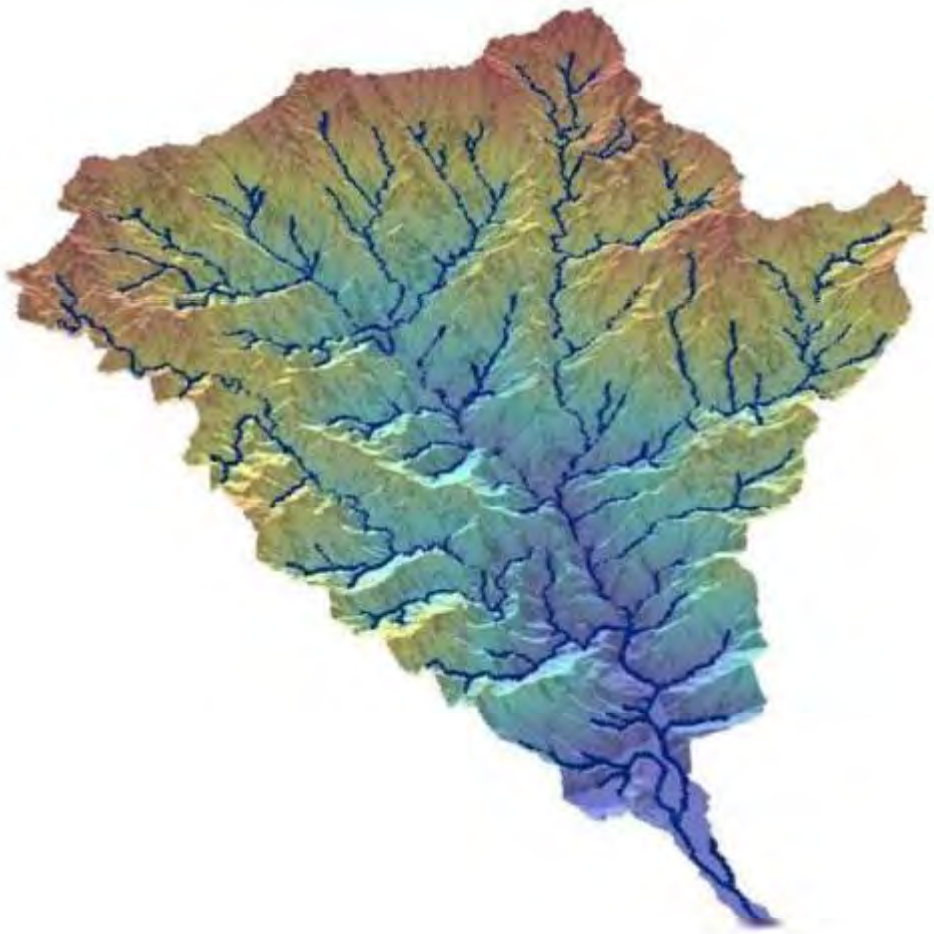


USGS StreamStats



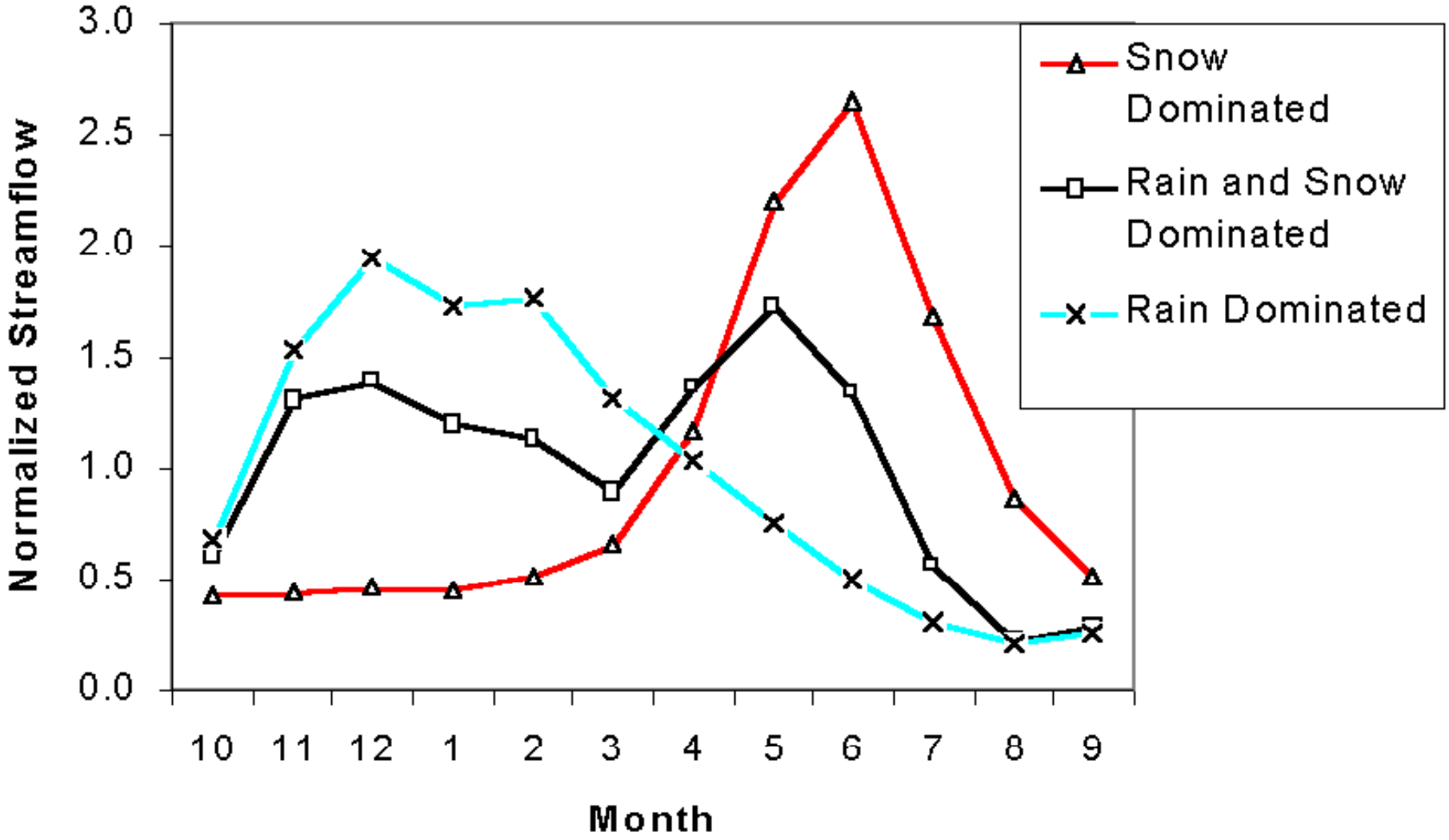
Drainage Basin Factors Affecting Runoff and Streamflow

- Precipitation amount and type
- Geology
- Soils
- Scale
- Slope
- Shape
- Aspect
- Land Cover

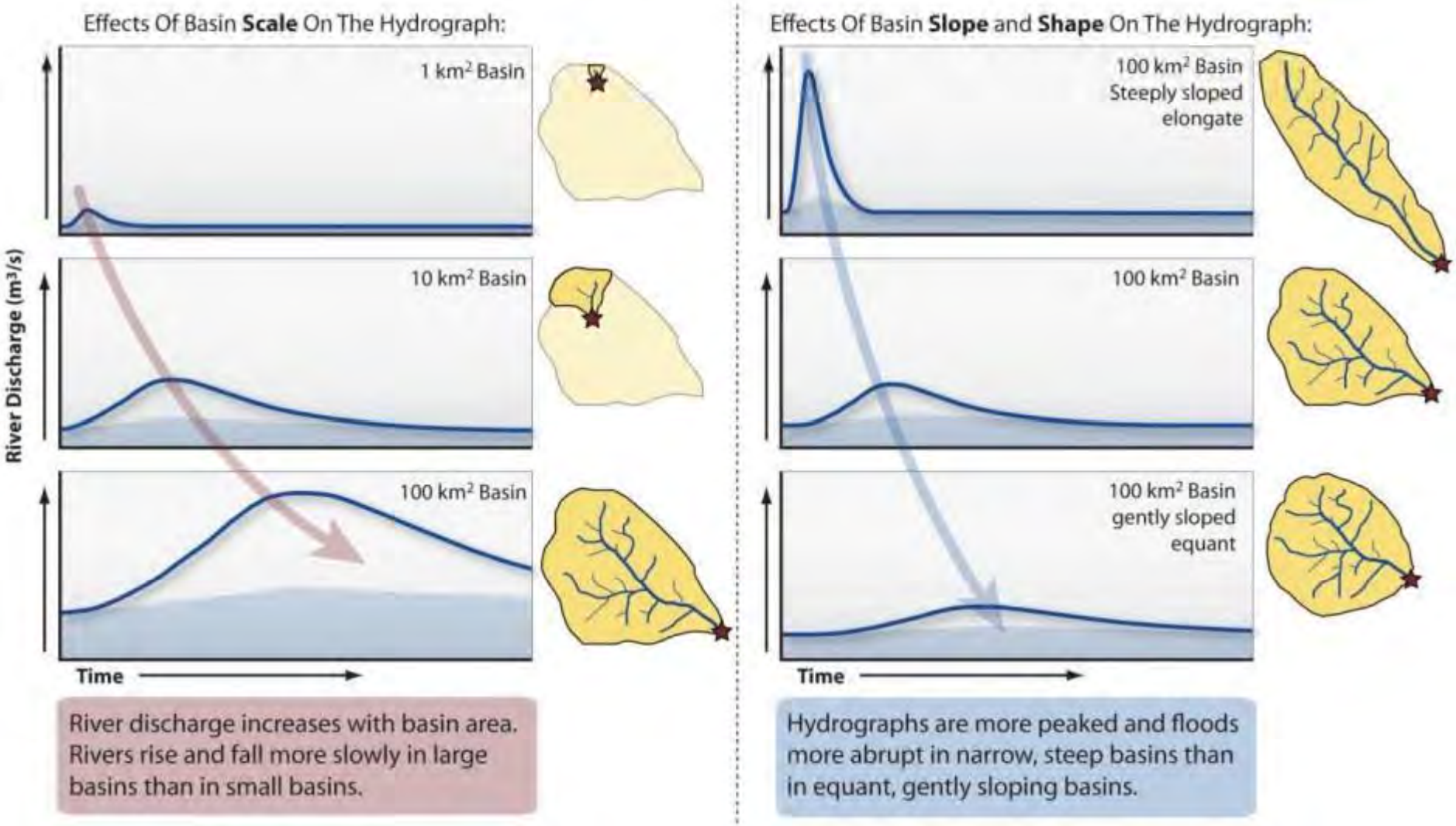


Graphic: D. Montgomery, UW

Precipitation Type Influences Streamflow

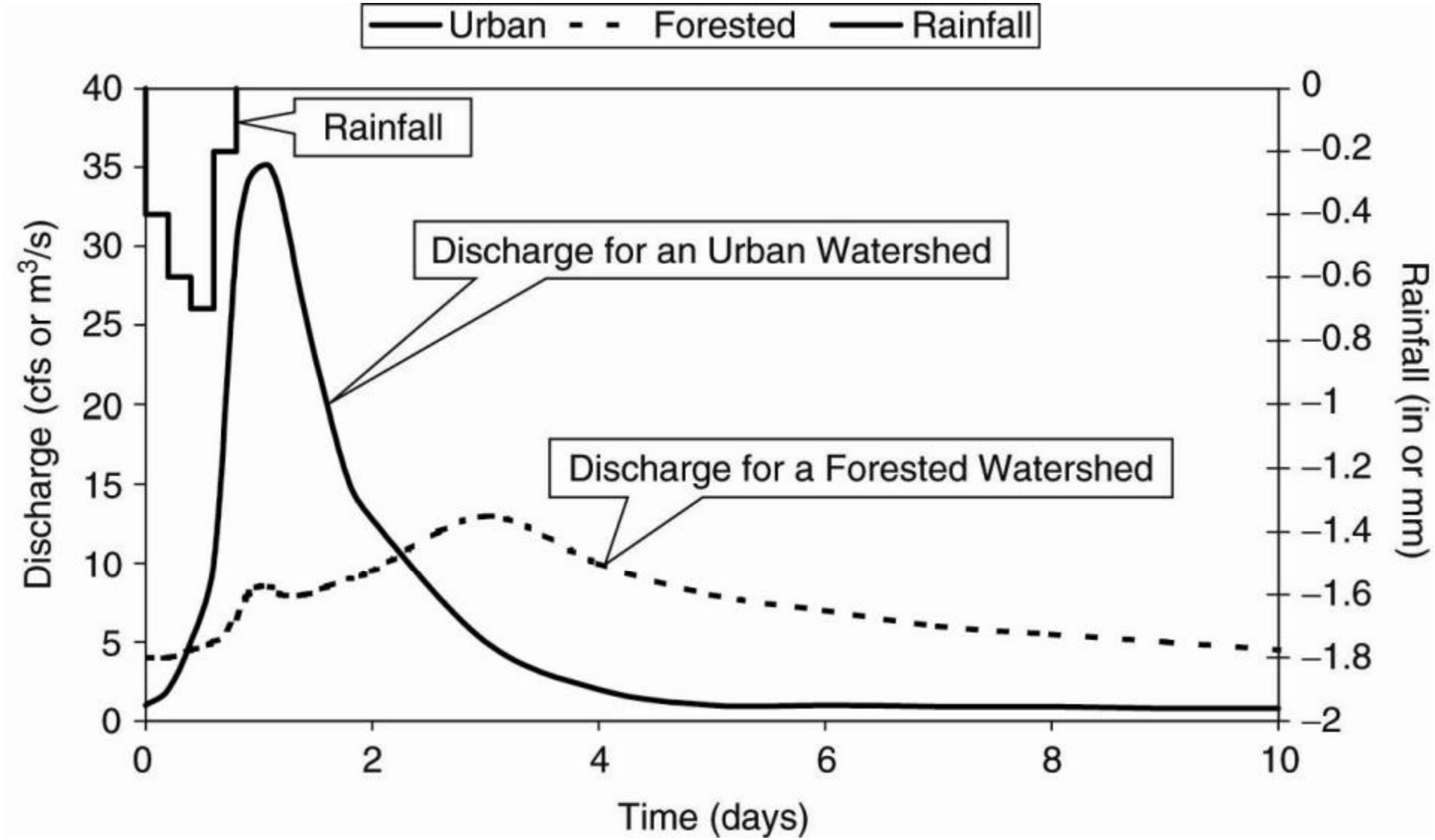


Basin Scale, Slope and Shape Influences Streamflow

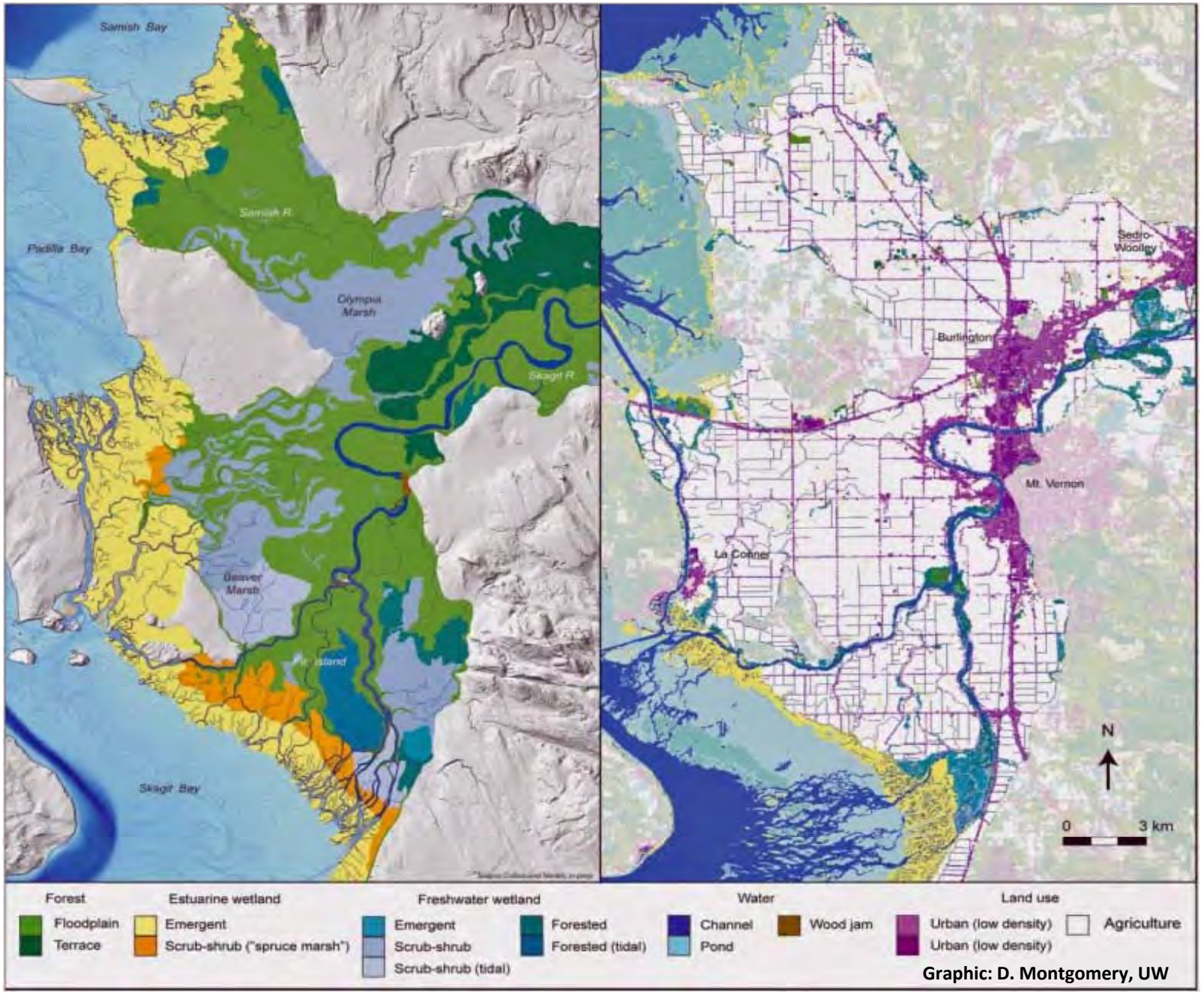


Graphic: D. Montgomery, UW

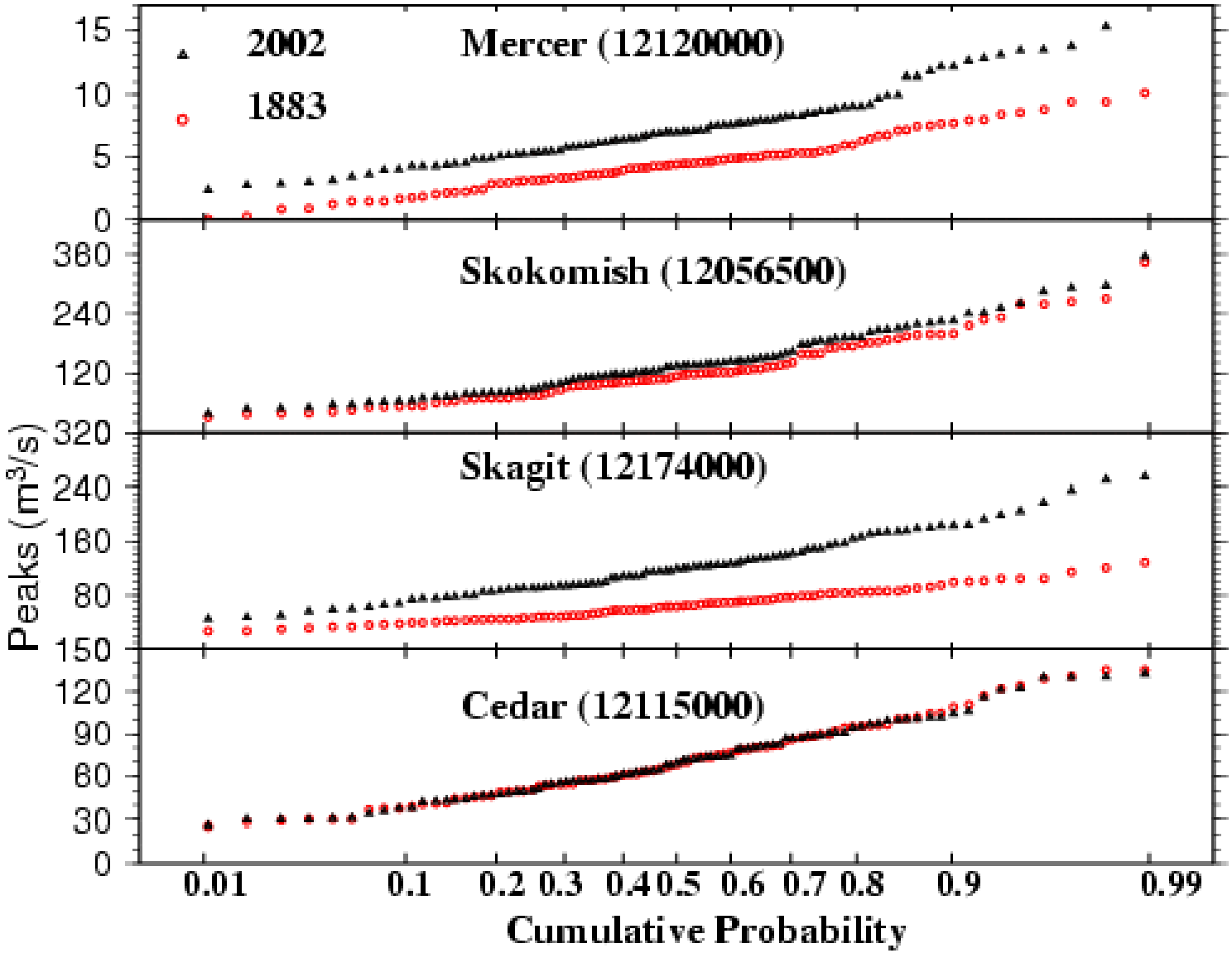
Land Cover Influences Streamflow



Land Cover Change—Skagit River, WA State



Land Cover Influences Streamflow



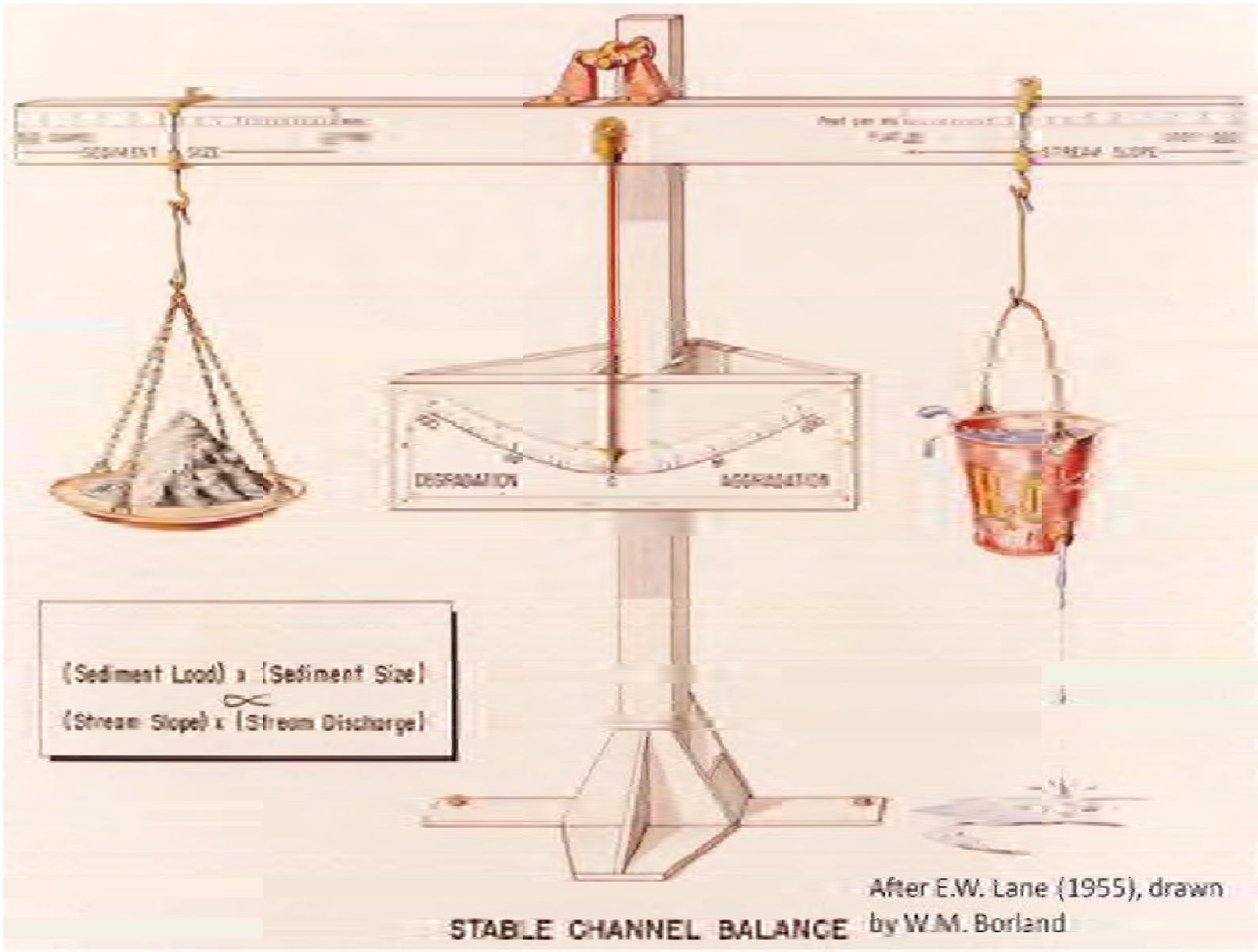
Graphic: Cuo et al. 2009

Definition

- **Fluvial Geomorphology: The study of landform changes driven by flowing water**
  - **Fluvial: of, found in, or produced by a river (from Latin *fluvius*)**
  - **Geomorphology: nature and origin of landforms**

Streamflow and Channel Form

(Fluvial) (Morphology)

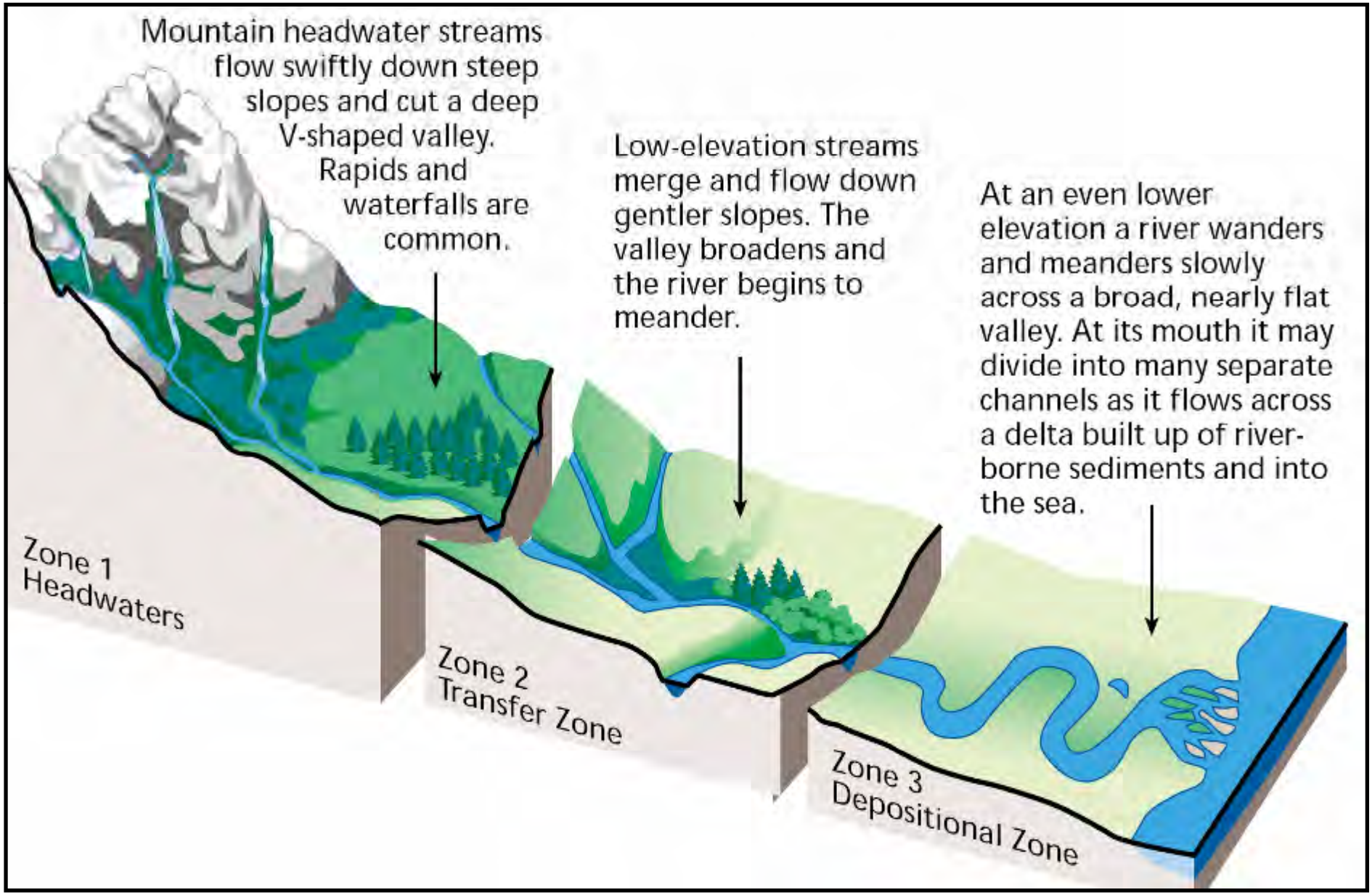


Governing Variables

- Climate, geology, topography, vegetation, and land use govern streamflow, large wood, and sediment balance.

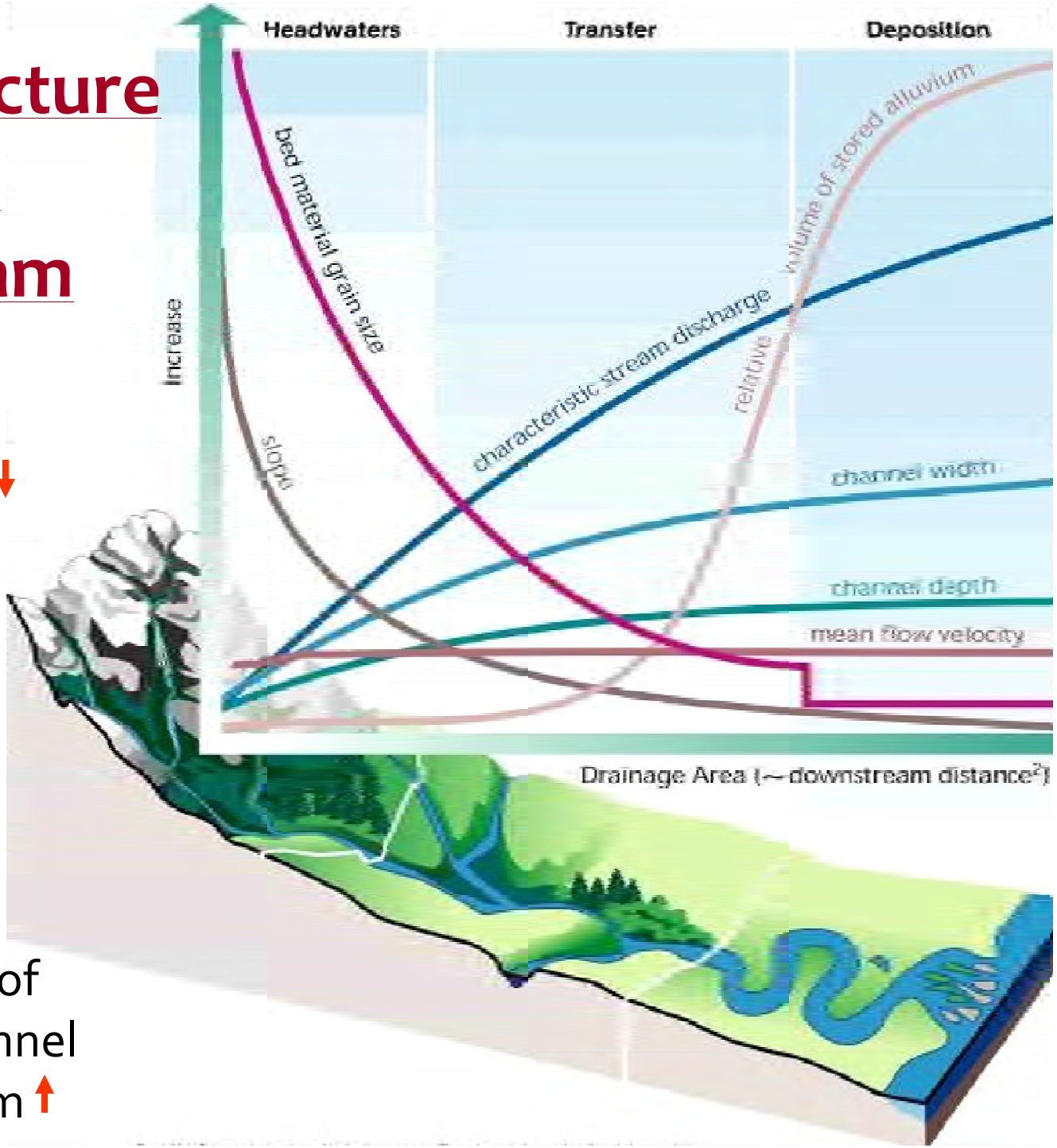
- River channel and floodplain morphology (width, slope, depth, pattern, etc.) adjusts to prevailing regime. Vegetation moderates adjustments.

River Systems and Processes



River Architecture Changes Downstream

- Slope ↓
- Bed material size ↓
- Streamflow ↑
- Channel width ↑
- Channel depth ↑
- Flow velocity ↑
- Material stored in floodplains ↑
- Relative influence of vegetation on channel and floodplain form ↑



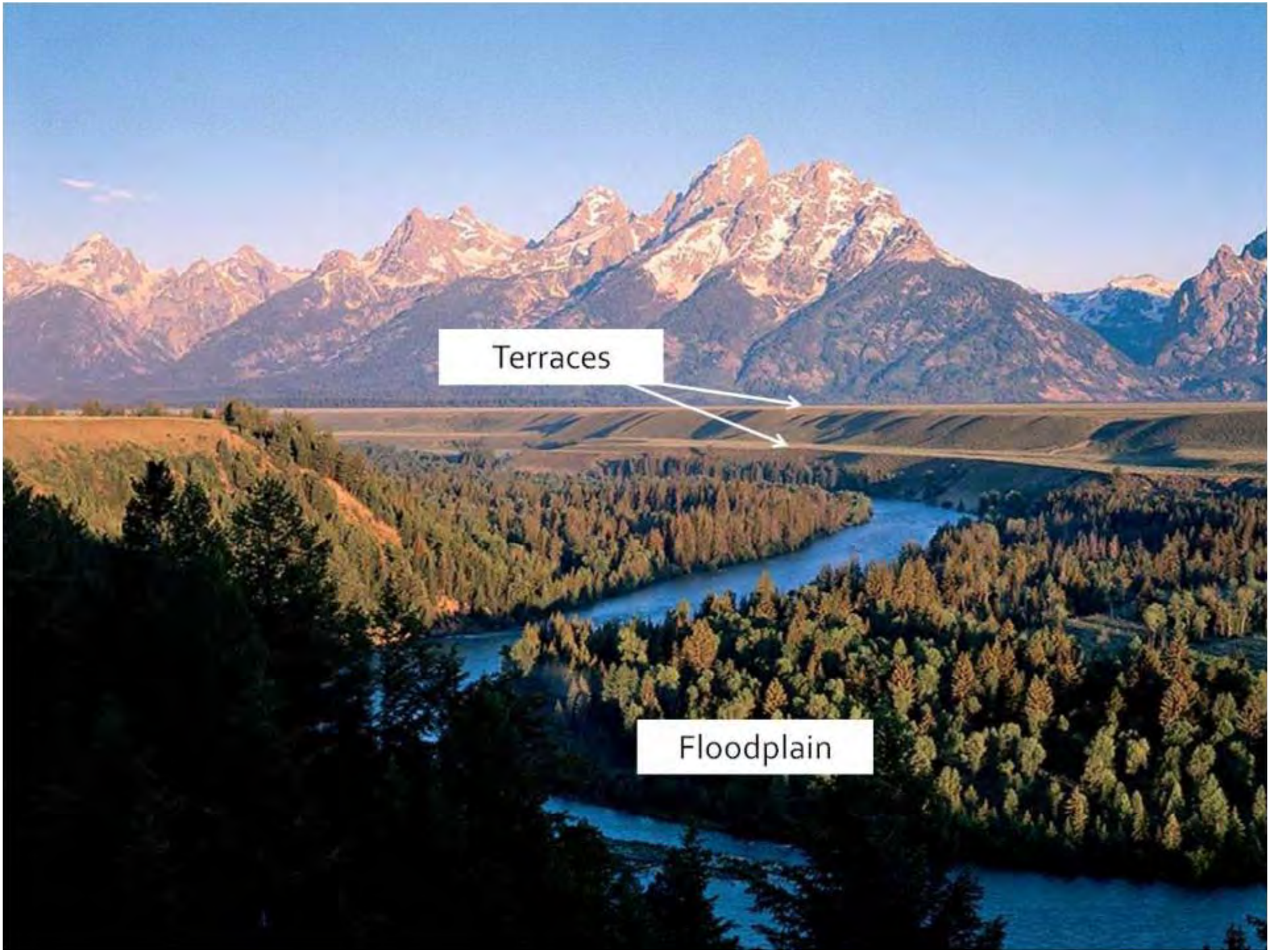
A Note on Channel Type

- **Alluvial**
  - Channels formed in and by sediment transported by the river (aka *alluvium*) under its current hydrology and climate.
  - "Self-formed" channels that are free to adjust their shape in response to flow changes.
- **Non-alluvial**
  - Channels *not* formed in alluvium
    - Bounded by bedrock or concrete
    - Deeply cut into hillslope deposits

Floodplains and Terraces

- **Floodplain - Surface built and maintained by a river channel *under the current hydrologic and sediment transport regime*.**

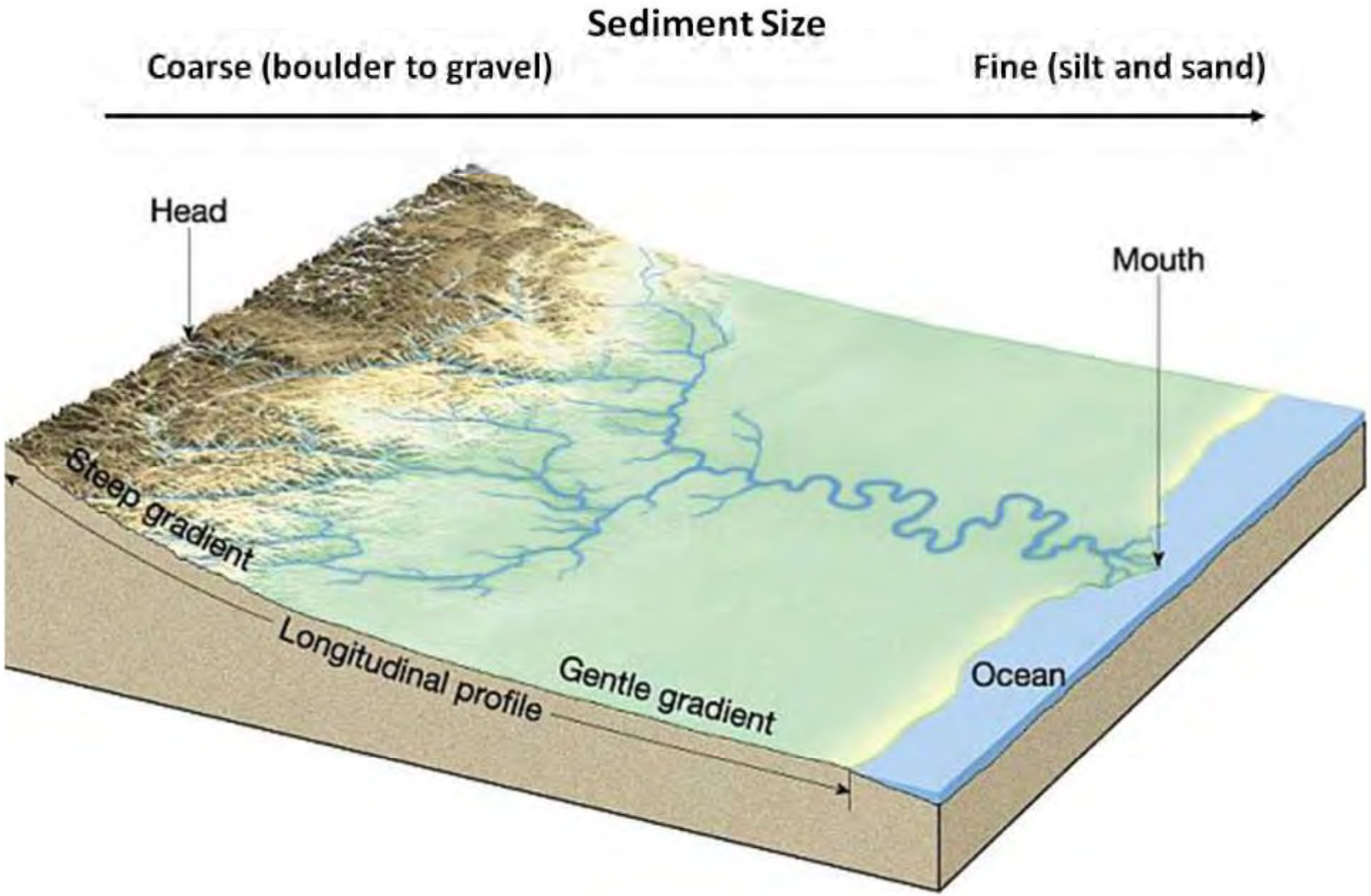
- **Terrace – Floodplain surfaces formed earlier under different climate and sediment transport conditions. Also known as "abandoned floodplain".**


Terraces
Floodplain

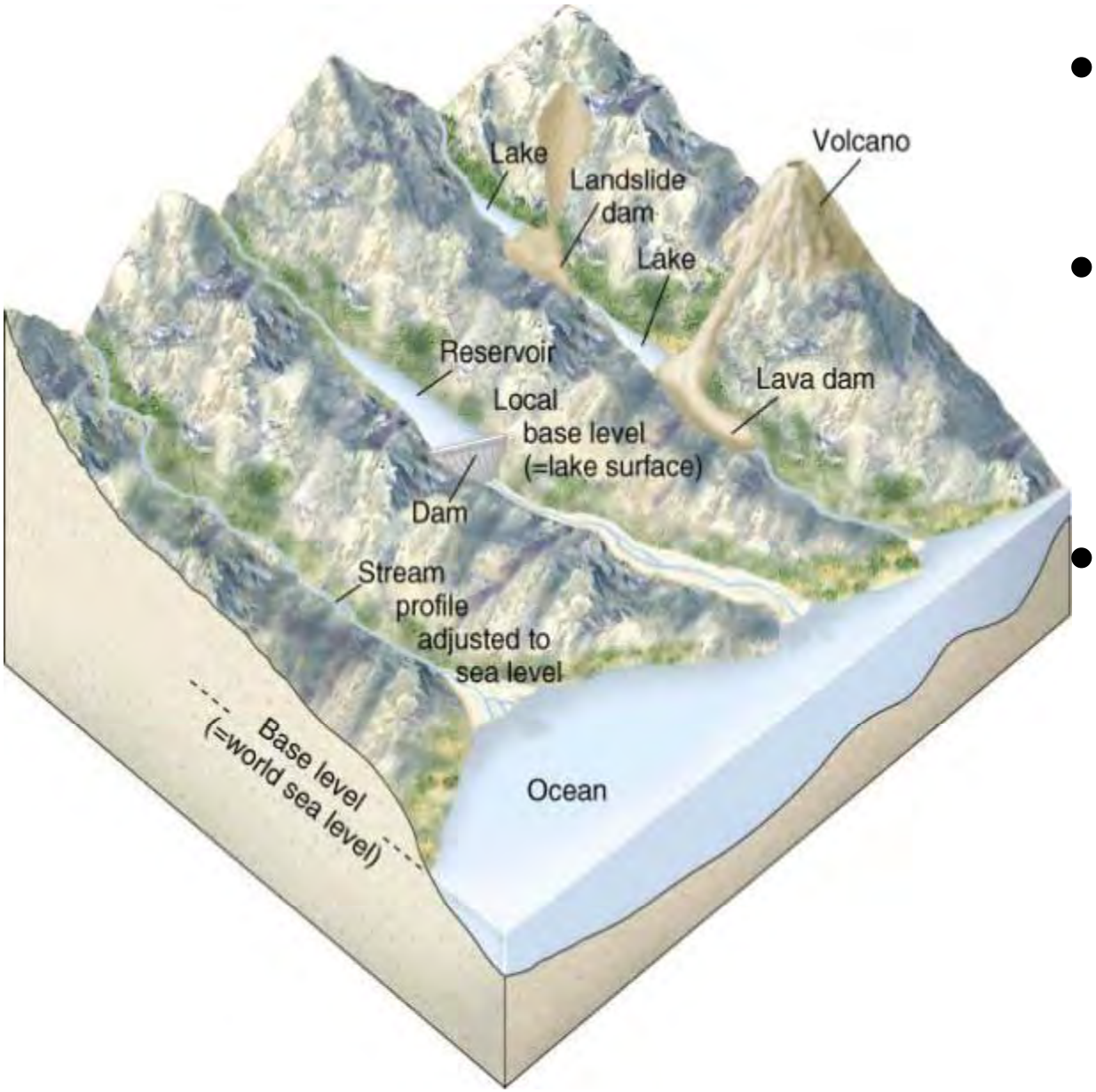
River Channels and Floodplains

- Profile – longitudinal form, slope, gradient
- Pattern – planform (aerial) appearance
- Dimension – cross sectional shape and size
  - Substrate – size and distribution of sediment
  - Vegetation – type and location along channel

Channel Profile



Base Level



- Limiting level for erosion
- Ultimate base level is global sea level
- Local base level controlled by dams, landslides, waterfalls

Channel Pattern

- Straight
- Braided
- Anabranched
- Meandering

➢ Either by *reach* or by *river*—channel patterns exist at a variety of scales

Straight

Straight

- Rare in nature – inherently unstable
- Are sinuous (bendy), but bends appear randomly
- Generally associated with bedrock, faulting and/or uplift
- Commonly attributed to human modifications

Braided

Braided

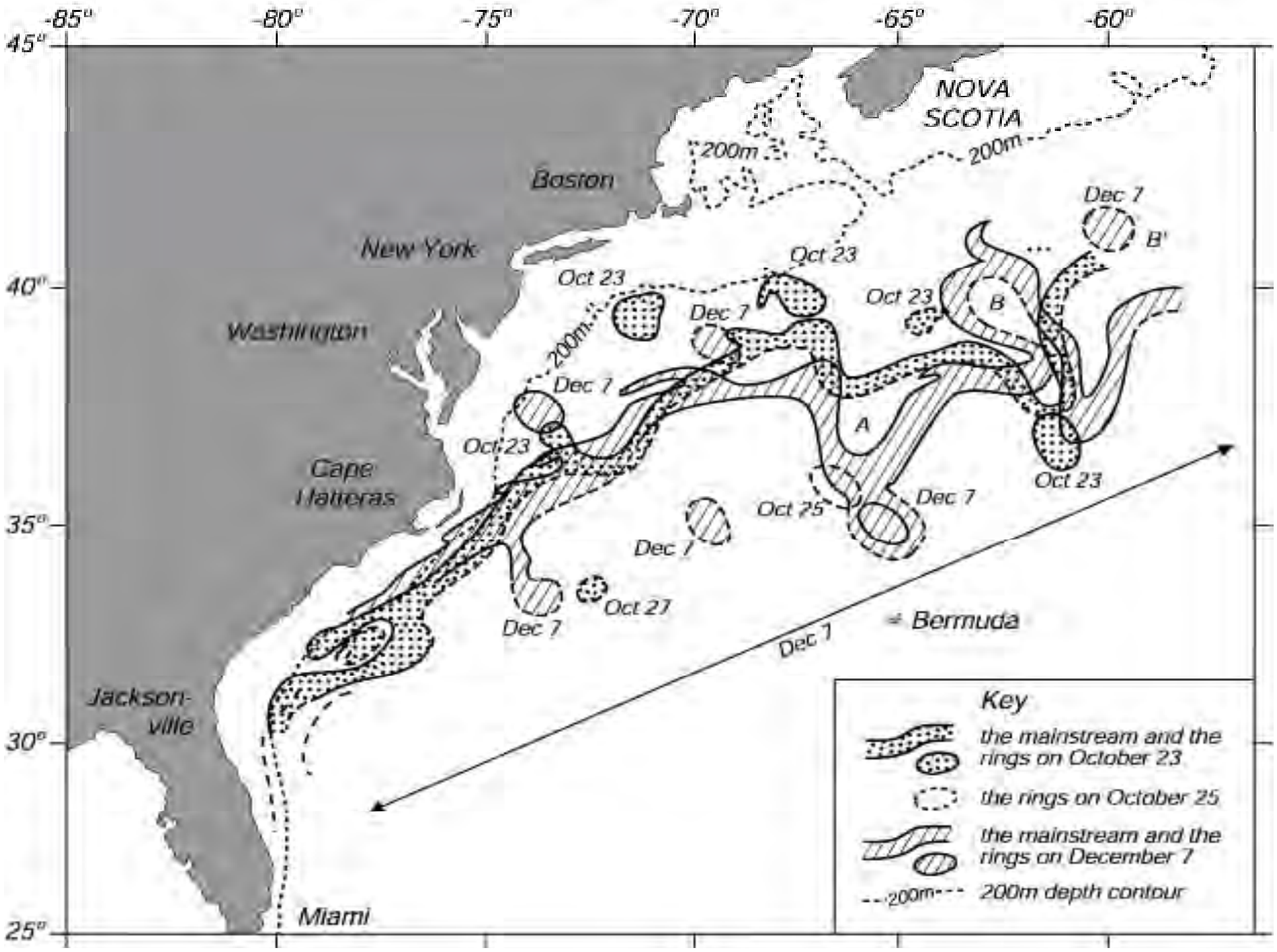
- Complex flow patterns
- Little to no vegetation
- Extreme channel migration rates
- Irregular but very active sediment transport and deposition
- Common at high latitudes and in mountainous areas or lowland sandbed settings
- Often seen after debris flow events

Anabranched

Anabranched

- Similar to braided although islands are stable and often vegetated (or stabilized by vegetation)
- Usually large sediment supply
- Low gradient and often fine-grained bank sediments

Meandering


-85°
-80°
-75°
-70°
-65°
-60°
45°
40°
35°
30°
25°
NOVA SCOTIA
Boston
New York
Washington
Cape Hatteras
Jackson-ville
Miami
Bermuda
200m
200m
200m
Oct 23
Dec 7
Oct 23
Dec 7
Oct 23
Dec 7
B'
B
A
Oct 23
Dec 7
Oct 25
Dec 7
Oct 23
Dec 7
Oct 27
Dec 7
Key
the mainstream and the rings on October 23
the rings on October 25
the mainstream and the rings on December 7
200m depth contour

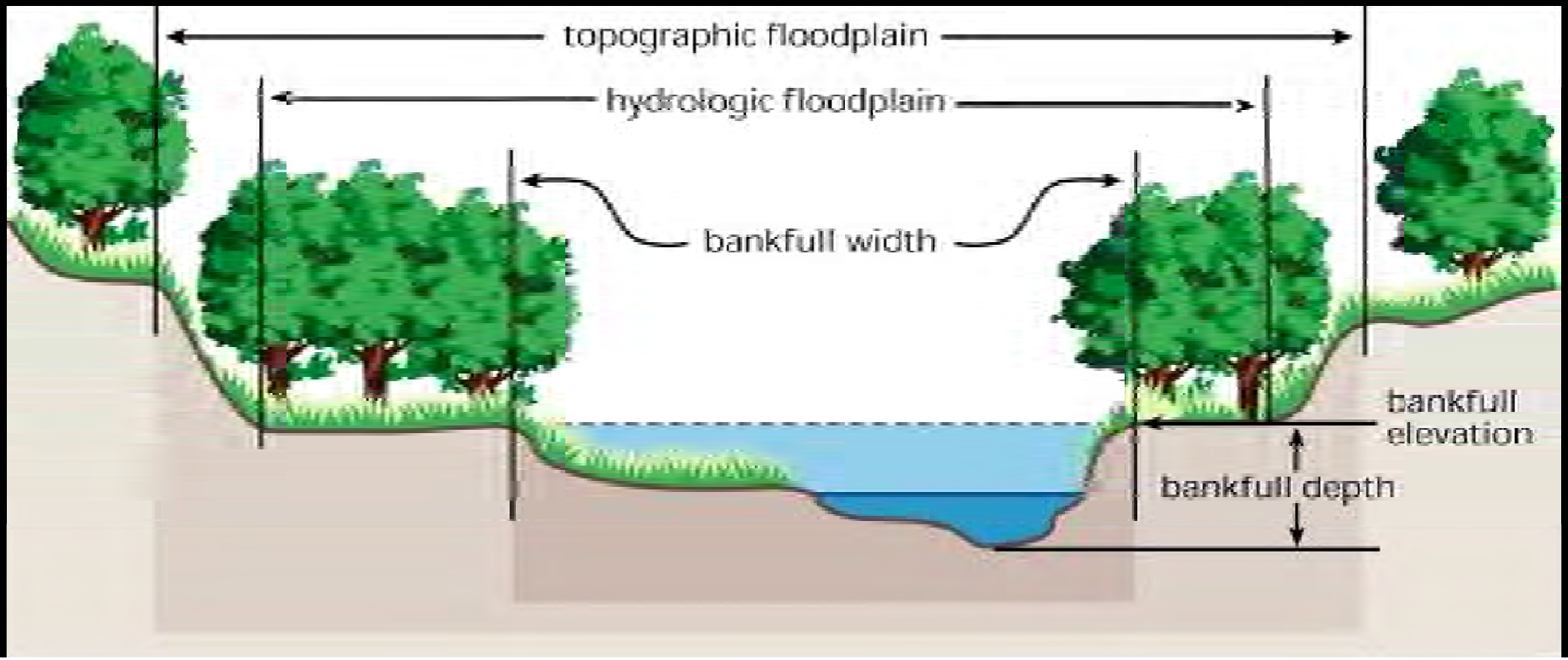
Streamflow and Channel Form

- Streamflow governs channel and floodplain morphology
- Major floods do a lot of work, but are infrequent
- Low flows minimally influence channel and floodplain morphology

- SO—that leaves the flows in the middle!!!

Bankfull Flow

- Discharge where water just begins to leave the stream channel and spread onto the floodplain. Occurs every 1 to 3 years (on average) in stable alluvial temperate streams.



Bankfull Flow

- Considerable research across the world shows a relationship between drainage basin area and bankfull flow
- Bankfull flow and channel dimensions
  - Channel Area (Width X Depth)
- Or, channel dimensions as a function of drainage area (Regional Curves)

More About Bankfull Flow

- Bankfull flow does the most amount of geomorphic "work" over time by:
  - Transporting biggest sediment
  - Maintaining channel form
  - Driving channel migration

- Transport of sediment bigger than sand begins at flows equal to about 60% of bankfull flow with most particles in motion at ~90% of bankfull flow.

Youngs Branch near Groveton, VA

Bankfull Flow Indicators

Bankfull Indicator	Reference
Minimum width/depth ratio	Wolman 1955 Pickup and Warner 1976
Highest elevation of channel bars	Wolman and Leopold 1957
Elevation of middle bench in rivers with several overflow sections	Woodyer 1968
Minimum width/depth ratio plus a discontinuity (vegetative and or physical) in the channel boundary	Wolman 1955
Elevation of active flood plain	Wolman and Leopold 1957 Nixon 1959
Lower limit of perennial vegetation	Schumm 1960
Change in Vegetation (herbs, grass, shrubs)	Leopold 1994
A combination of • Elevation associated with the highest depositional features • Break in bank slope • Change in bank material • Small benches and other inundation features • Staining on rocks • Exposed root hairs	Rosgen 1994

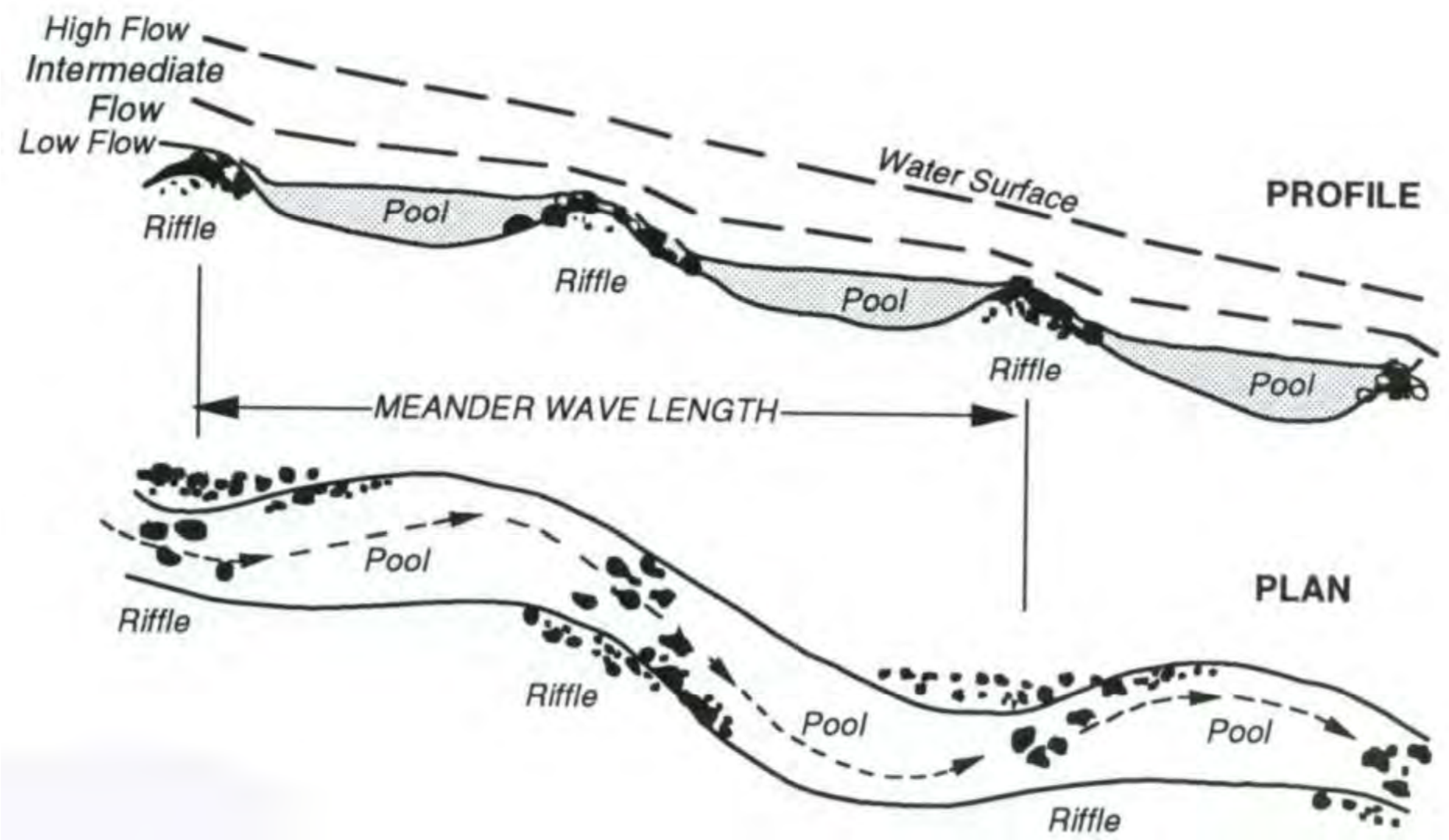
Meandering

- Most commonly observed channel pattern
- Meander patterns are fairly predictable—one meander sequence occurs every 10 to 14 bankfull channel widths
- Pools and riffles are the primary structural channel units – spaced about 5 to 7 bankfull channel widths apart
- Some meanders are stable over long time spans

Entrenched Meander

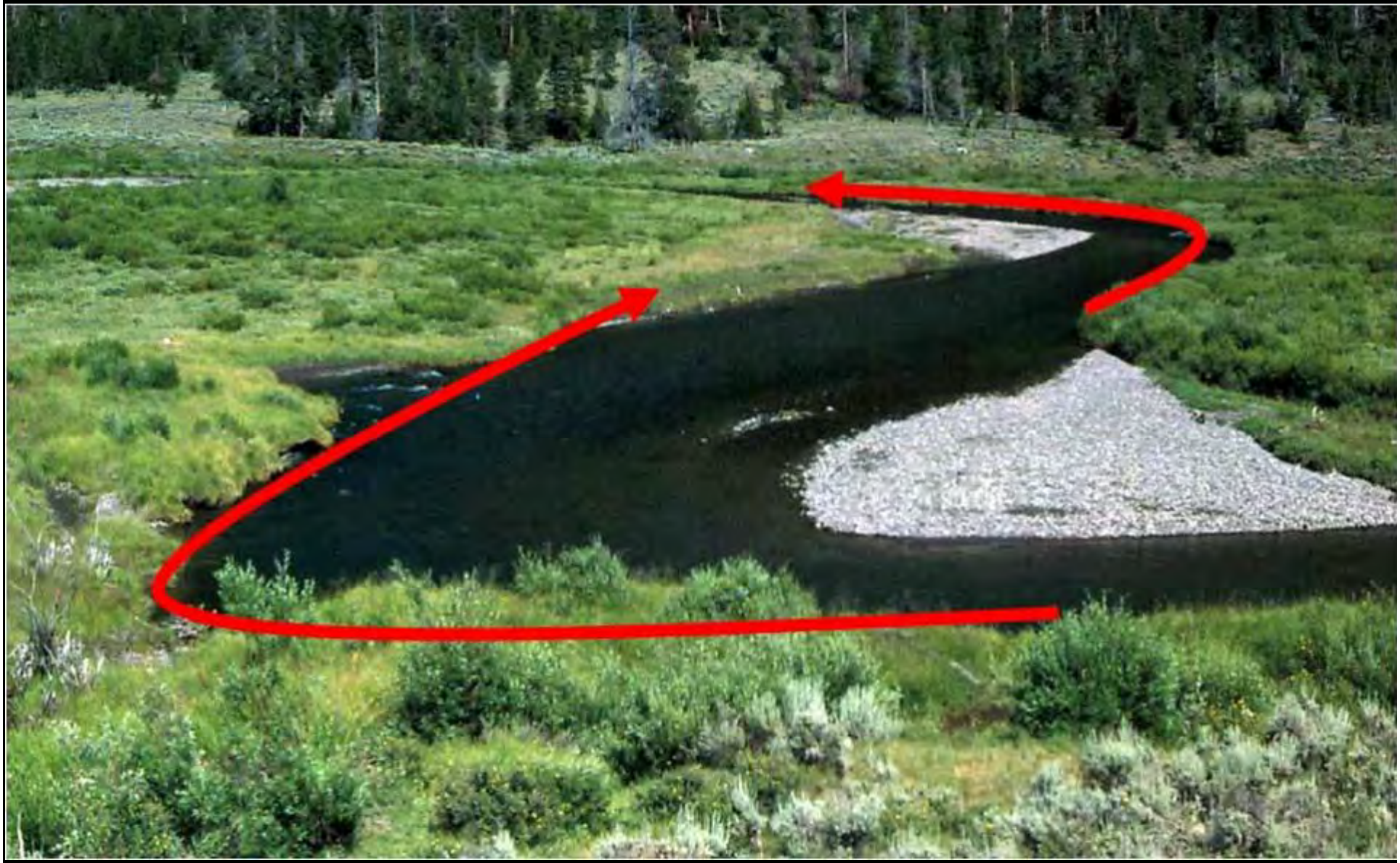
Meander Metrics Related to Channel Width

Riffles and Pools

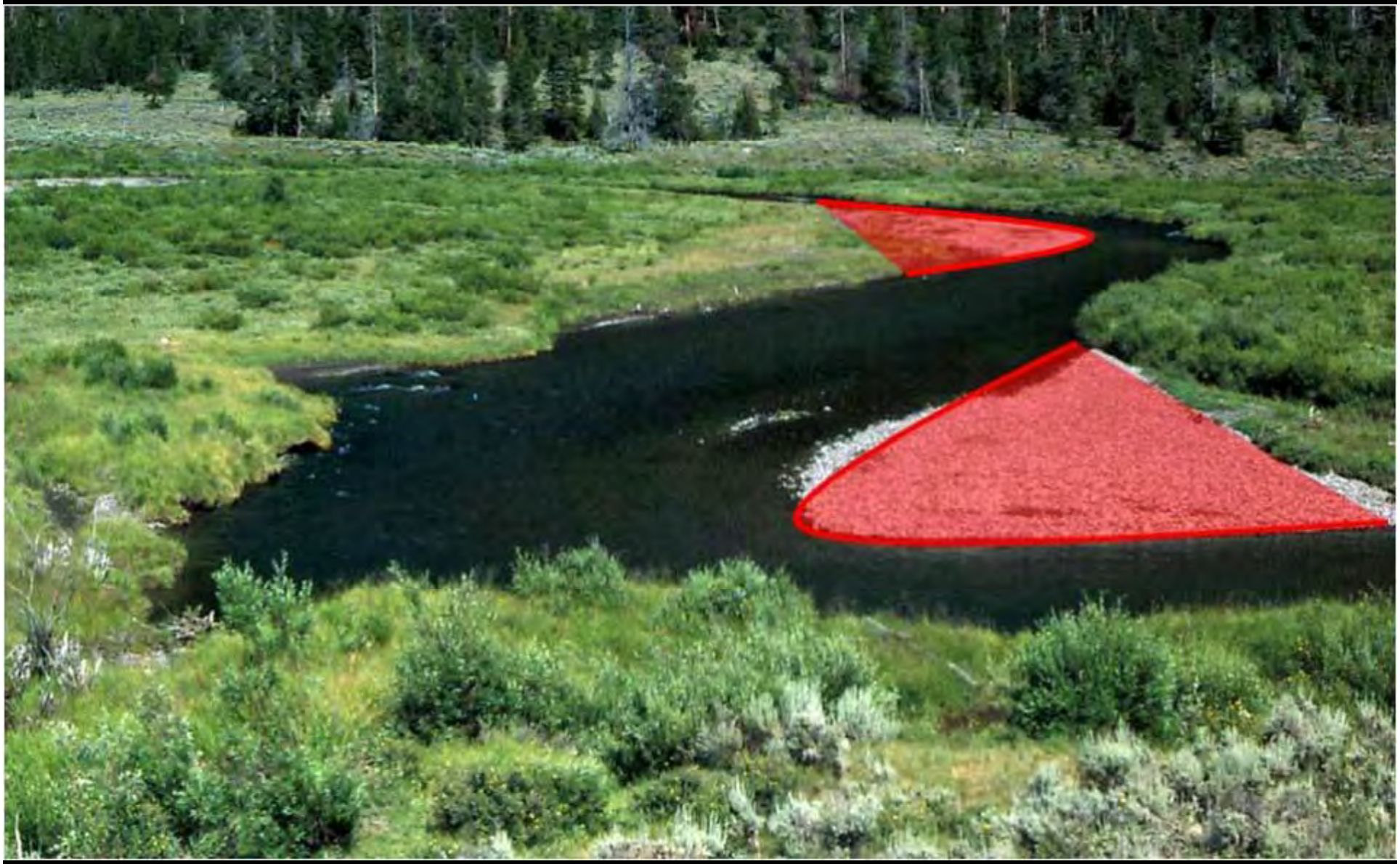


Meander Hydraulics

Meander Hydraulics—Erosion



Meander Hydraulics—Deposition



Meander Hydraulics

- Creates pools and riffles through bar formation and maintenance
- Important for floodplain evolution

Channel Migration & Floodplain Evolution

Channel Migration & Floodplain Evolution

Sediment Transport

Sediment Transport

- Wash (Dissolved) Load
  - not a big player in channel and floodplain structure
- Suspended Load
- Bed Load

Suspended Load Transport

- Generally < 0.2mm in diameter (silt and clay)
- Accounts for 80-95% of sediment flux from continents to oceans
- Essential to channel and floodplain formation and maintenance
- Can be a significant water quality problem
    - Deposition covers gravels and cobbles
    - Pesticides adsorb to soil particles

Bed Load Transport

- Generally > 0.2mm in diameter (sand to boulders)
- Significant influence on channel and floodplain composition, shape, location, etc.
- Notoriously hard to measure and/or predict
- Moves by rolling, sliding, or bouncing along streambed

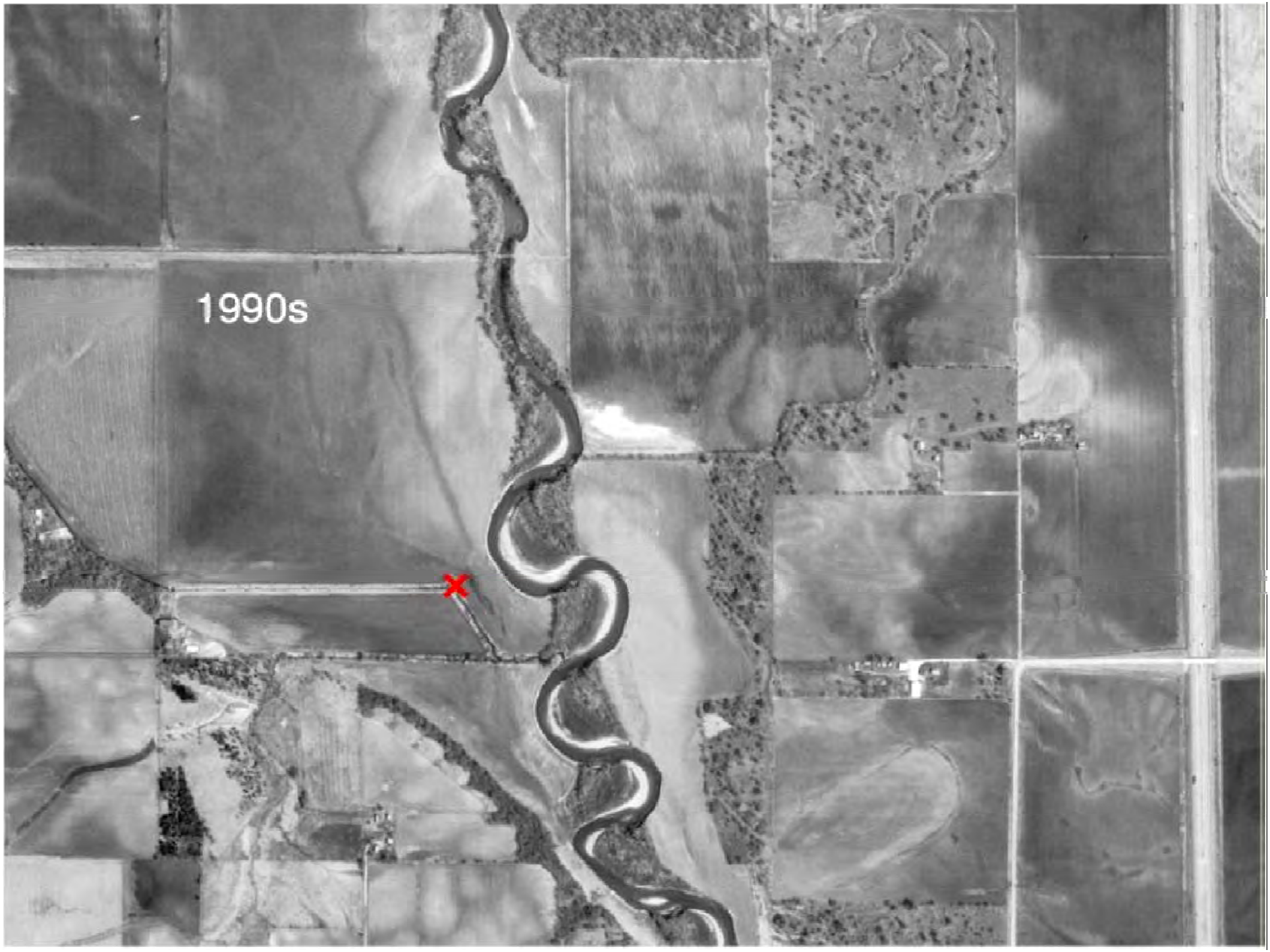
River Response

- Channelization for transportation corridors, flood control, development or agricultural production
- Dams built to store water for irrigation and/or flood control
- Land use changes
- Gravel mining


Channelization
Walla Walla River, 1964


1930s


1970s

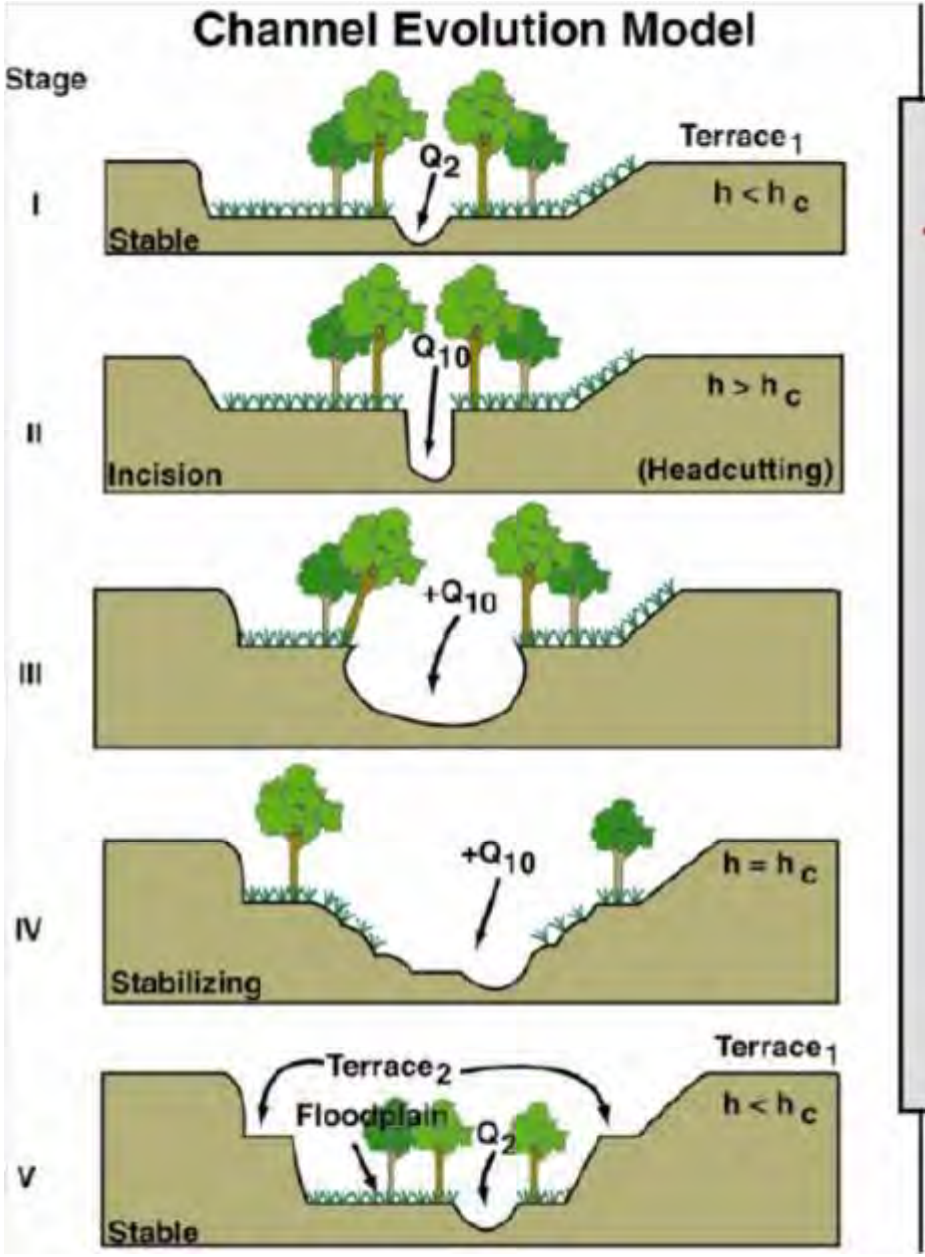

1990s


2002


2007

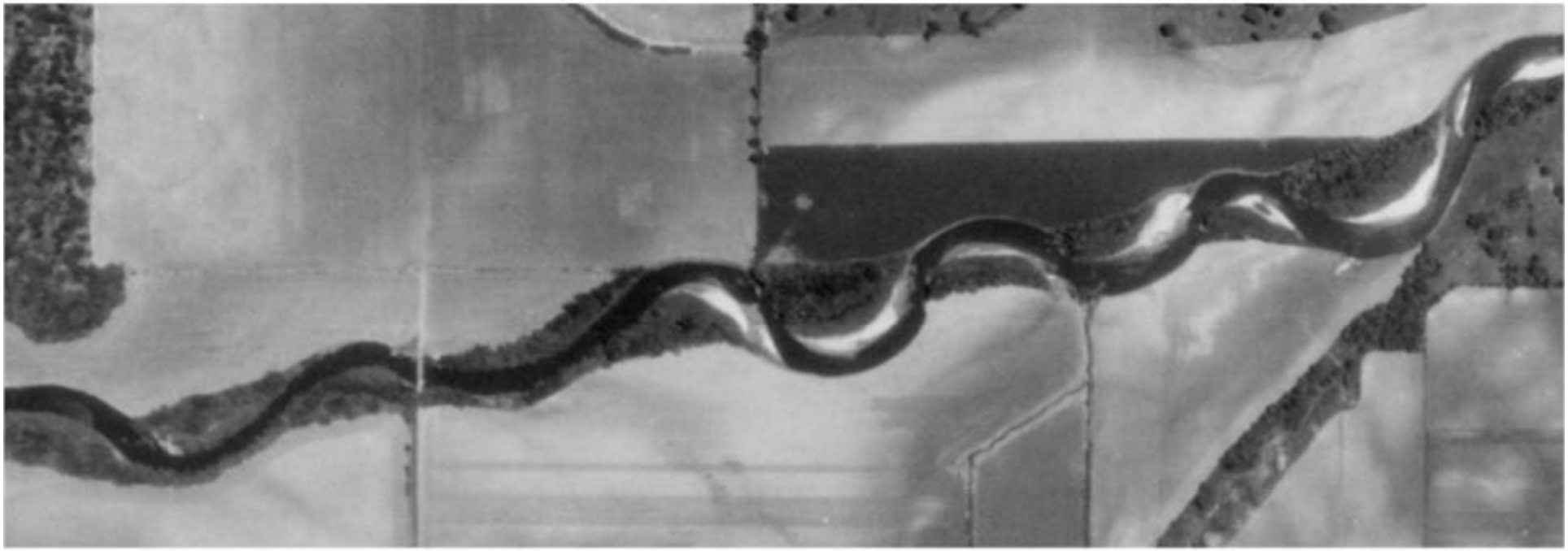

1930s
1970s
2007

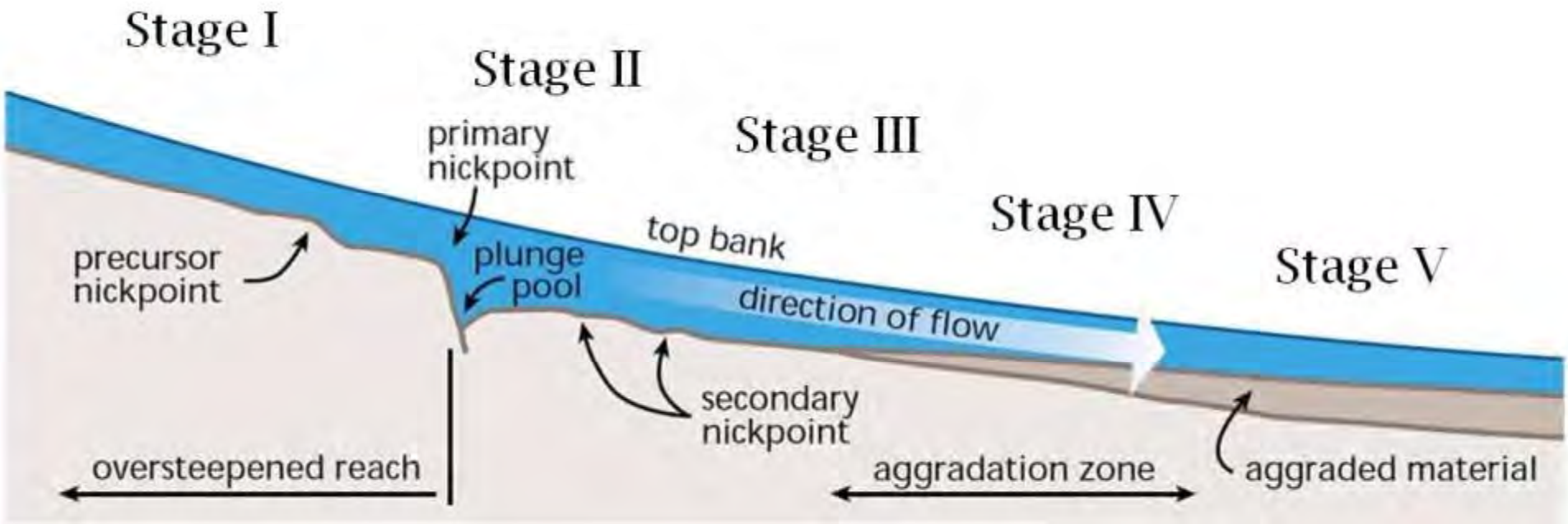
Channel Evolution Model



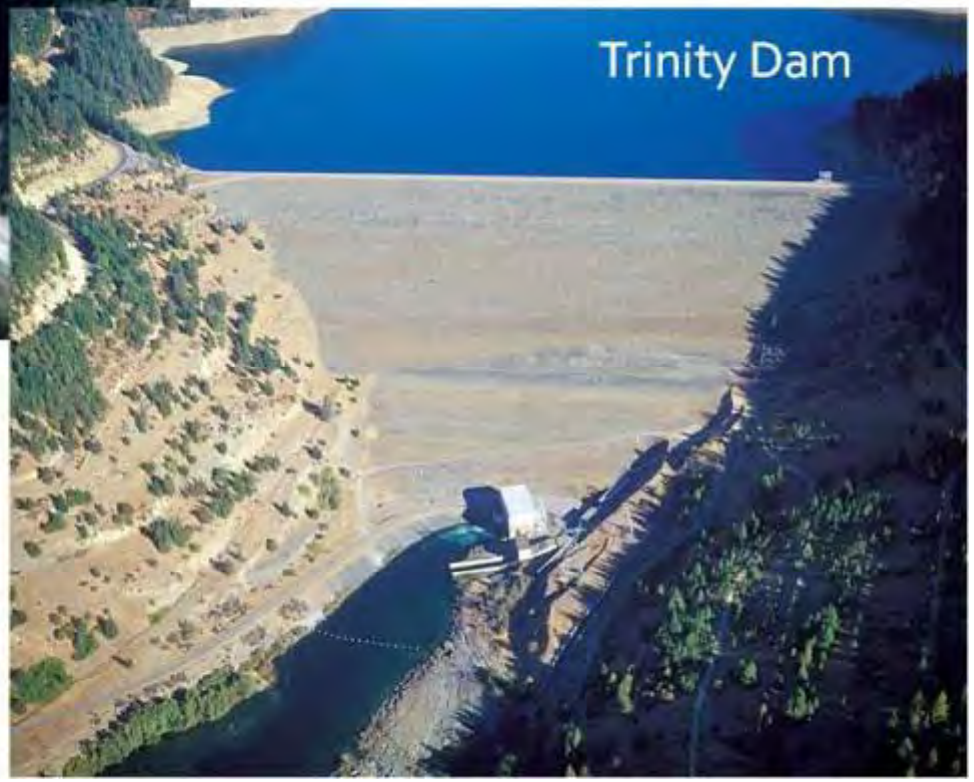
Channel Evolution Model

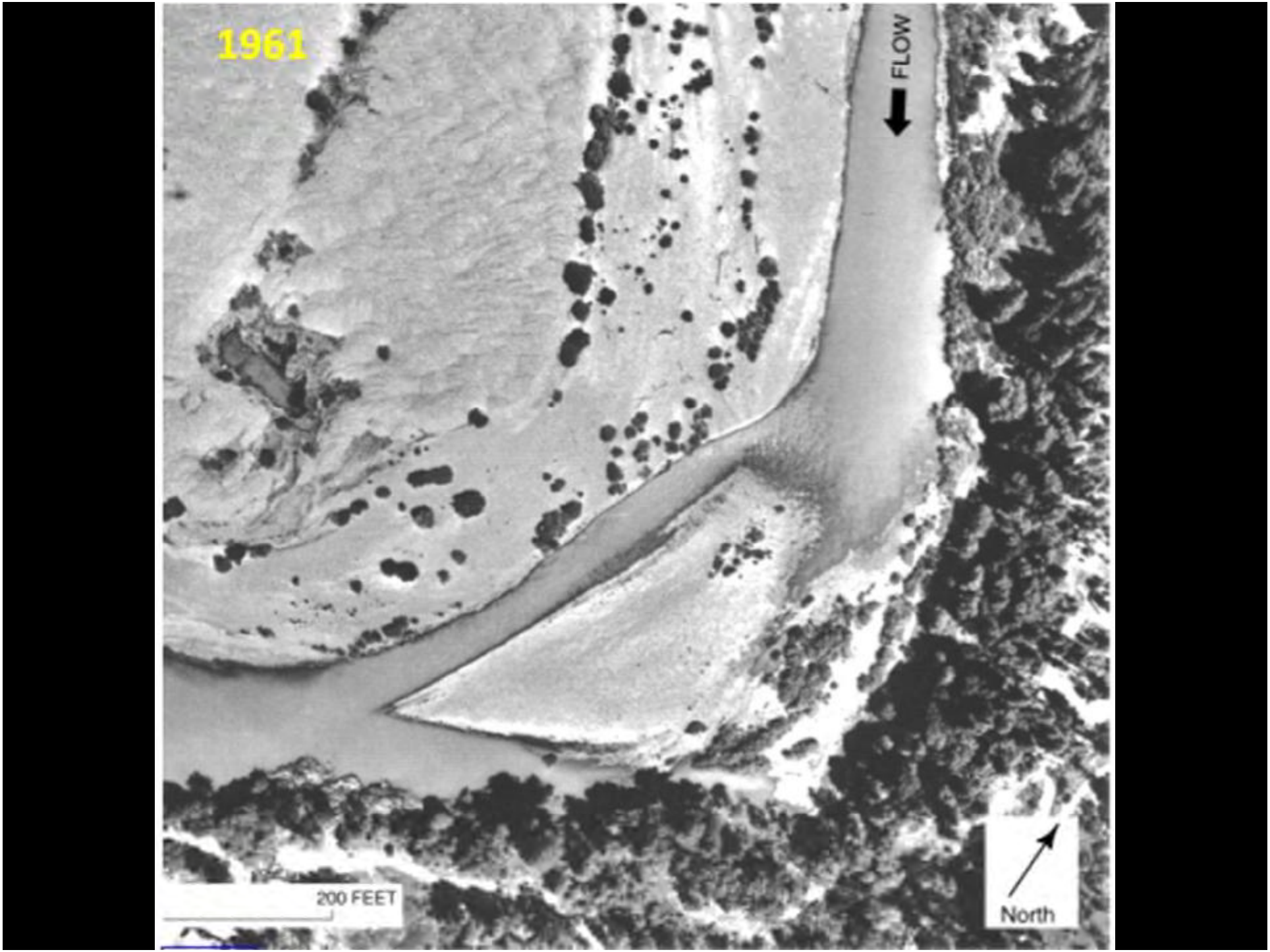
- Stage I: The waterway is a stable, undisturbed natural channel.
- Stage II: The channel is disturbed by some drastic change such as forest clearing, urbanization, dam construction, or channel dredging. Instability sets in with scouring of the bed.
- Stage III: Destructive bank erosion and channel widening occur by collapse of bank sections.
- Stage IV: Stabilizing - The banks continue to cave into the stream, widening the channel.
- Stage V: Re-equilibrium occurs, and bank erosion ceases. Riparian vegetation once again becomes established.

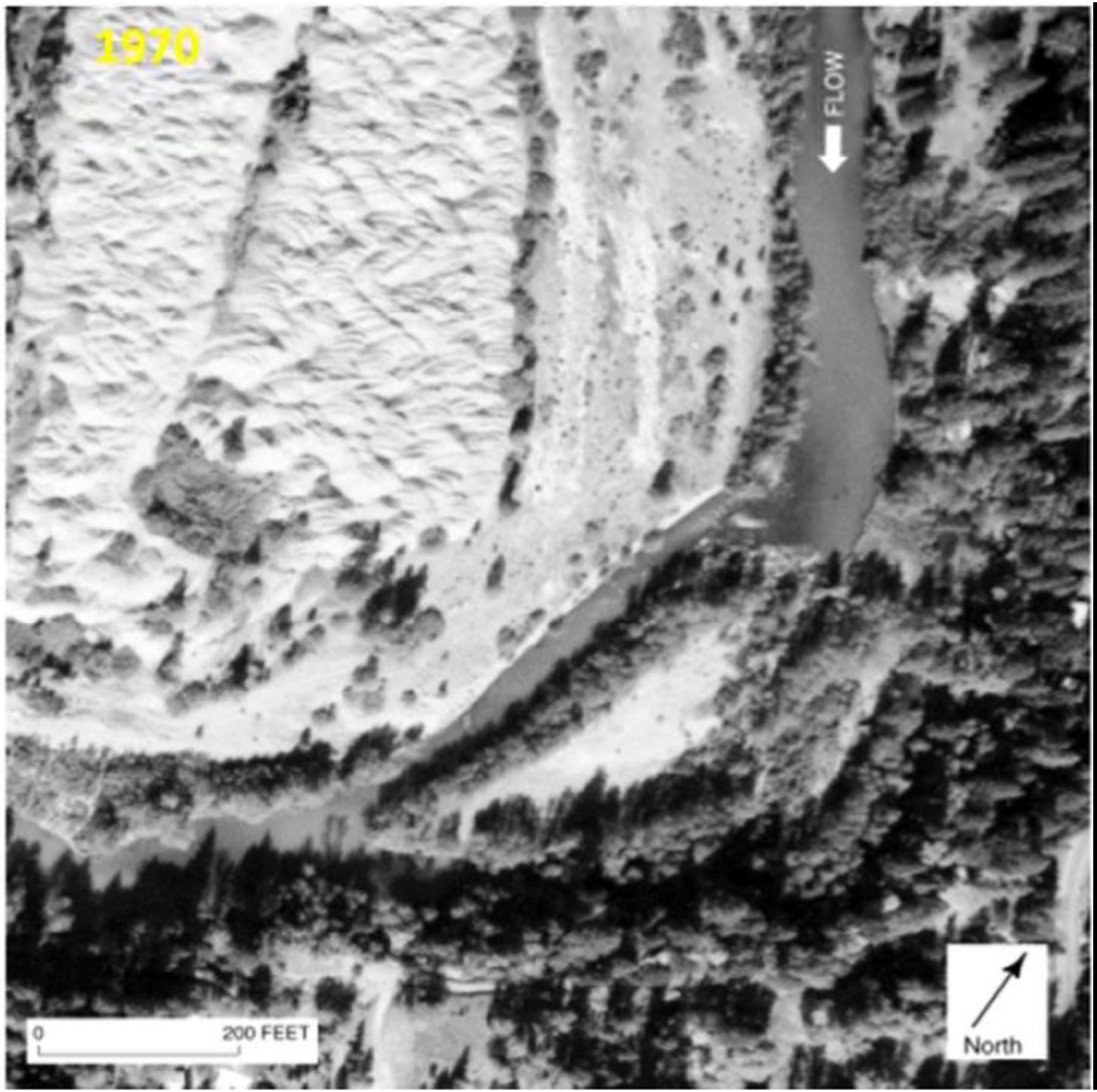


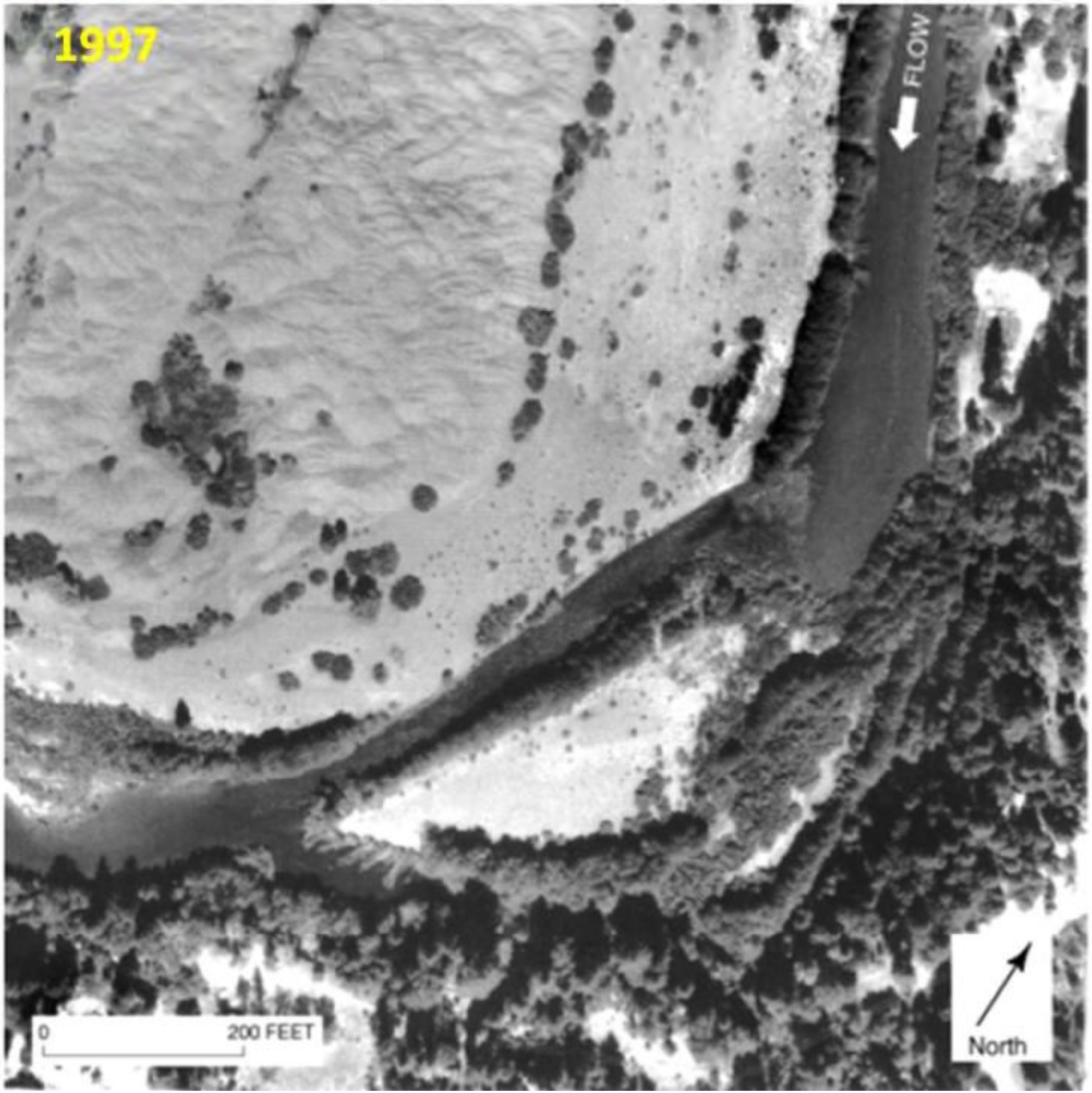

Stage I
Stage II
Stage III
Stage IV
Stage V
primary nickpoint
precursor nickpoint
plunge pool
top bank
direction of flow
secondary nickpoint
oversteepened reach
aggradation zone
aggraded material

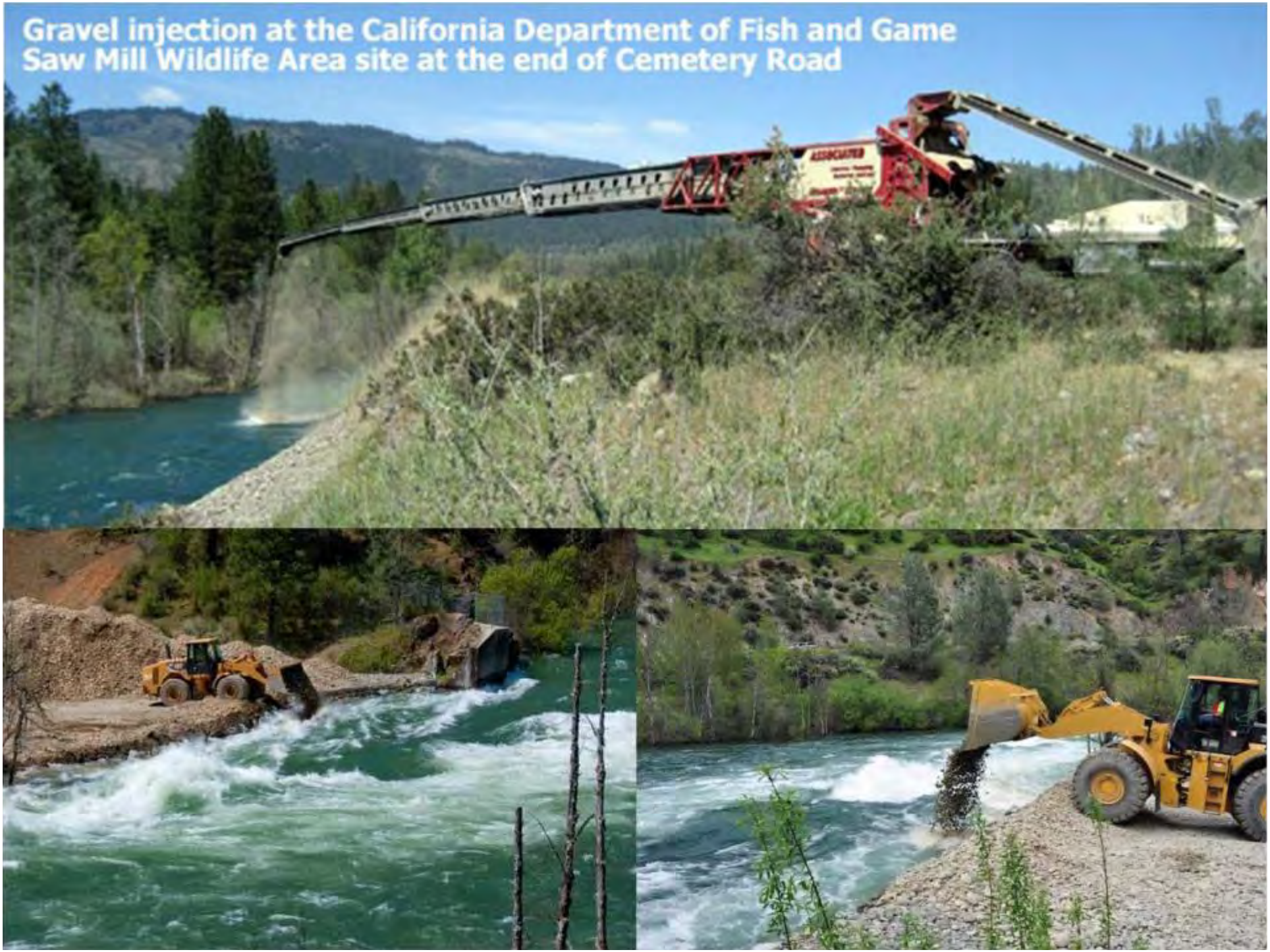
Dams—Trinity River, CA



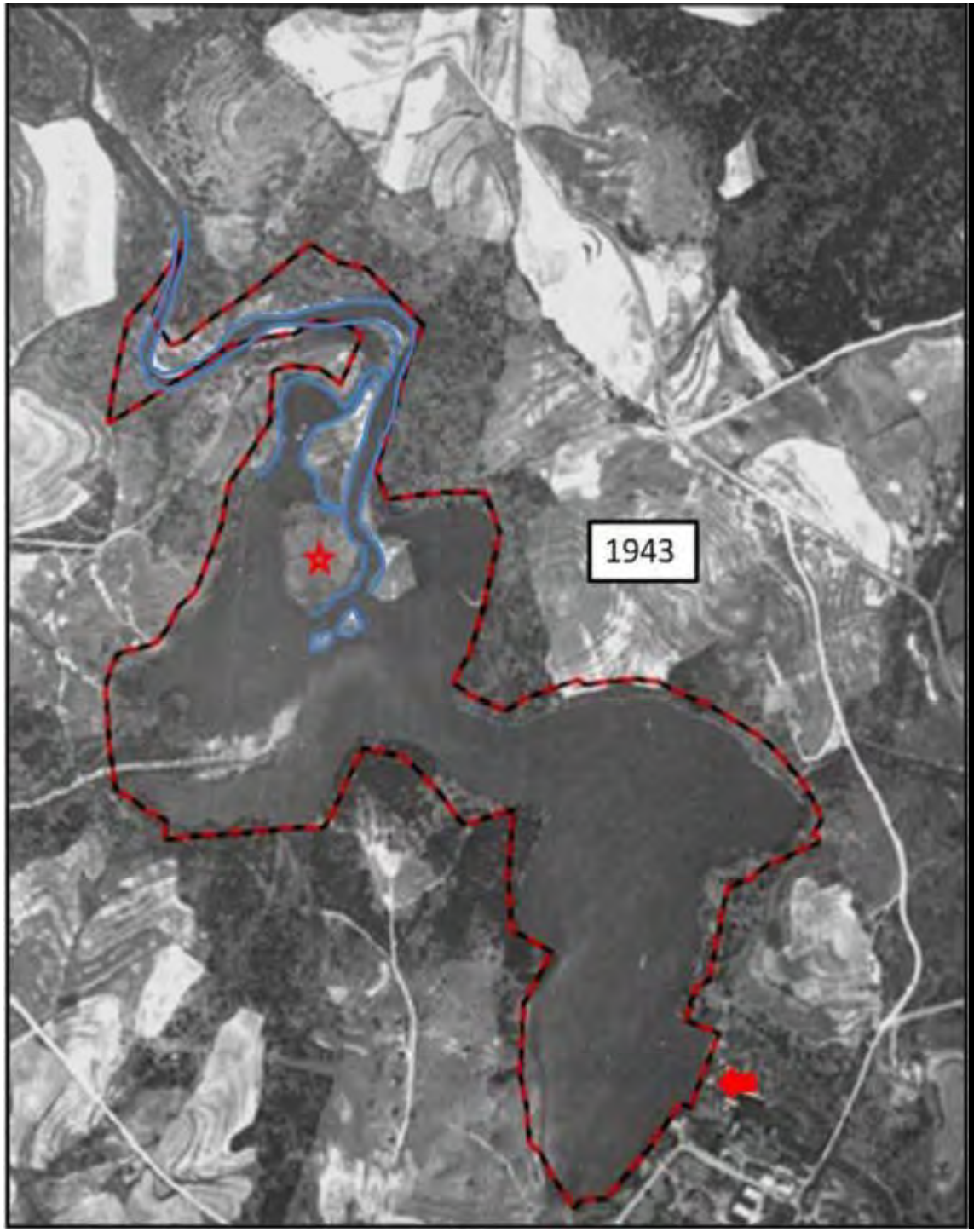

1961
FLOW
200 FEET
North


1970
FLOW
0
200 FEET
North


1997
FLOW
0
200 FEET
North

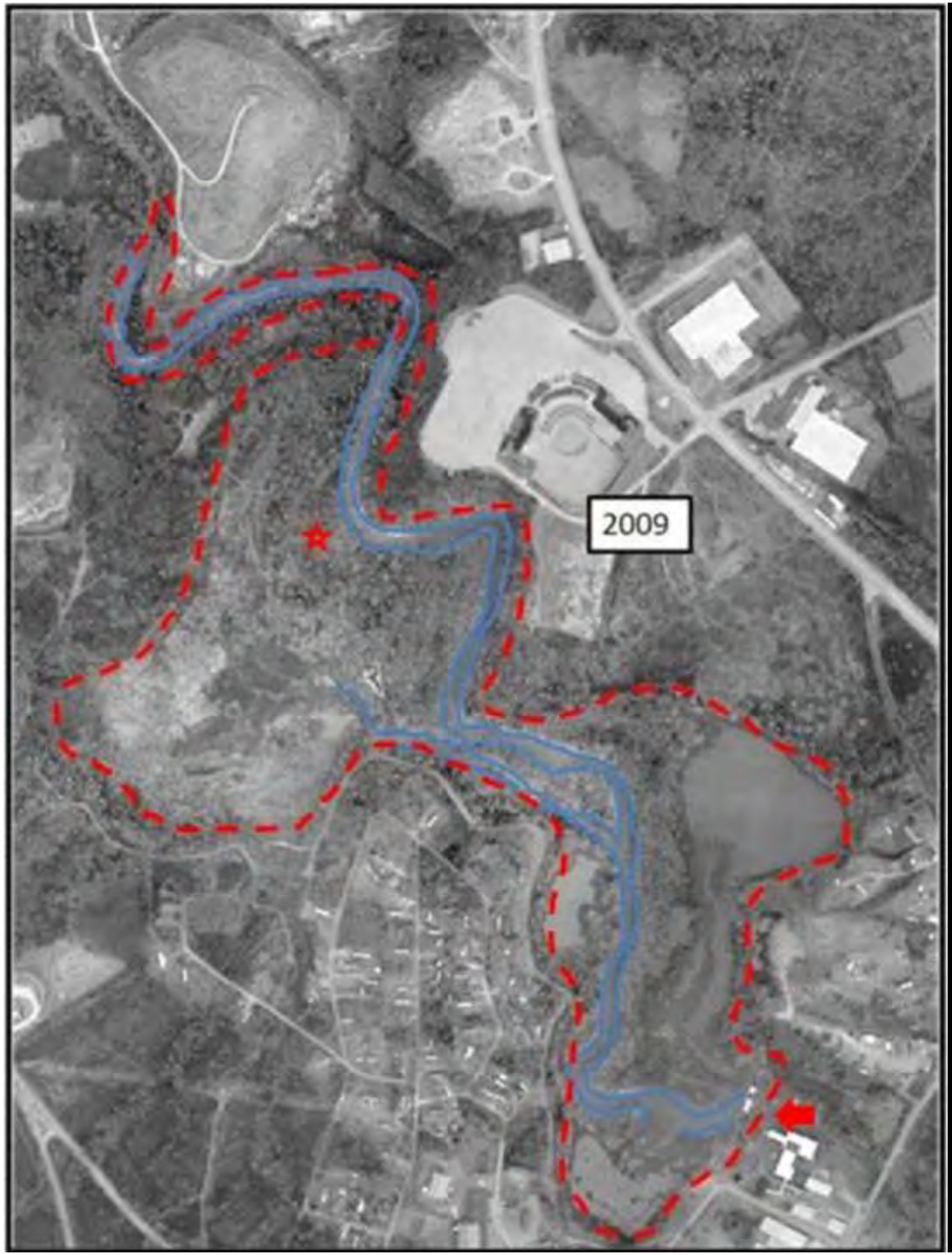

Gravel injection at the California Department of Fish and Game
Saw Mill Wildlife Area site at the end of Cemetery Road

Conestee Dam, Reedy River near Greenville SC



Lake Conestee

1943



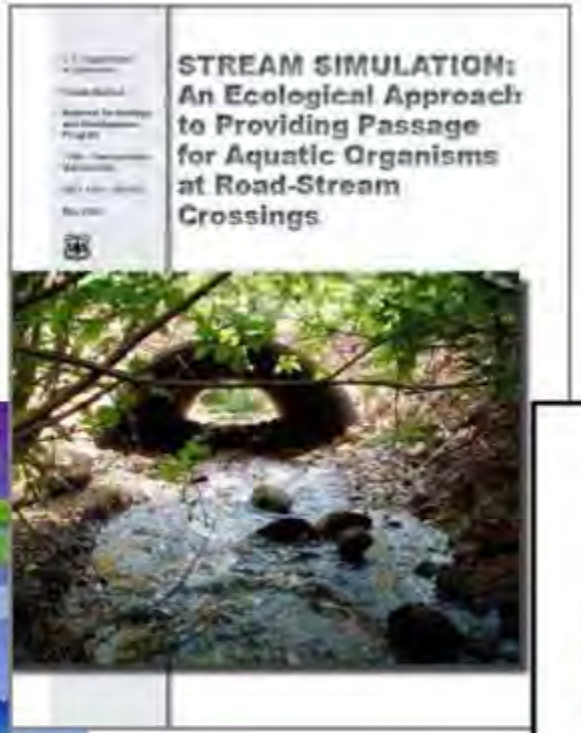
Lake Conestee 2009

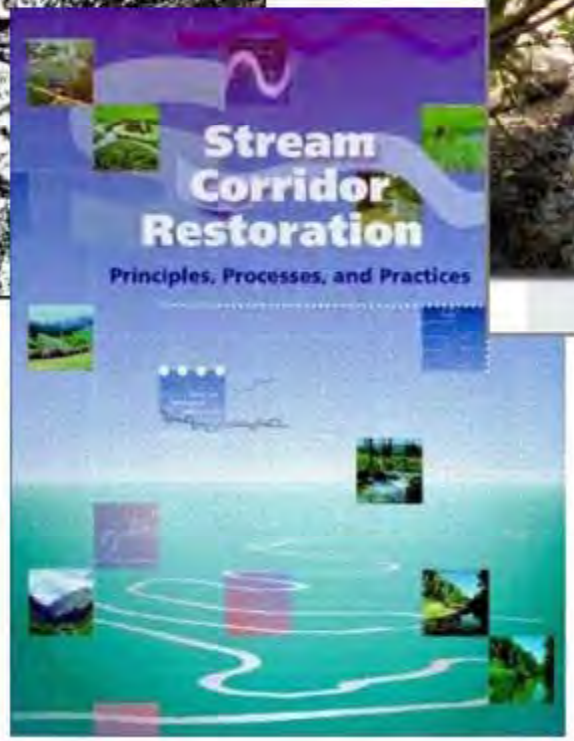
Lake Conestee

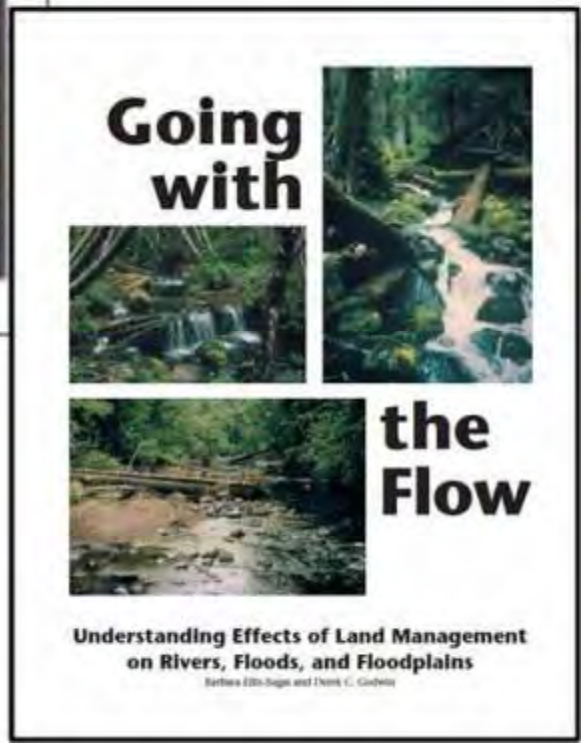
2011

Lake Conestee—1943 to 2011

River Science Primers







End

United States Department of Agriculture
Natural Resources Conservation Service

USDA NRCS