RECLAMATION

Managing Water in the West

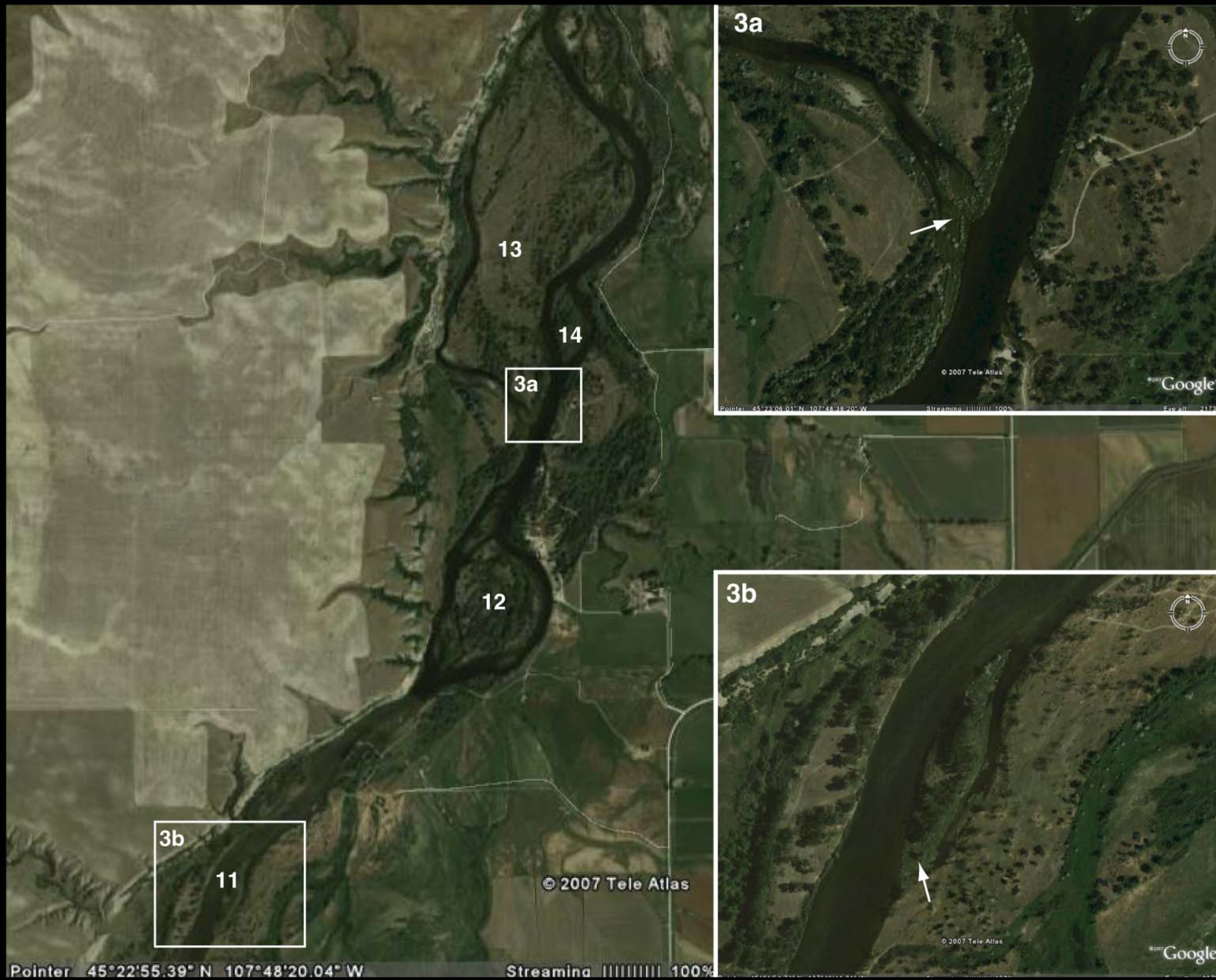
Bighorn River Side channel Investigations downstream of Yellowtail Dam and Afterbay

Geomorphic Analysis

U.S. Department of the Interior
Bureau of Reclamation

Statement of problem

- Progressive side channel abandonment
  - Disconnected entrances
  - Shallowing at side channel mouths
- Loss of habitat in side channels
- Side channel loss appears
  to be continuing today (based on field observations)
- Appears to have gotten worse
  in about the last decade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11
© 2007 Tele Atlas
Pointer 45°22'55.39" N 107°48'20.04" W
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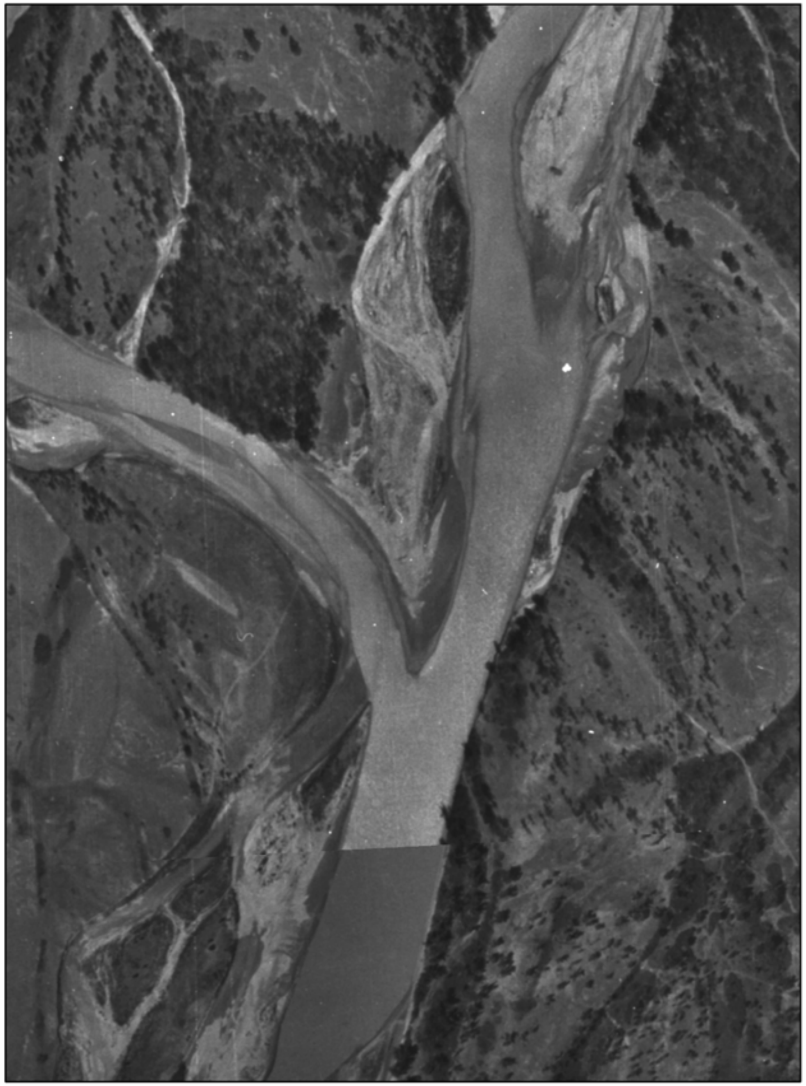
Channel change: complex 13

1939 (Q=1827 ft^3/s)



2006 (Q=1990 ft^3/s)

Why are side channels important?

- **Side channel:**
  - secondary channel connected to the main channel on upstream and downstream ends
  - narrower in width and shallower in depth with slower velocities than the main channel

- **Provides:**
  - Critical habitat for spawning and rearing
  - Typically more stable flows and temperature regimes compared to main channel
  - Habitat for a variety of wildlife
    - Amphibians, birds, reptiles, mammals, mollusks

Geomorphic Analysis

- **Geomorphology: Geo=earth; morph=form**
  - **the study of the classification, description, nature, origin, processes, and development of present *landforms*… and the history of geologic changes recorded by these surface features (from Nuendorf et al. 2005).**
  - **Fluvial Geomorphology:**
    the study of the physical form of rivers and the processes that create and shape river features.

Songha River, China

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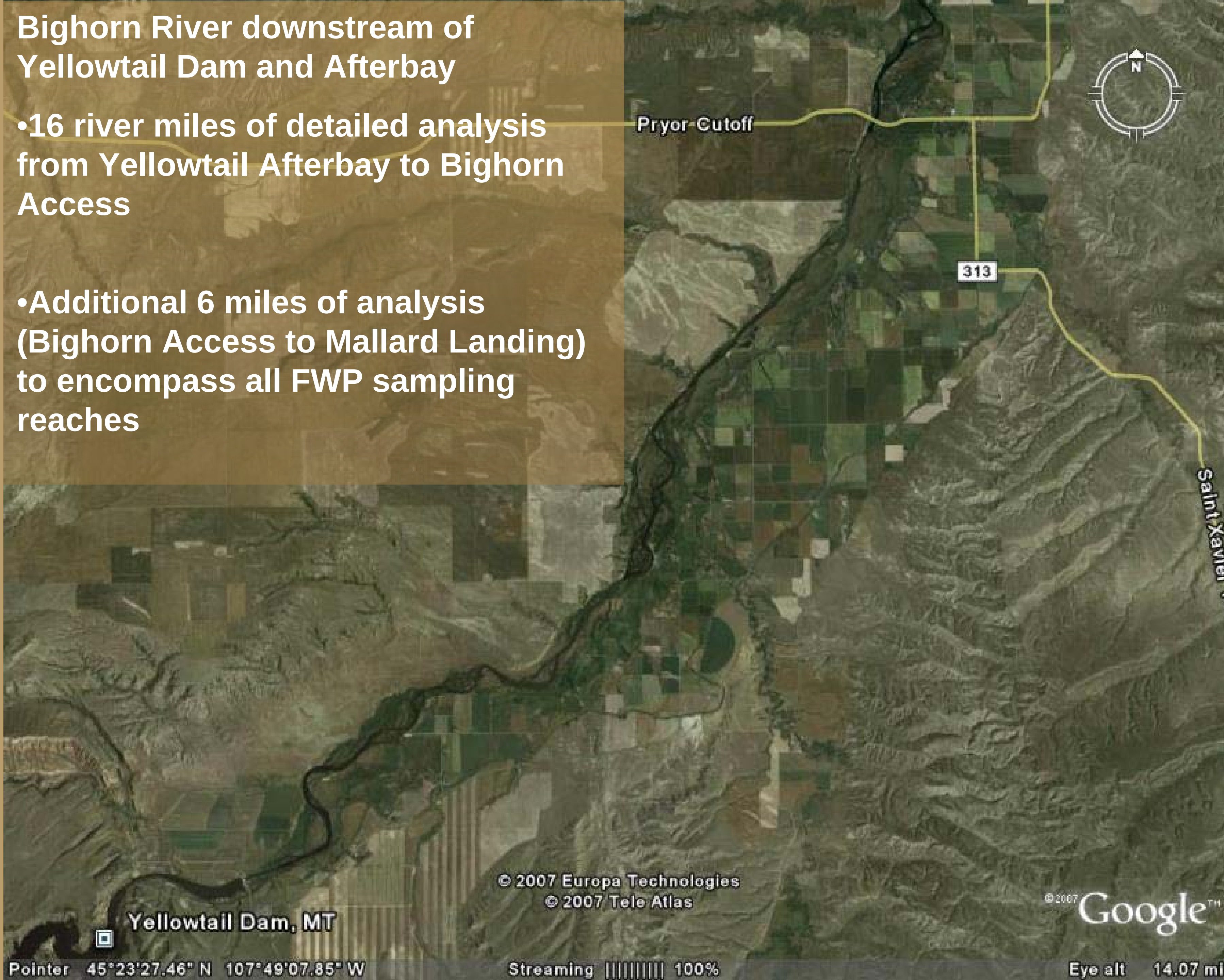
Bighorn River downstream of Yellowtail Dam and Afterbay

- 16 river miles of detailed analysis from Yellowtail Afterbay to Bighorn Access

- Additional 6 miles of analysis (Bighorn Access to Mallard Landing) to encompass all FWP sampling reaches



Study objectives

- Investigate vertical changes along the lower Bighorn River downstream from Yellowtail Dam and Afterbay
- Investigate lateral change and stability along the same reach
- Identify side channels that have been lost or are at risk in the post-dam flow regime

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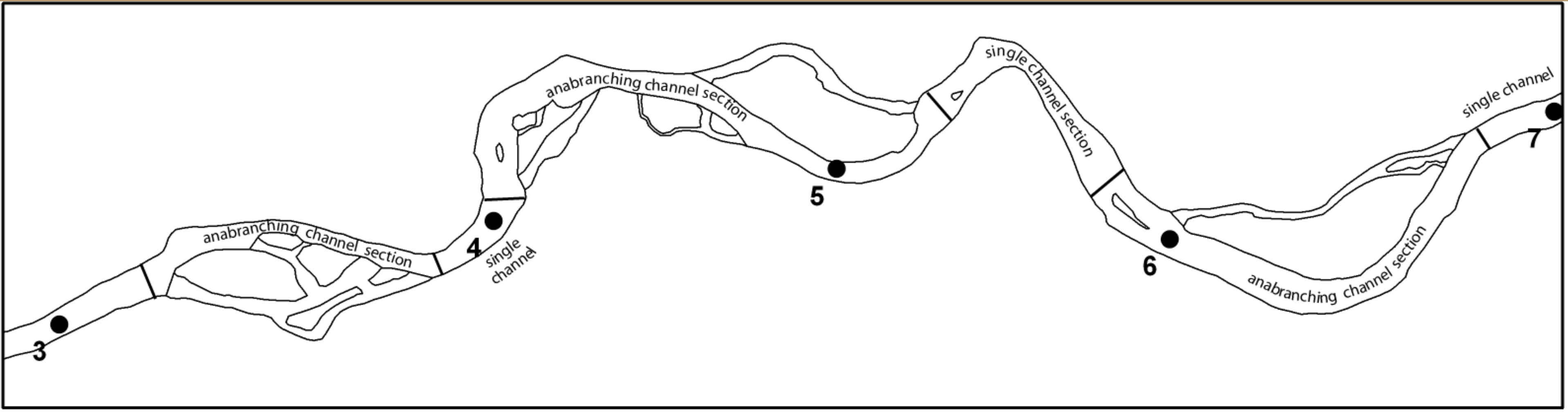
Bighorn River Channel morphology

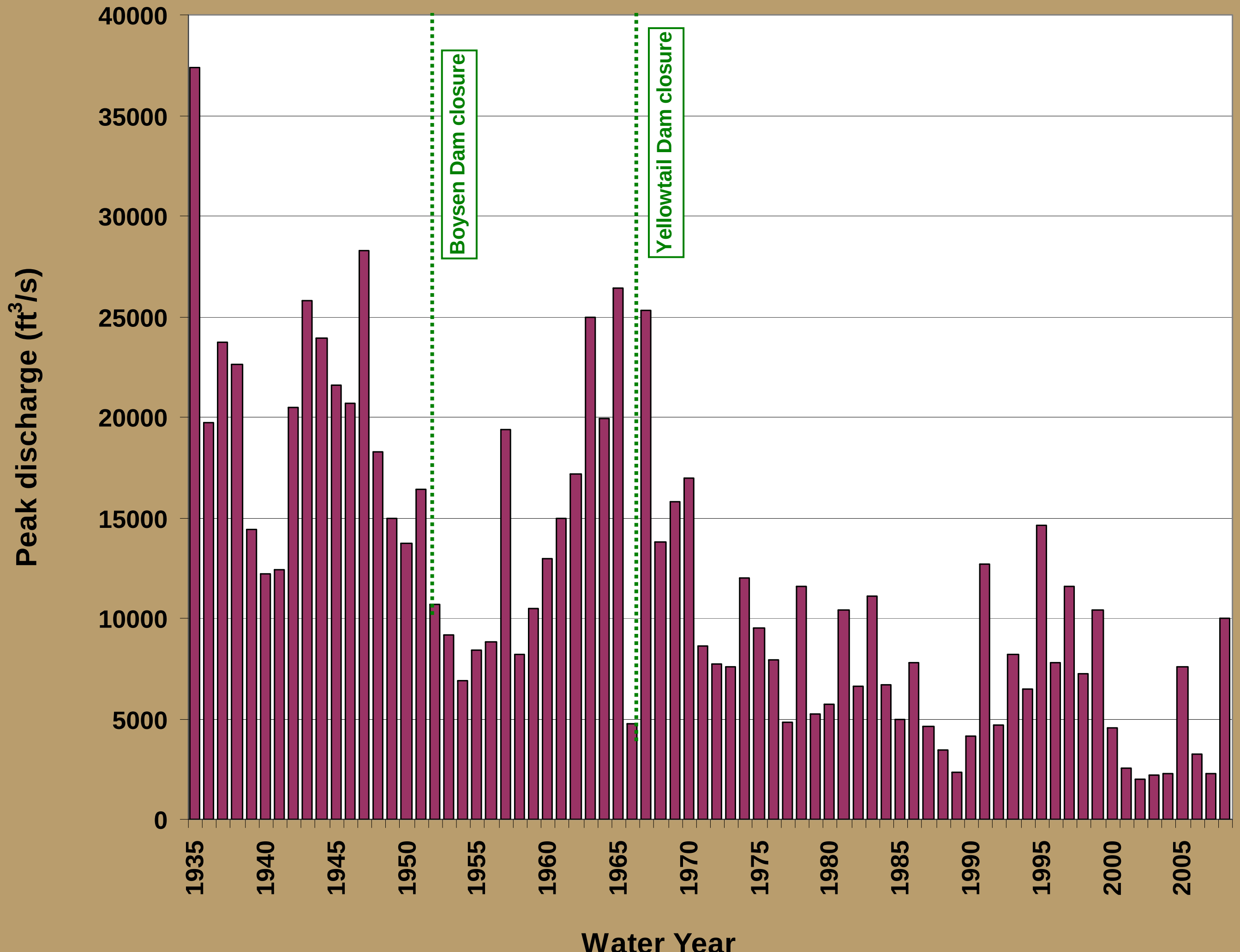
anabranching system: **"system of multiple channels with stable alluvial islands over decades to centuries that divide flow at discharges up to bankfull"**

- **Type 5 (Nanson & Knighton, 1996): gravel dominated, laterally active river sytem**
  single thread reaches separated by multiple thread reaches; dominant main channel
  slope= 0.0016
  sinuosity = 1.2



Annual peak discharge

Bighorn River downstream of Yellowtail Dam and Afterbay



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Vertical channel change

Evaluated historical changes in bed elevations:

1. **MEAN STREAMBED ELEVATION (MSBE)**
   Cross section data gathered at USGS gaging station #06287000 (1935-2000)

2. **CROSS SECTION COMPARISON**
   Cross section data gathered at three cross sections initially surveyed during the wetted perimeter study (Frazer, 1997) (1997-2009)

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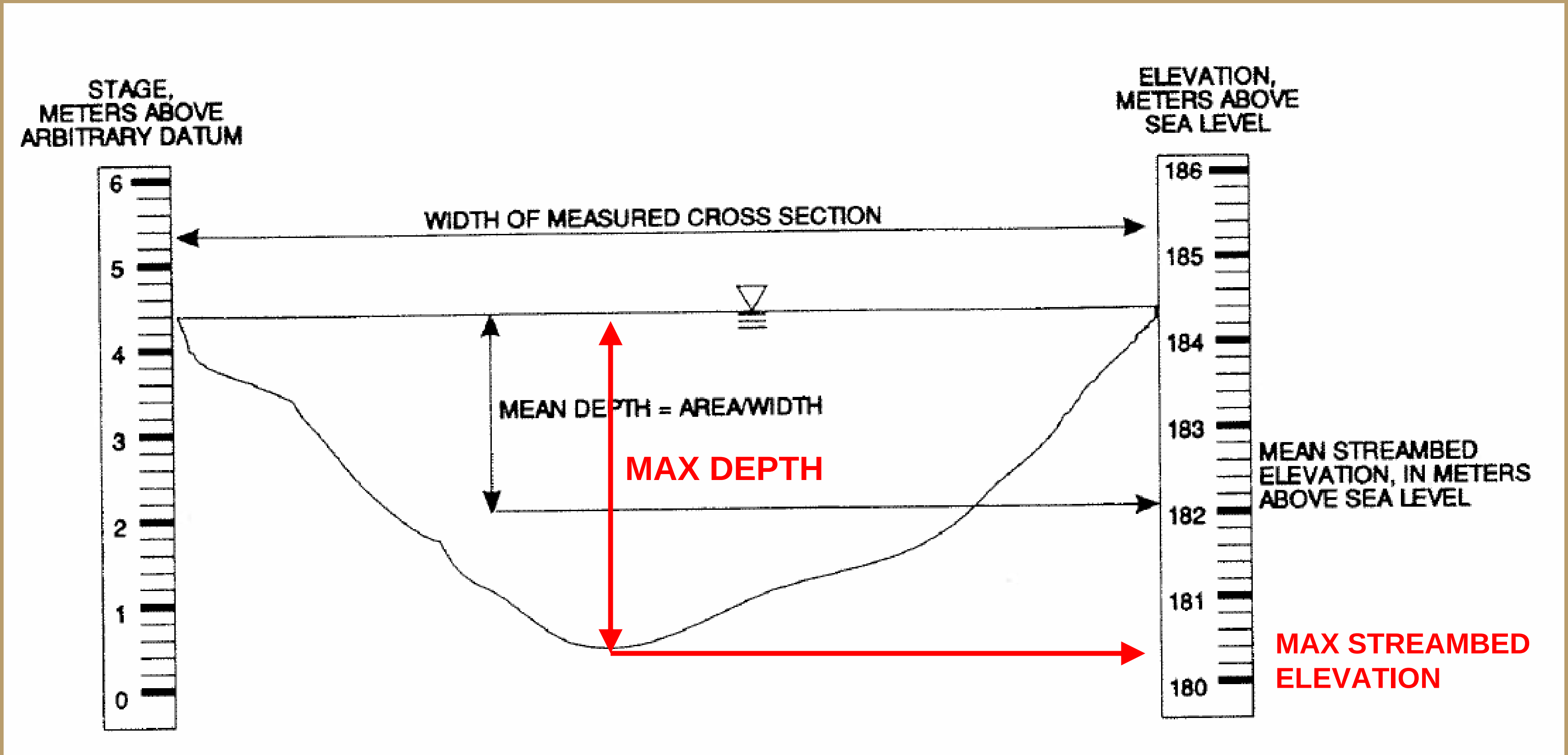
Gaging station measurements: mean streambed elevation (MSBE)



(modified from Jacobsen, 1995)

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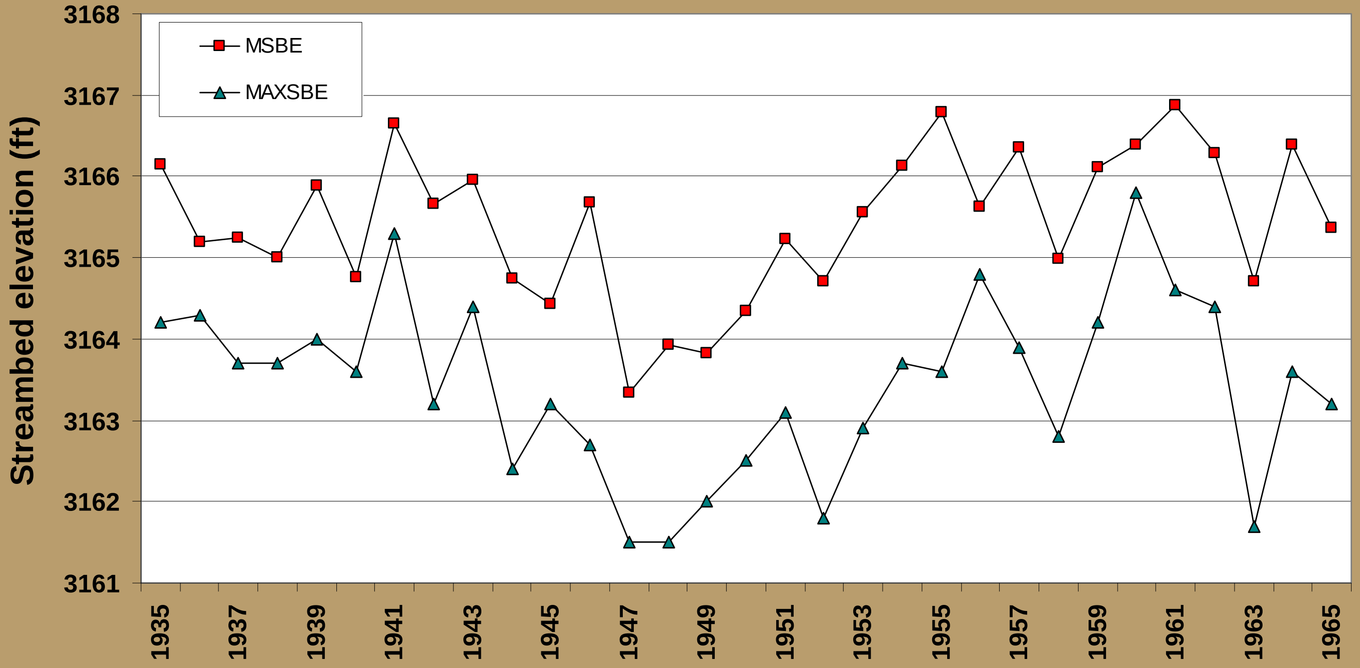
Gaging station data: 1935-1965



- Fluctuations up to 3.3 ft (MSBE) and 4.3 ft (MAXSBE)
- Parallel trends in MSBE and MAXSBE

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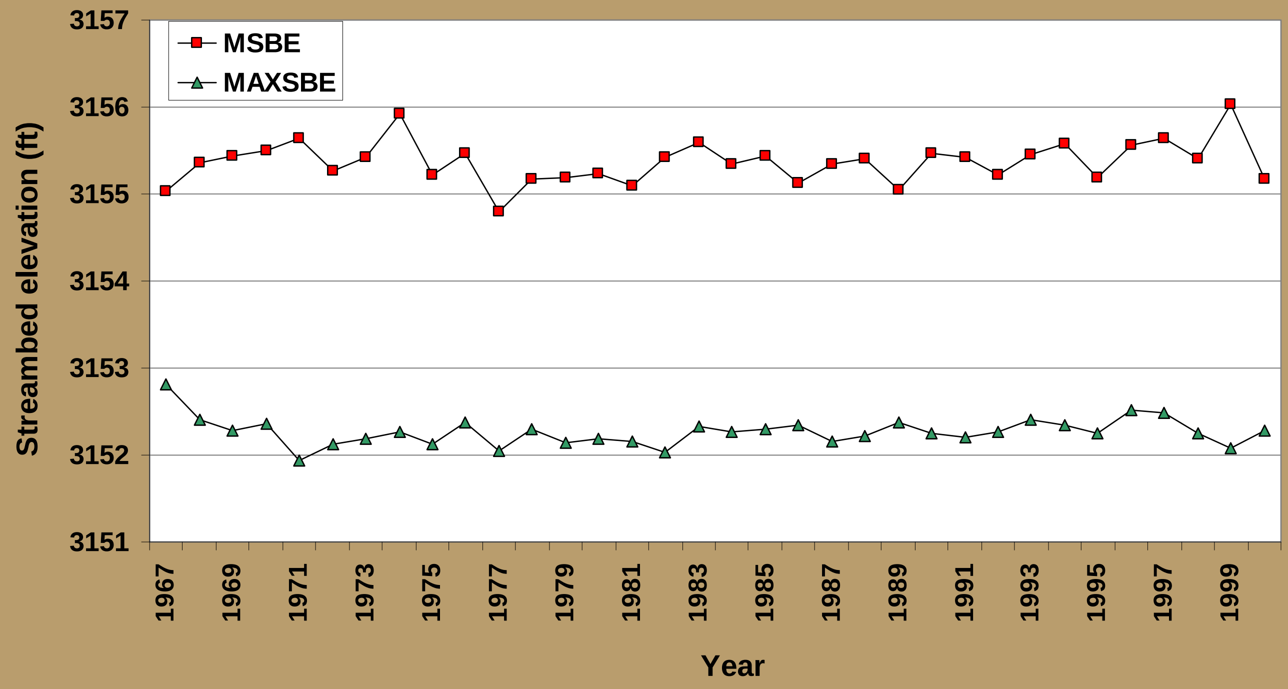
Gaging station data: 1967-2000



- Fluctuations of up to 1.2 (MSBE) and 0.9 (MAXSBE)
- MSBE and MAXSBE trends parallel each other
- Indicates stability, not incision, at gaging station cross section

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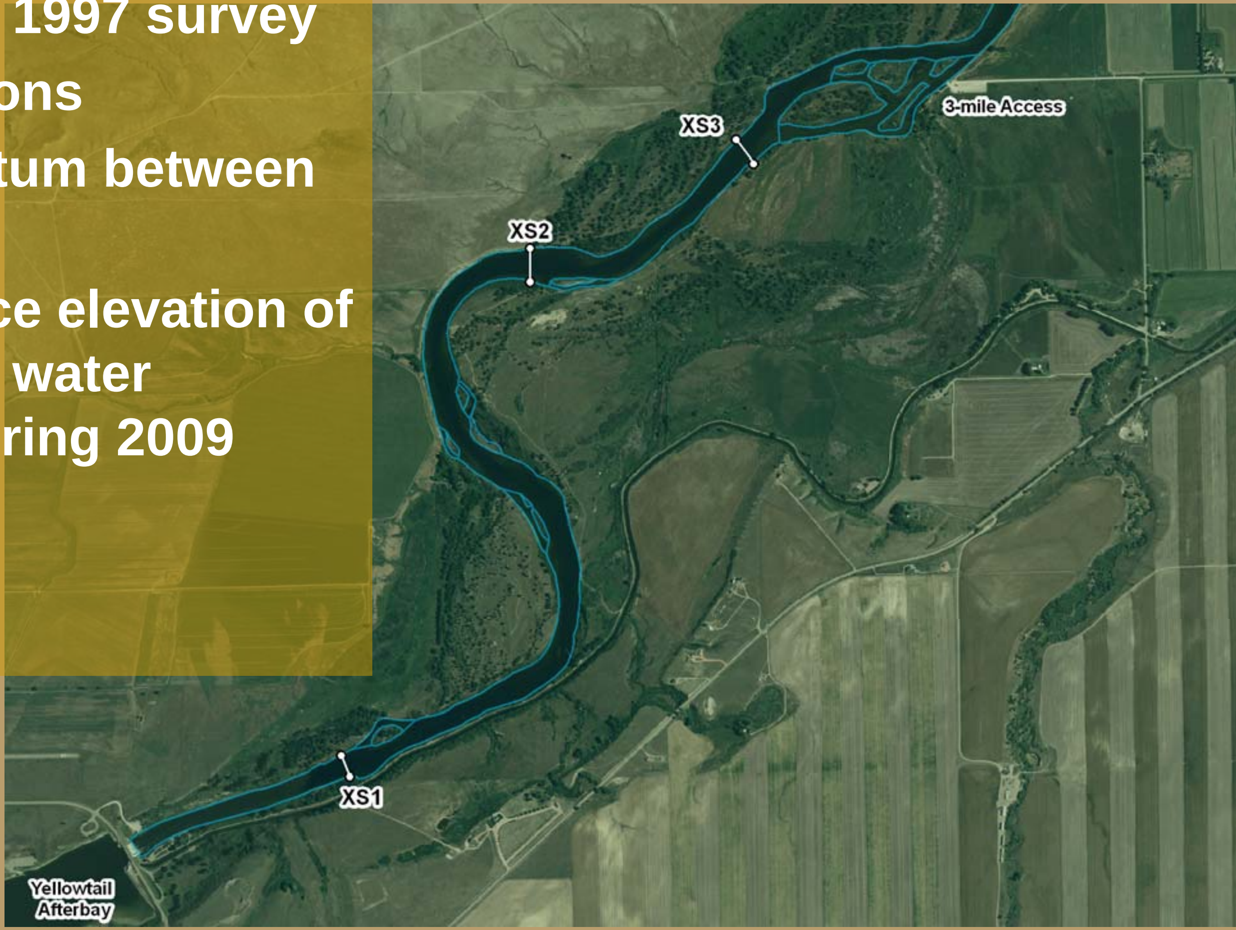
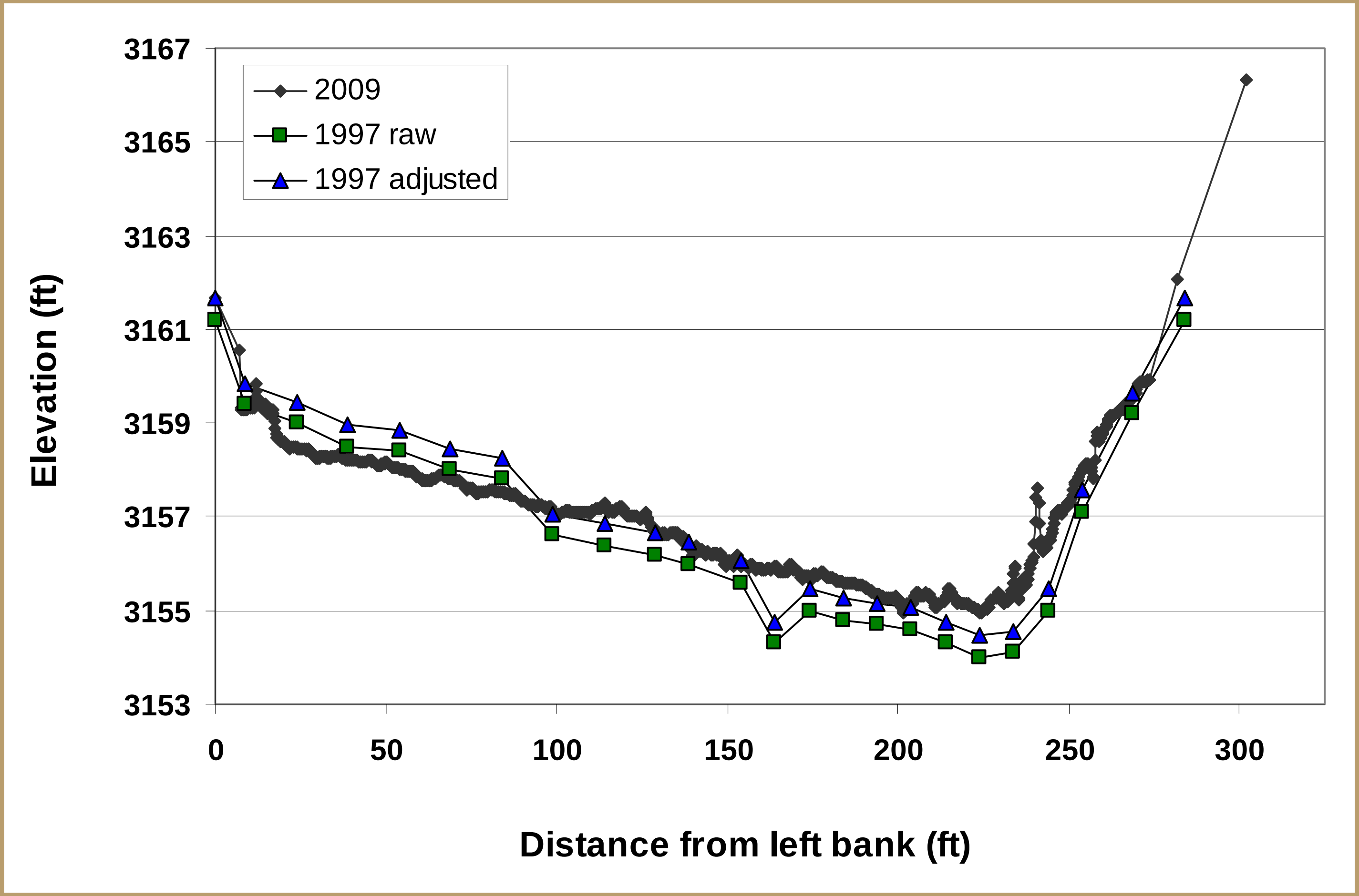
Repeat cross section survey (1997-2009)

- Benchmarks appear to have been established following 1997 survey
- Water surface elevations
  - discrepancy in datum between surveys
- Adjusted water surface elevation of 1997 survey to match water surface elevations during 2009 survey (Q_{diff} = 18%)



Cross section 1: upper section



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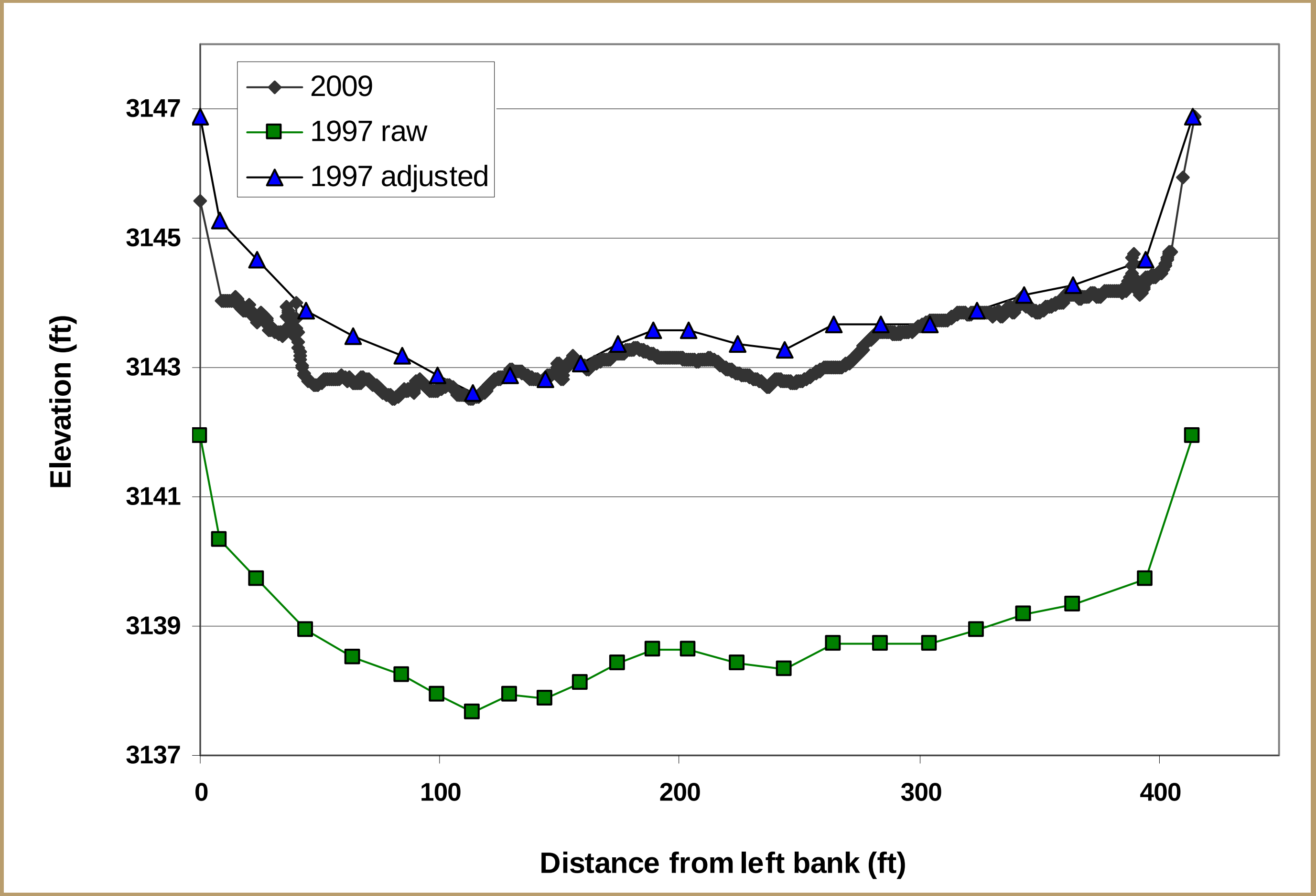
Cross section 2: middle section



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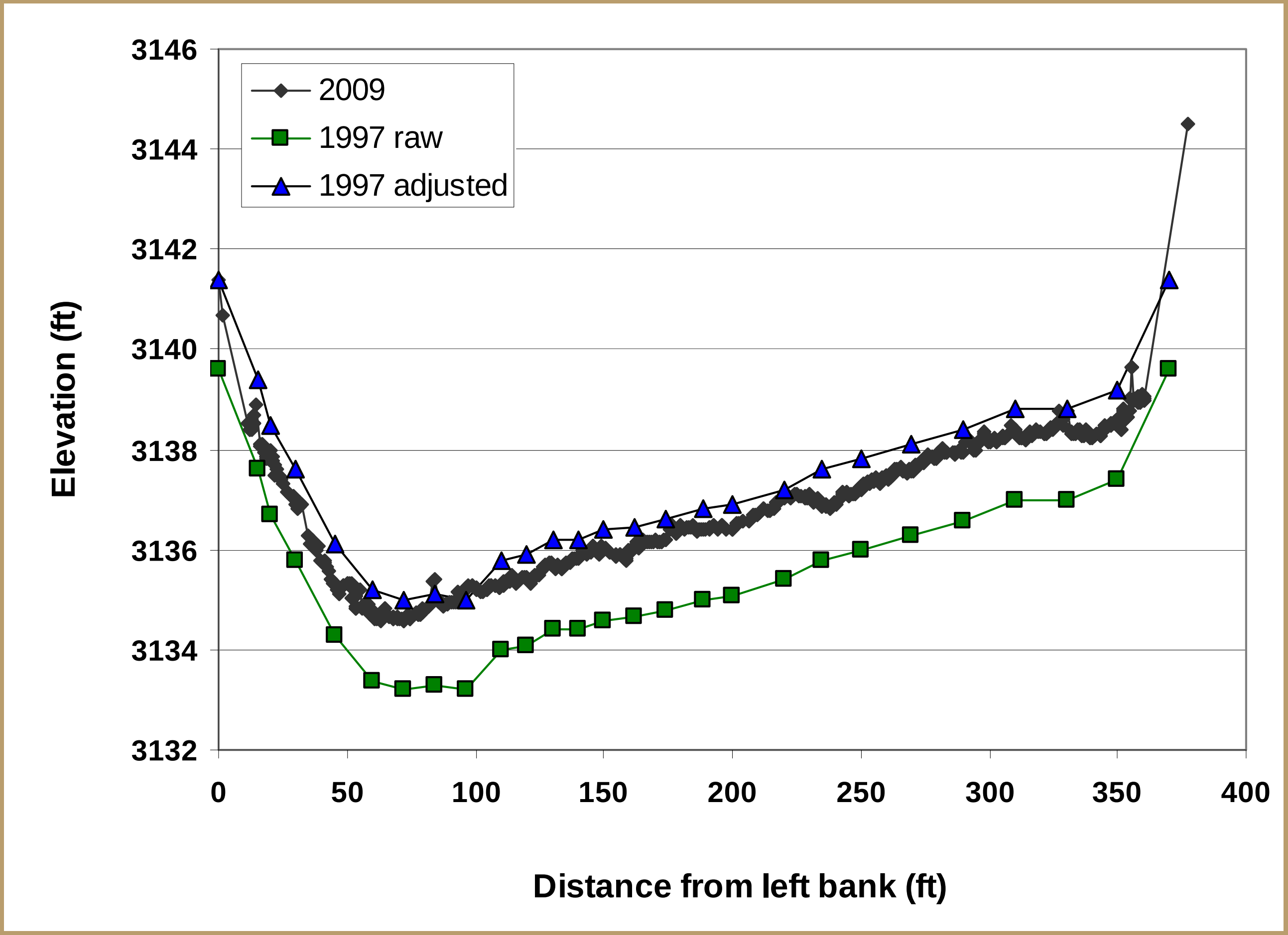
Cross section 3: lower section



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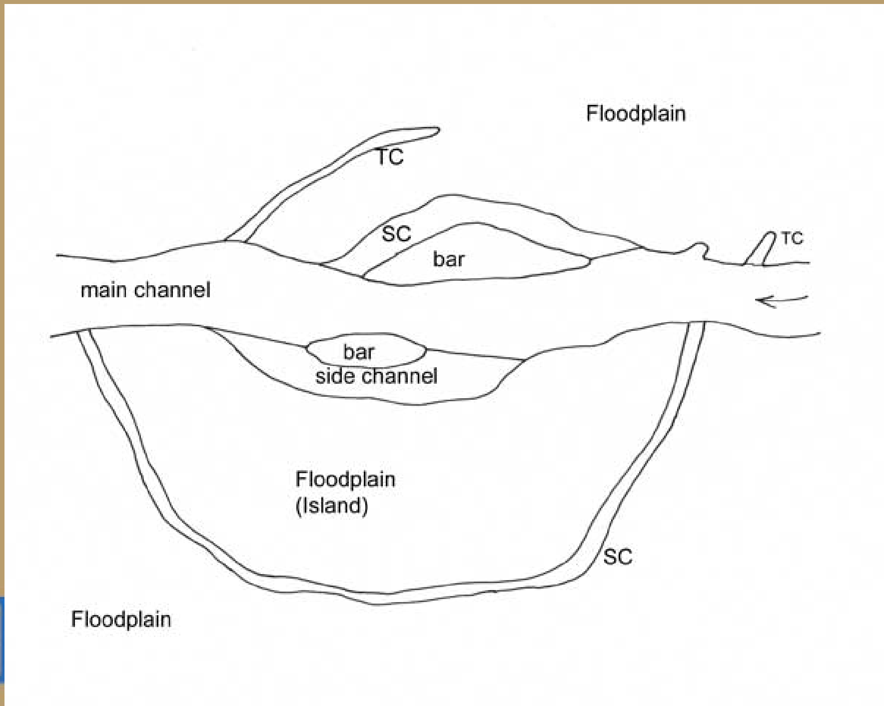
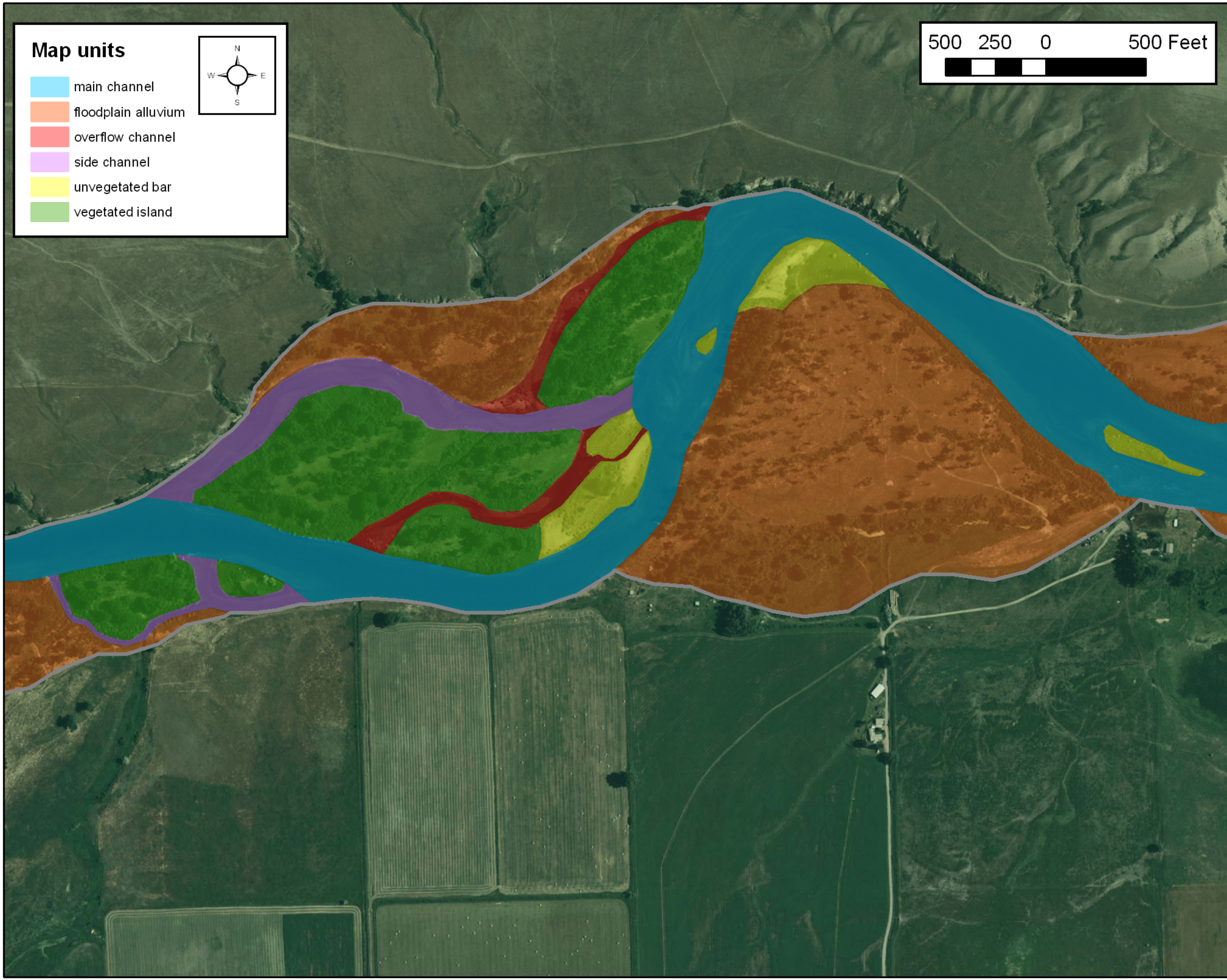
Lateral channel change: Geomorphic mapping and historical channel analysis

- 7 sets of rectified historical aerial photography
  - 1939, 1954, 1961, 1970, 1980, 1991, 2006
- Mapped main channel and side channel positions
  - Other geomorphic features such as unvegetated channel bars, vegetated islands and overflow channels
- Calculated areal coverage of geomorphic features
- Evaluation of complex history and side channel stabilization




Map units
main channel
floodplain alluvium
overflow channel
side channel
unvegetated bar
vegetated island
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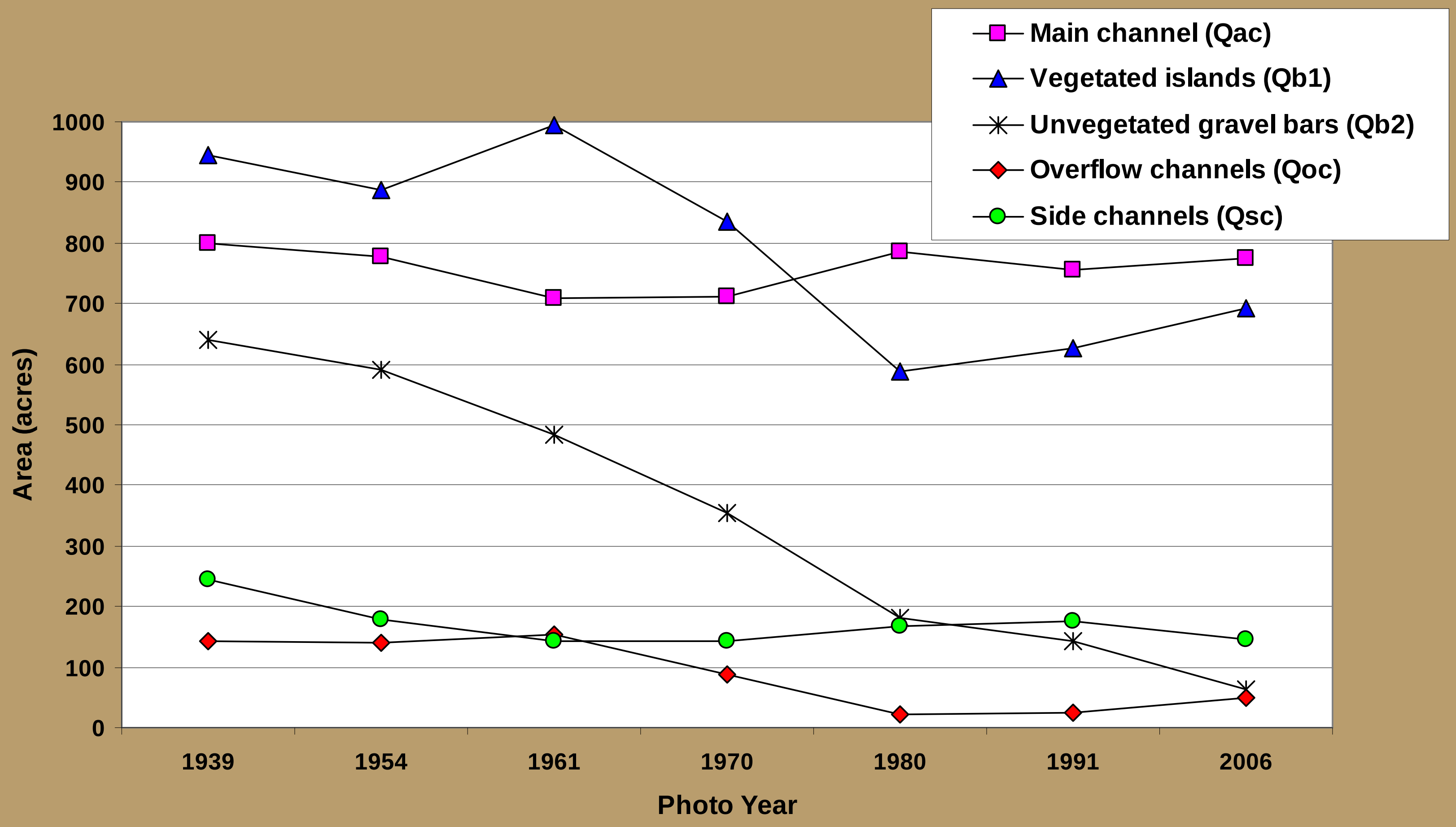
500 250 0 500 Feet

Trends in mapped features



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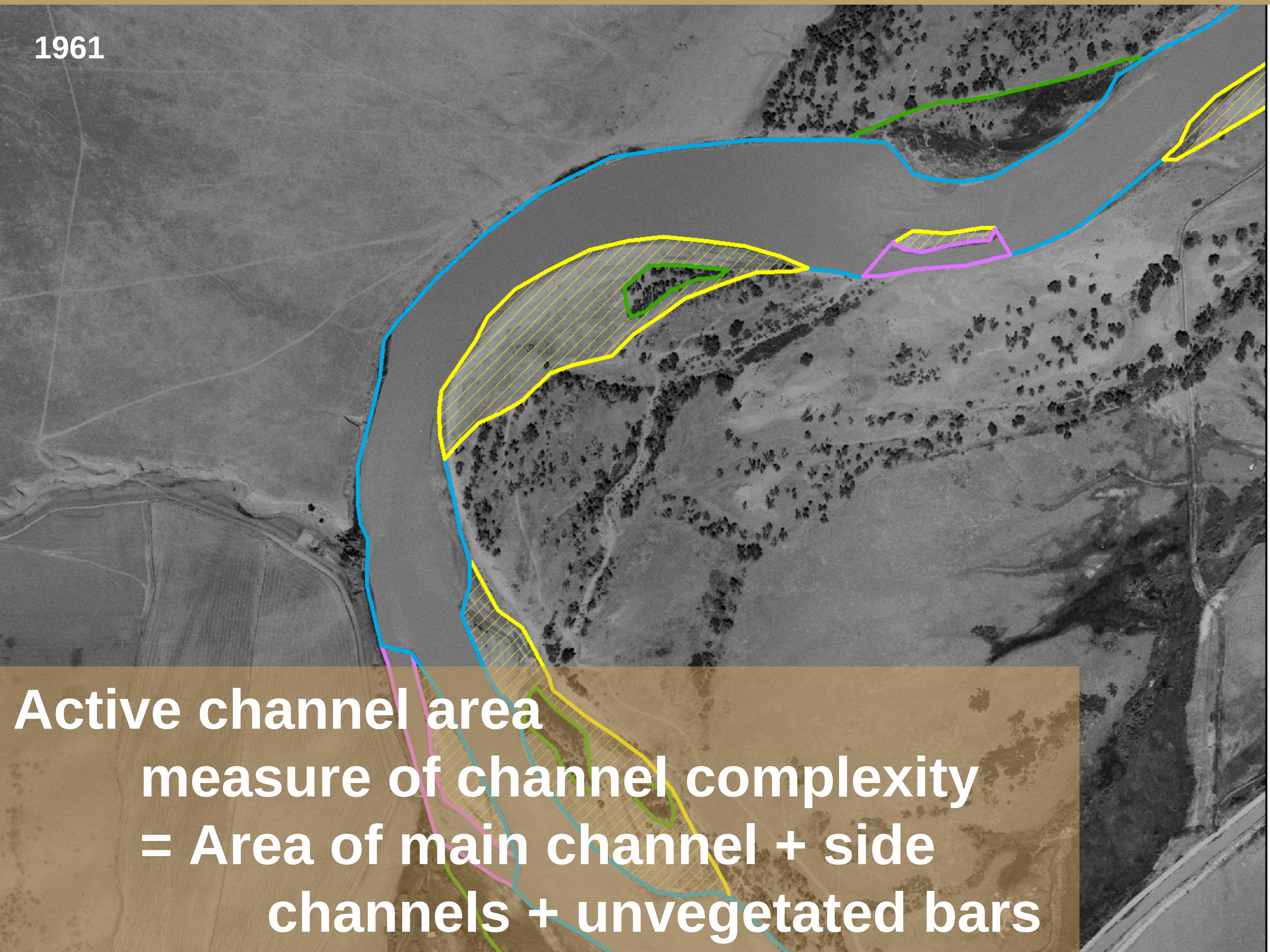

Active channel area

measure of channel complexity

= Area of main channel + side channels + unvegetated bars

Active channel area

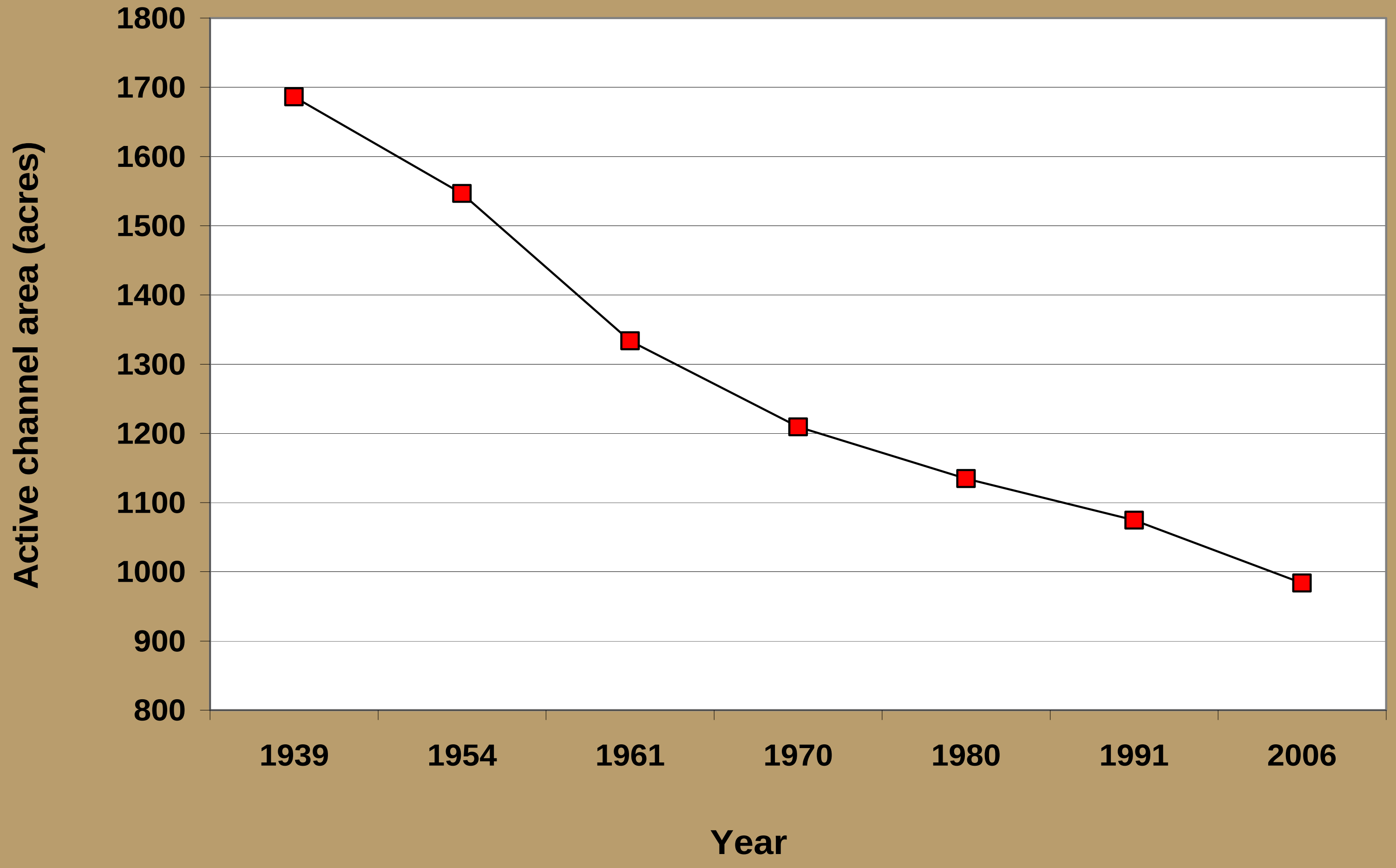

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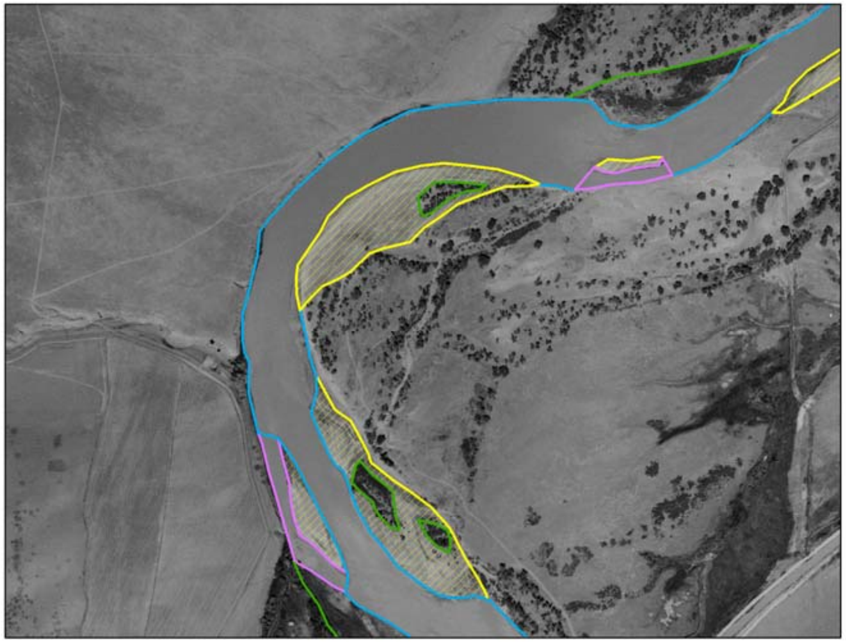
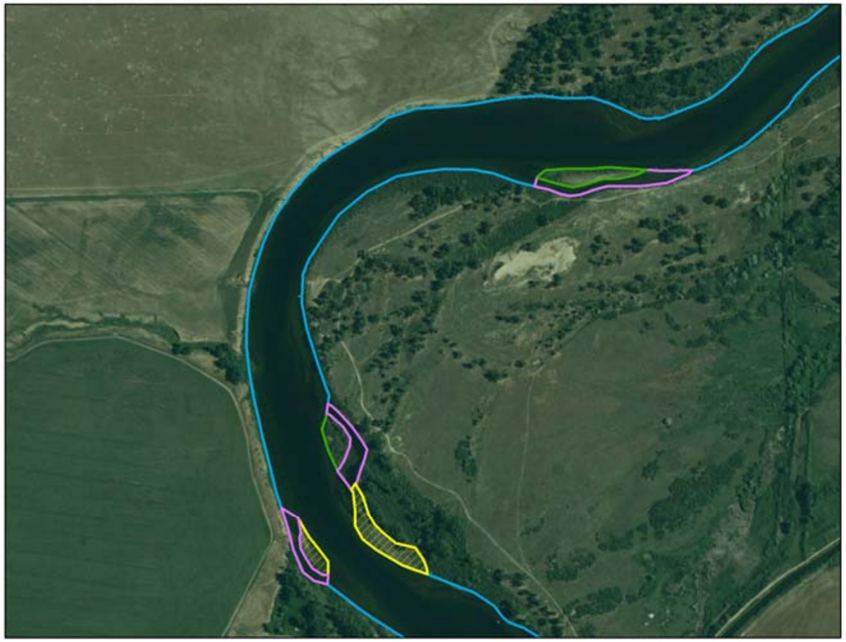
Illustration of active channel area



1961



2006

- **1961-2006: Vegetation growth on unvegetated gravel bars (shown in yellow)**

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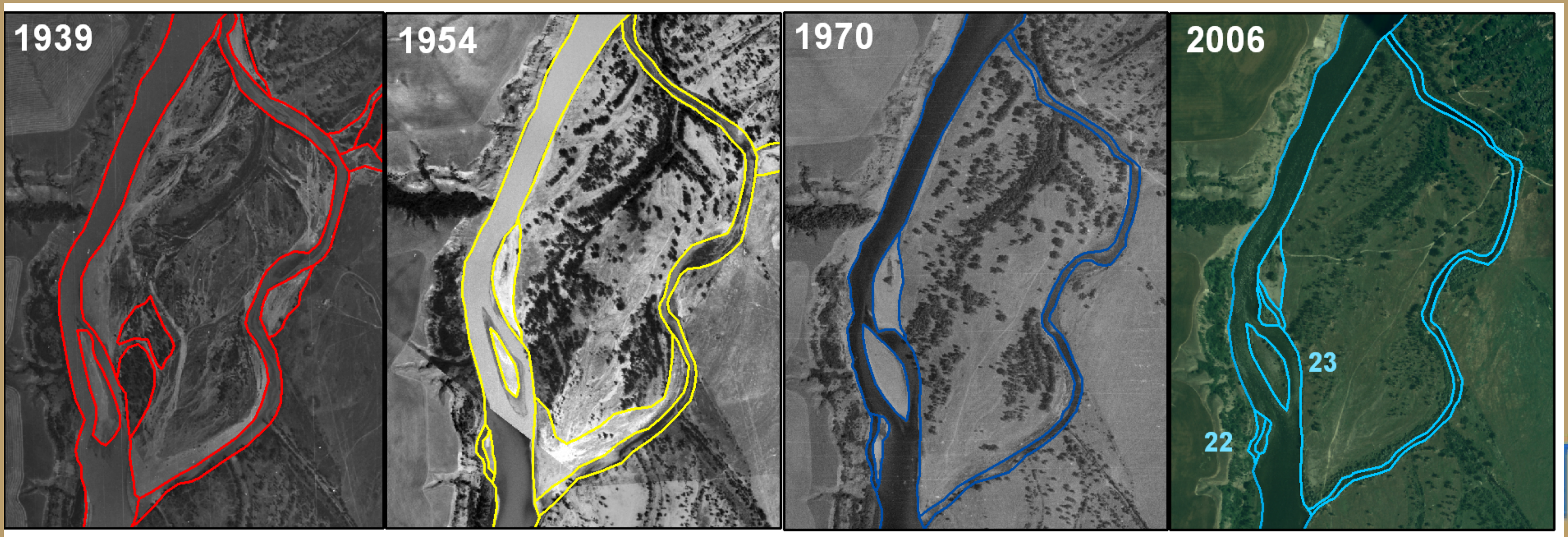
Channel complex histories

- Nomenclature from FWP studies; added channel complexes downstream of RM 16
- Channel change of main stem and side channels from 1939-2006
- Period in which 2006 channel pattern developed or stabilized

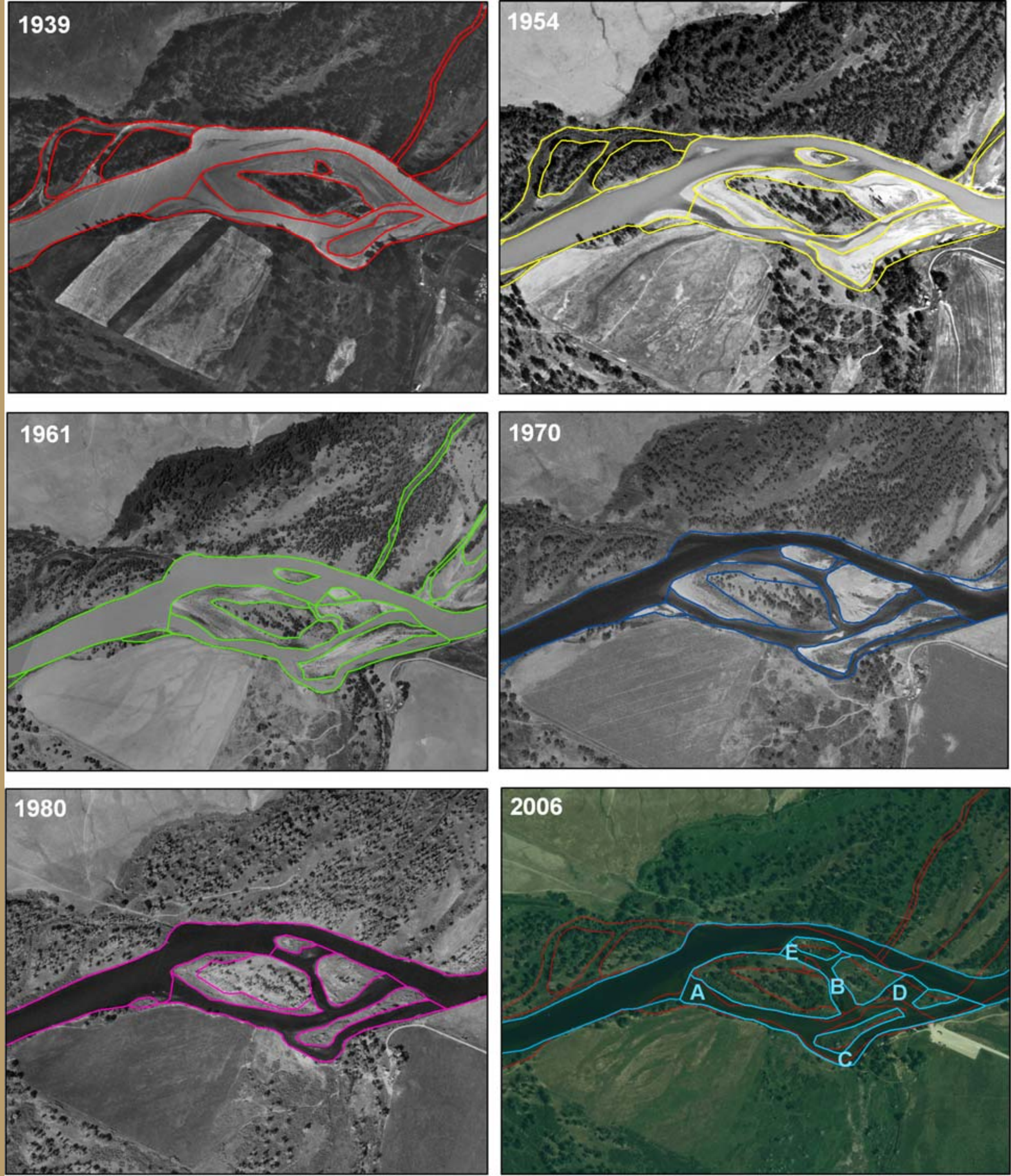


Complex 6

general configuration since 1939

Side channels stabilized by 1970

Vegetation growth on bars from 1970-2006



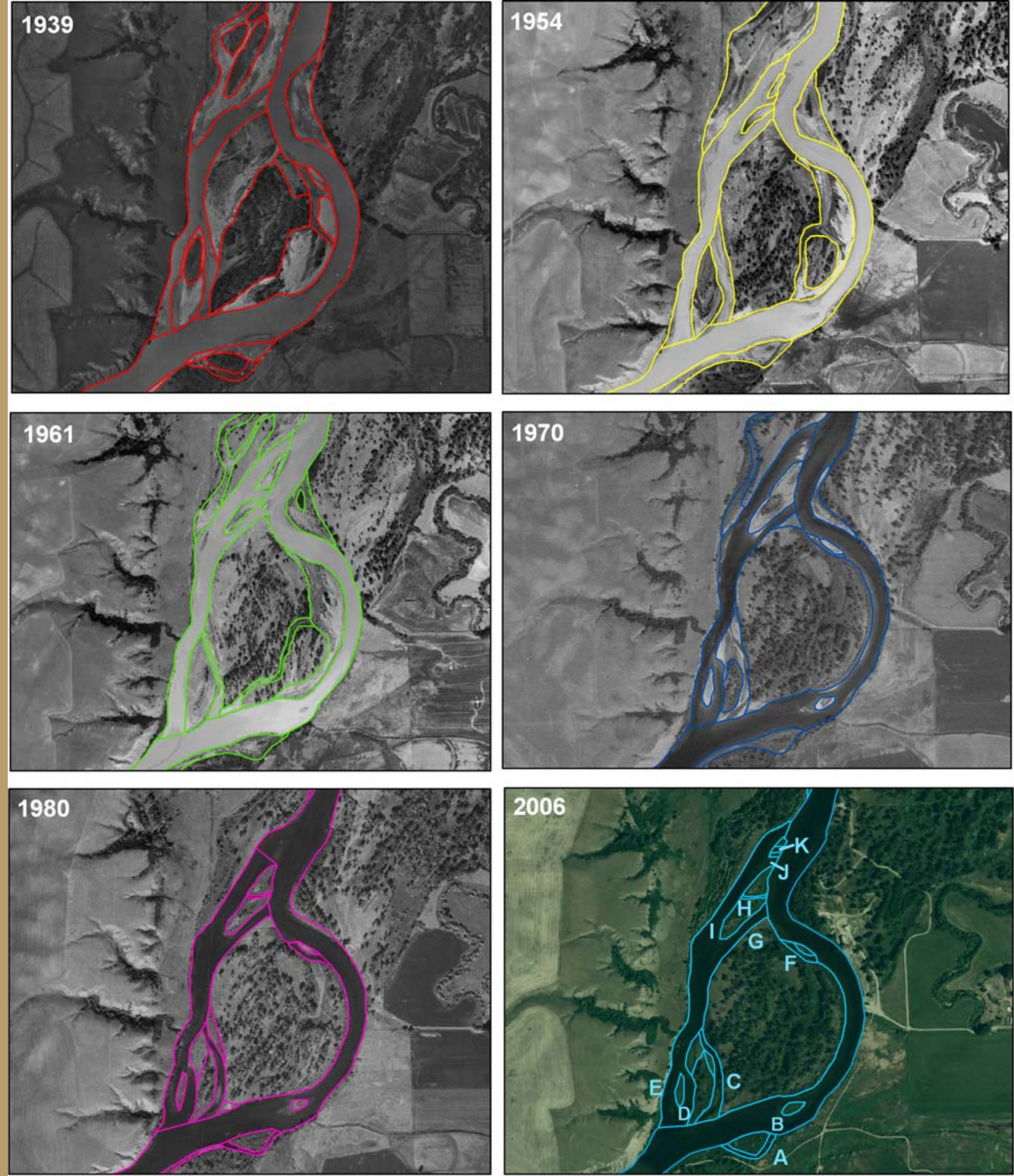
Complex 12

General channel configuration since 1939

All side channels established by 1980

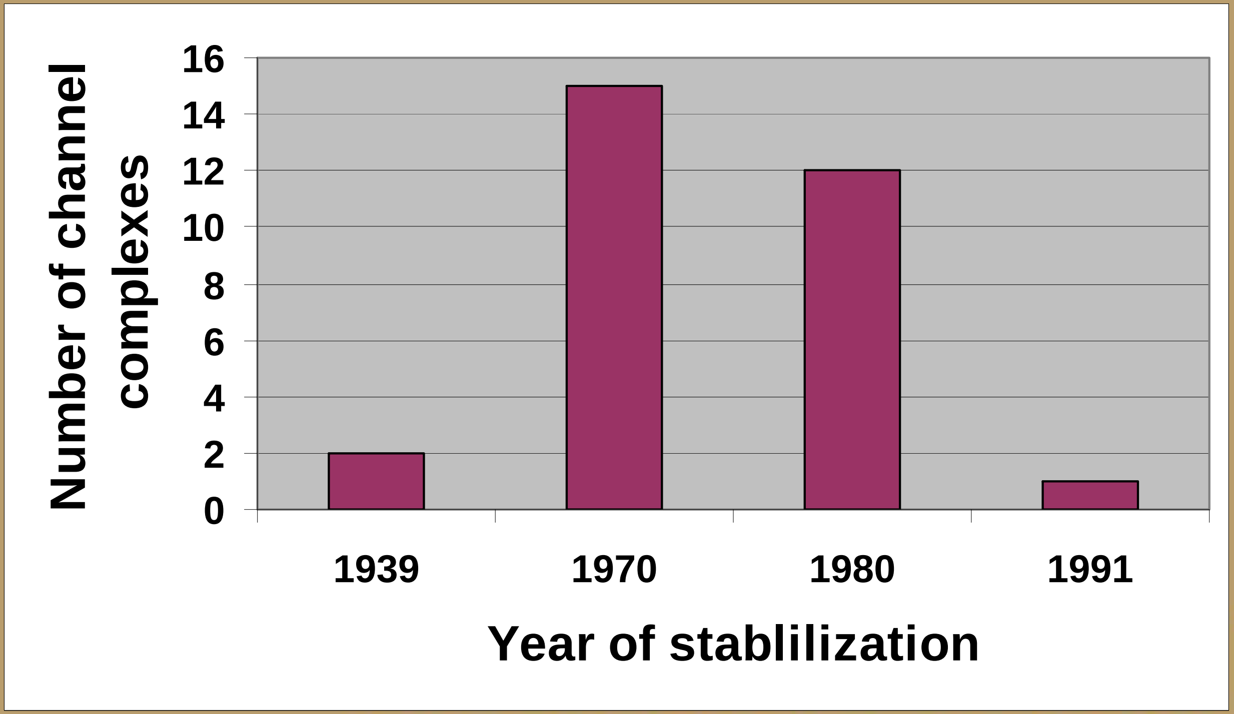
Vegetation growth on large island and some smaller islands

Formation of new channels between 1980 and 2006 (12J and 12K)



Stabilization of channel pattern

- Most channel positions “fixed” by 1980
- General channel configurations in place by 1961; 1939 in some locations
- Indicates a very stable channel planform; some side channels have been in their current locations for at least 70 years



Side channel 1

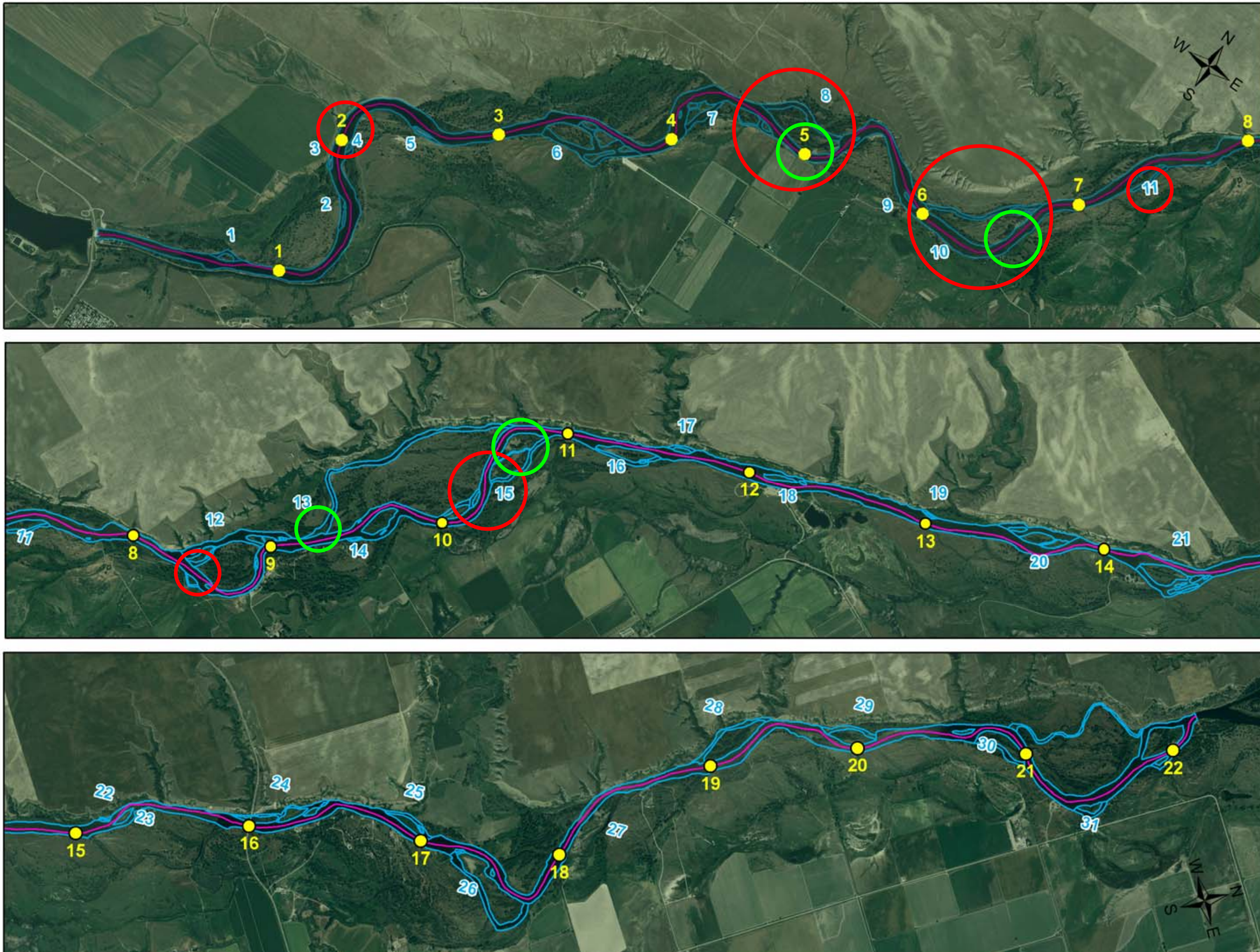
1939

2006

- **1939: side channel 1 in 2006 position; several overflow channels**
- **2006: overflow channels have filled in; vegetation of mid-channel bar**

Side channel loss 1961-2009

- Abandoned
  - No flow during 2009 field surveys (3,000<Q<4,000 ft^3/s)
  - Vegetation establishment at side channel entrances
  - Backwater and fine sediment accumulation at mouth
- At risk of abandonment
  - Shallow flow at entrance
  - Discontinuous flow
  - Sediment deposits
  - Vegetation establishment



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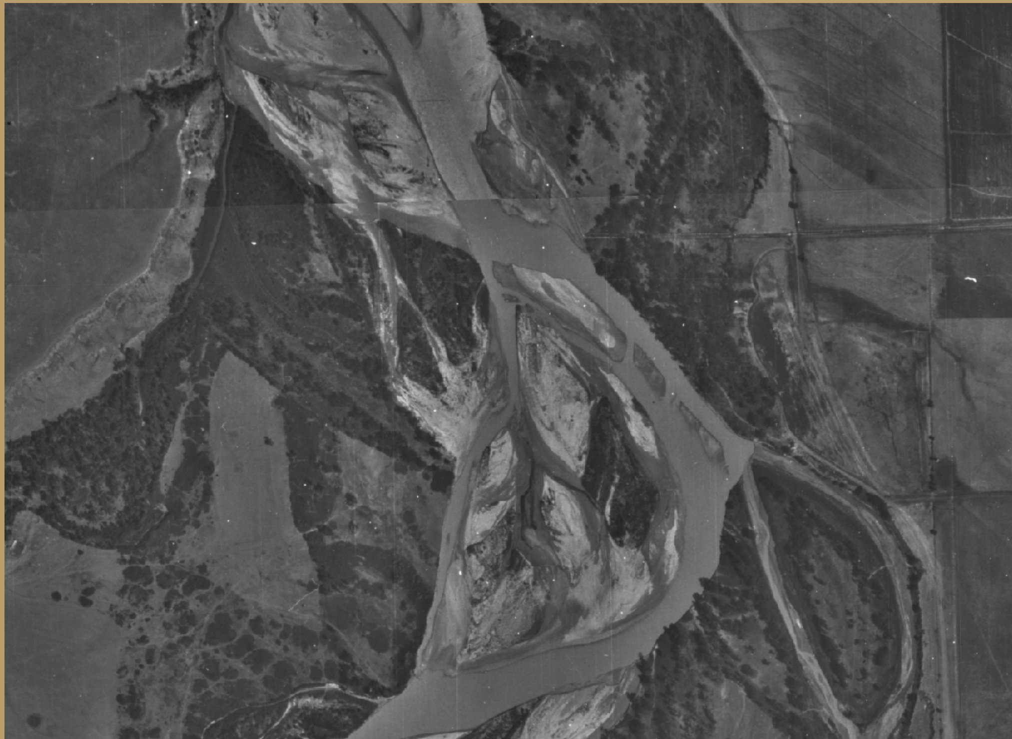
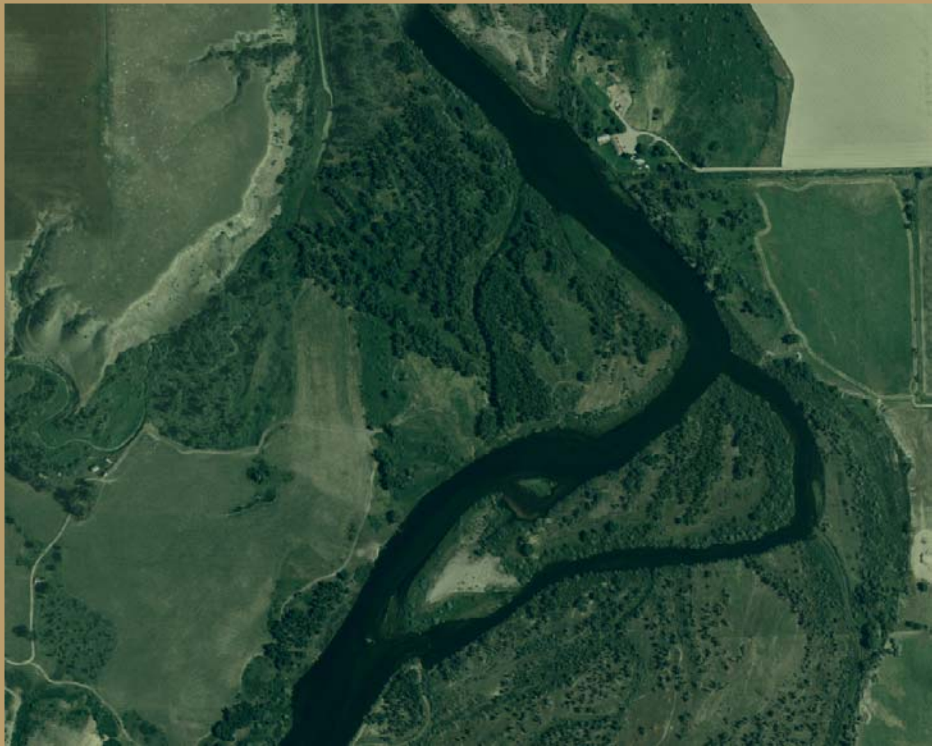
Process of side channel abandonment

- **Pre-Yellowtail Dam (pre-1966)**
  - **laterally active channel with highly variable flow regime and high sediment load**
  - **Erosion-based channel forming process = channel avulsion, causing the creation of new side channels and overflow channels**



Side channel abandonment (continued)

- **Post-Yellowtail Dam (1966-2009)**
  - Reduced peak discharge and sediment supply results in lower potential for lateral channel change and bed scour
  - Sediment retention in side channels, accretion of bed
  - Sediment berms at side channel entrances formed as natural levees by main channel lower flows
  - Vegetation encroachment: further reduces velocities and ability to scour side channels

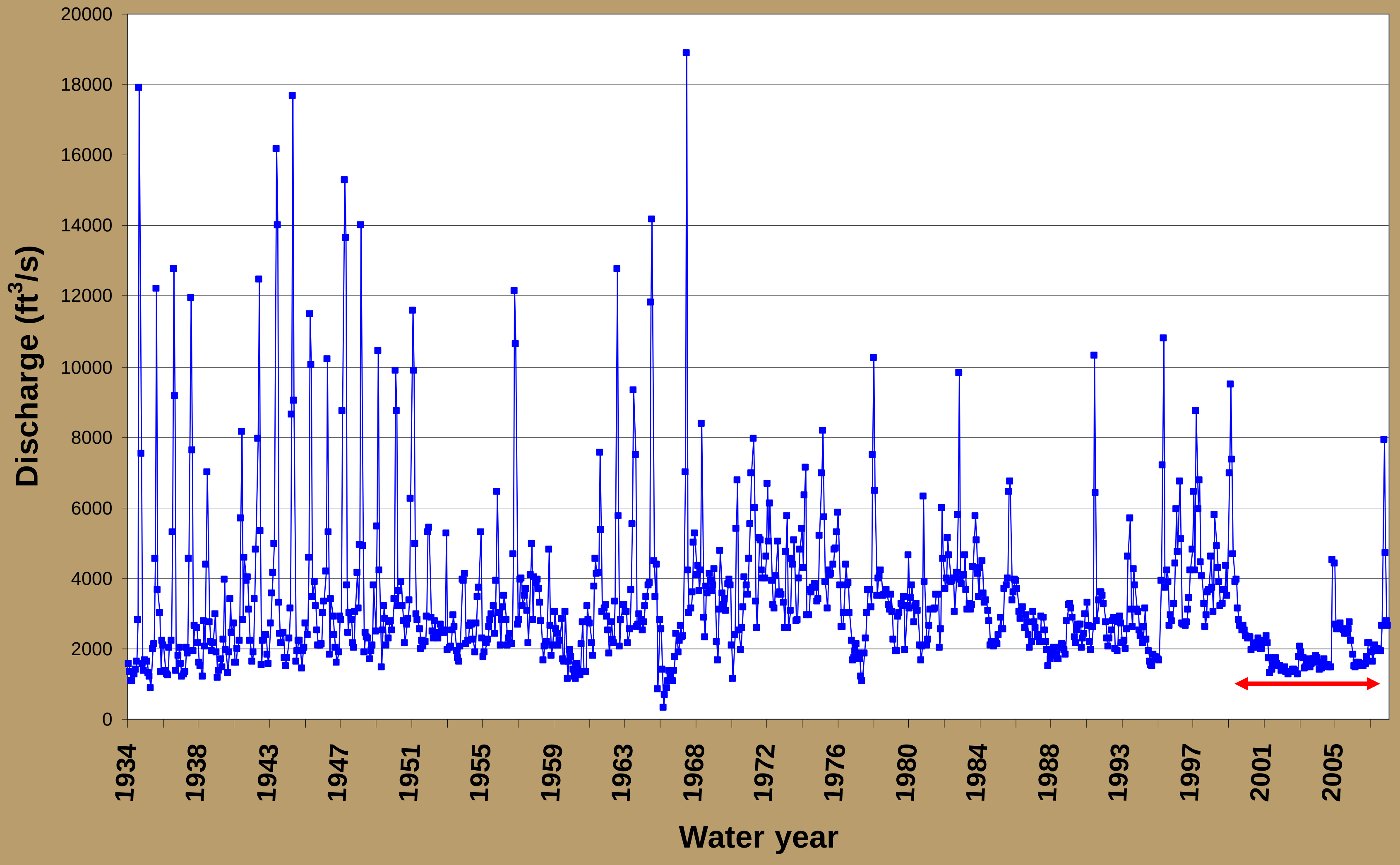


Channel change: Complex 13

1991 (Q=3030 ft^3/s)

2006 (Q=1990 ft^3/s)

Monthly mean flow: 1935-2008



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Observations of the June, 2009 Peak Discharge (12,800 ft^3/s)

Summary

- Cross section data show evidence of stability rather than incision or lateral migration
- Geomorphic mapping reveals dramatic reduction in active channel area, driven primarily by a decrease in unvegetated gravel bars; main channel area and side channel area have remained similar
- Channel configurations were “fixed” in place about one decade following dam construction (1970-1980)
- Side channel loss is occurring by sediment deposition and vegetation encroachment in channels

Side Channel Investigations
Fiscal Year 2010

- Geomorphic Analysis
- Hydraulic Modeling: discharges required to inundate critical side channels
- Evaluation of Alternatives

Bathymetric Survey

- **Side channels were surveyed on foot in late April and early May 2009 (over 6,600 points).**
- **Real Time Kinematic (RTK) Global Positioning Satellite (GPS) surveying equipment was used.**

Bathymetric Survey

- The main river channel was surveyed with SONAR in Apr/May 2009
  - MT Fish Wildlife and Parks provided the boat and driver – thanks to Earl Radonski for great driving
- We used an Acoustic Doppler Current Profiler (ADCP) to obtain depths.
  - Individual depths from four beams were obtained for each ‘ping’ or ‘ensemble’.
- RTK GPS survey equipment was used to obtain position and elevation.
- Discharge was approximately 4500 cfs during this survey

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Bathymetric Survey

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Bathymetric Survey

- **An additional survey was performed in August 2009 to fill in some missing data**
- **Discharge was approximately 3000 cfs during this survey**
- **The hydraulic model will be verified with water surface elevations from these two surveys.**

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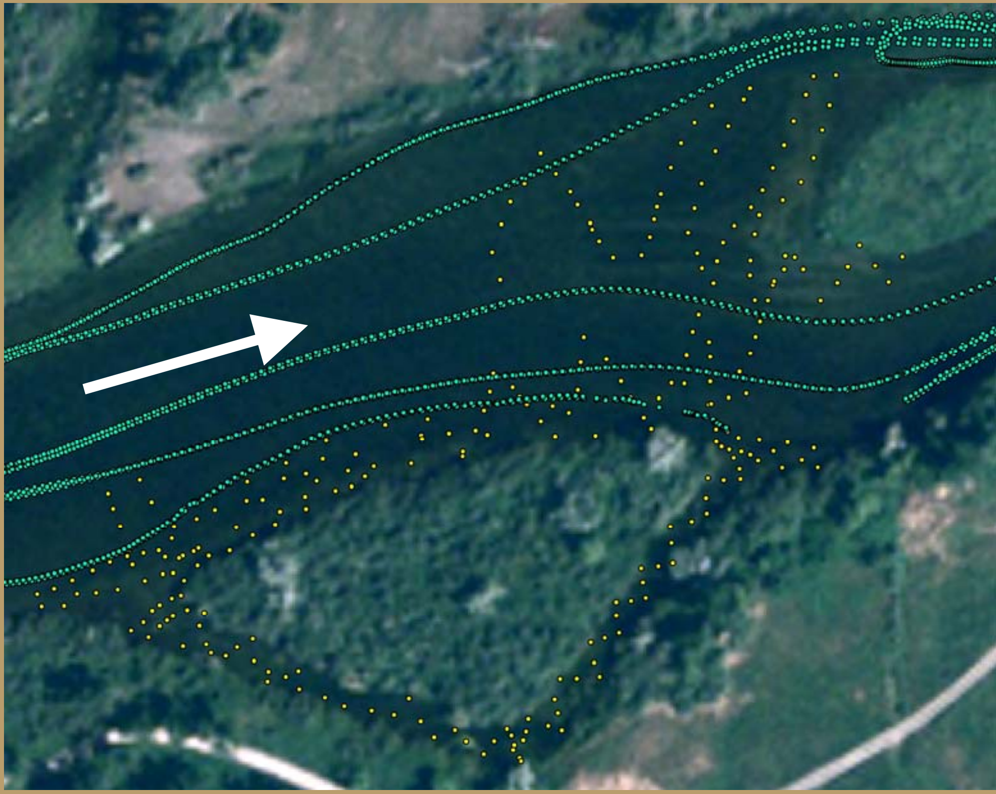
Bathymetric Survey



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Aerial Data

- We have acquired topographic information flown with Synthetic Aperture Radar (SAR)
- Flight dates are reported as December 2008 – July 2009
- Stated accuracies are 5 meters in the horizontal and 1 meter in the vertical
- This is less than desired for building a terrain surface for a 2D hydraulic model
  - However this could be made to work in LiDAR is not flown
- Model accuracies will necessarily suffer if the SAR data is used.

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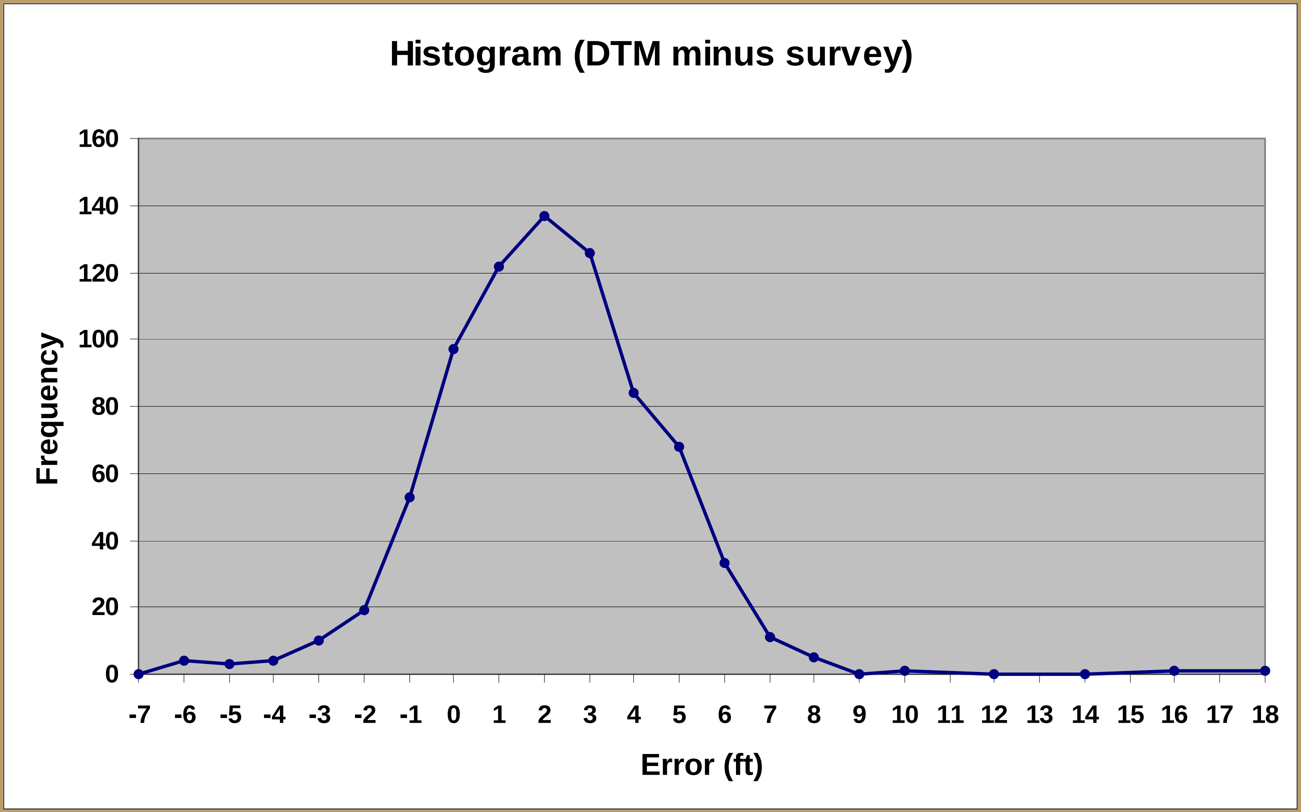
Aerial Data

- Mean Error = +1.6 ft
- Std. Dev. = 2.4 ft
- n = 779



The primary concerns regarding these data is the misrepresentation of the height of the islands and the overall channel width, however:

- **Approximate horizontal error is 4 – 6% of the overall channel width.**

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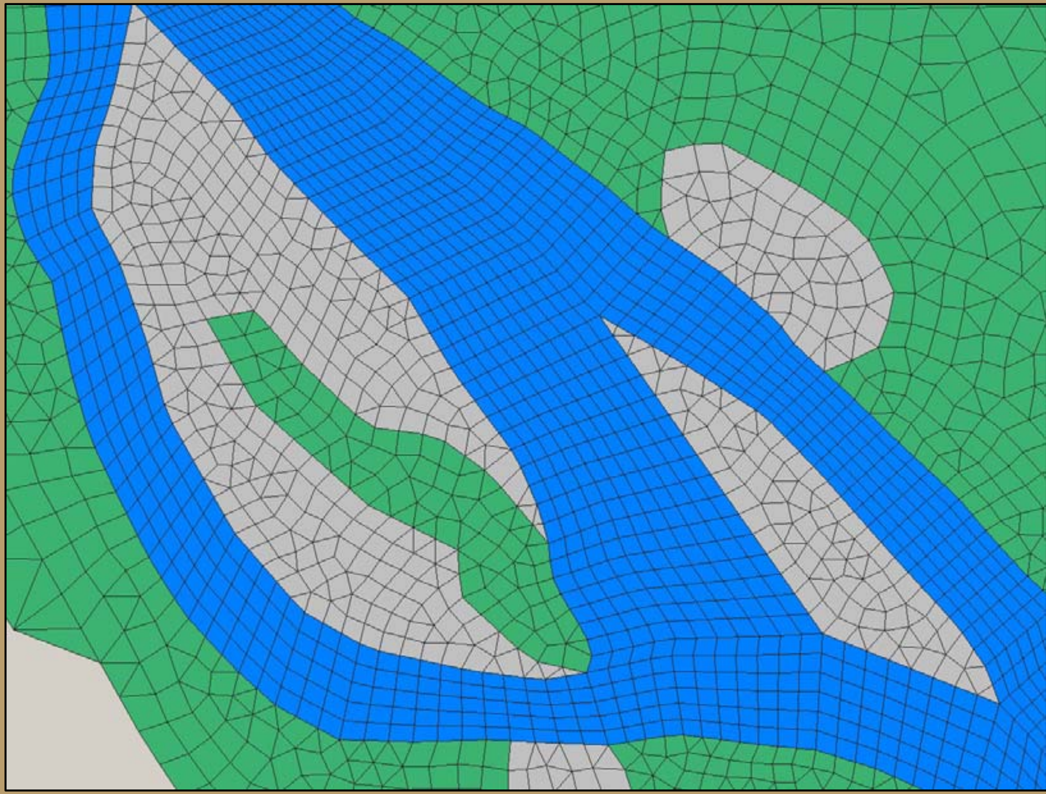
2-Dimensional Depth Averaged Modeling

- **Benefits:**
  - Able to model split channel flow and complex flow dynamics
  - Can specify varying roughness values for different areas of the model
  - Allows user to examine conditions at any point on the river rather than just at measured cross sections

Example of Mesh generation



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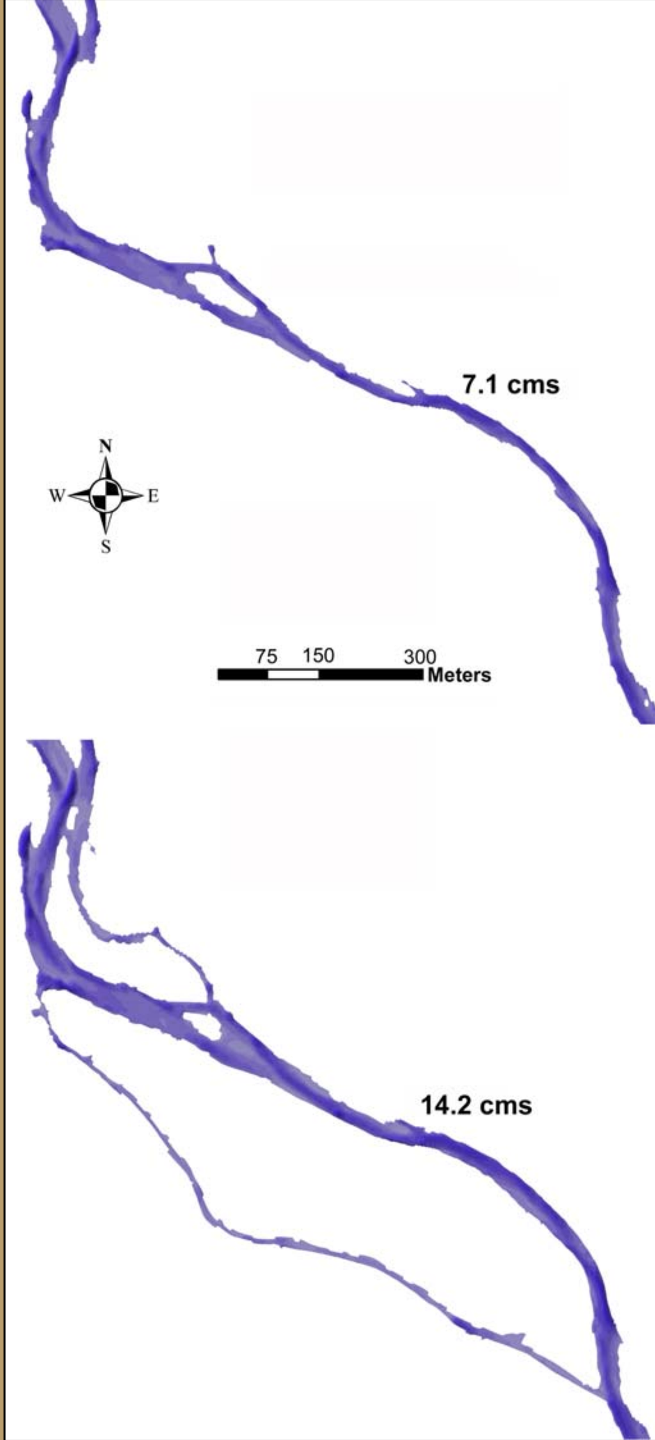

Hydraulic Modeling

- Will provide information on flows that will activate side channels
- Inputs:
  - River geometry
    - Bathymetric survey
    - Topographic survey
  - Channel roughness
    - Index of surface roughness; resistance of surface to water flow
  - Discharge
    - Range of flow values required to wet and inundate side channels to specified depths and velocities

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