Integrating high-resolution vegetation data and 14 years of topographic surveys to quantify impacts to sandbar campsites, Grand Canyon National Park

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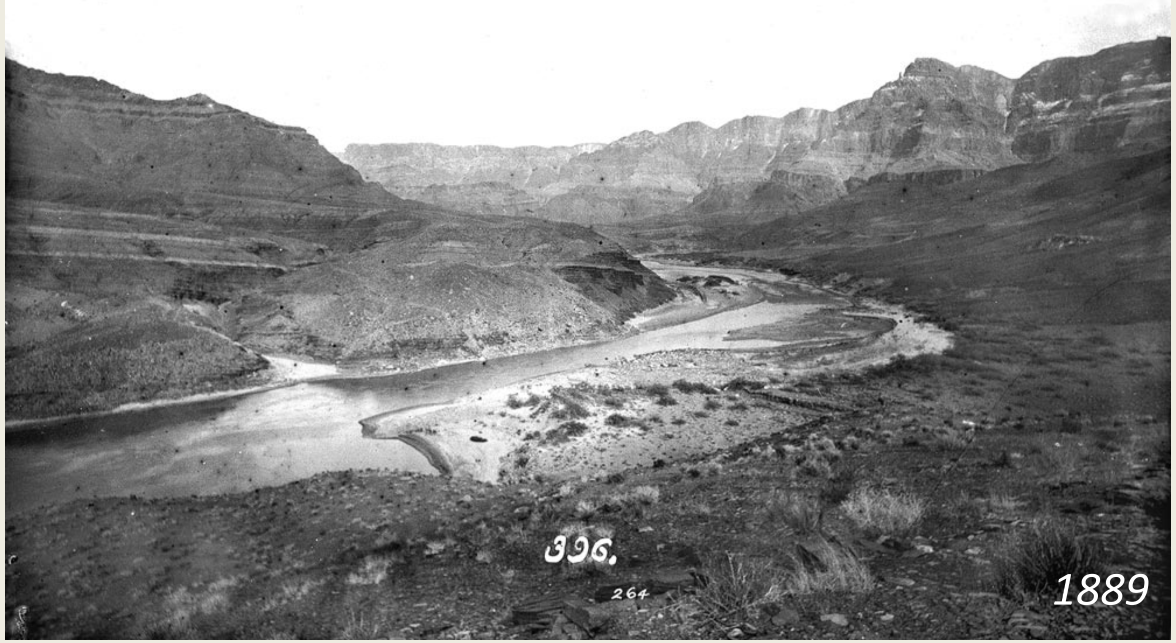
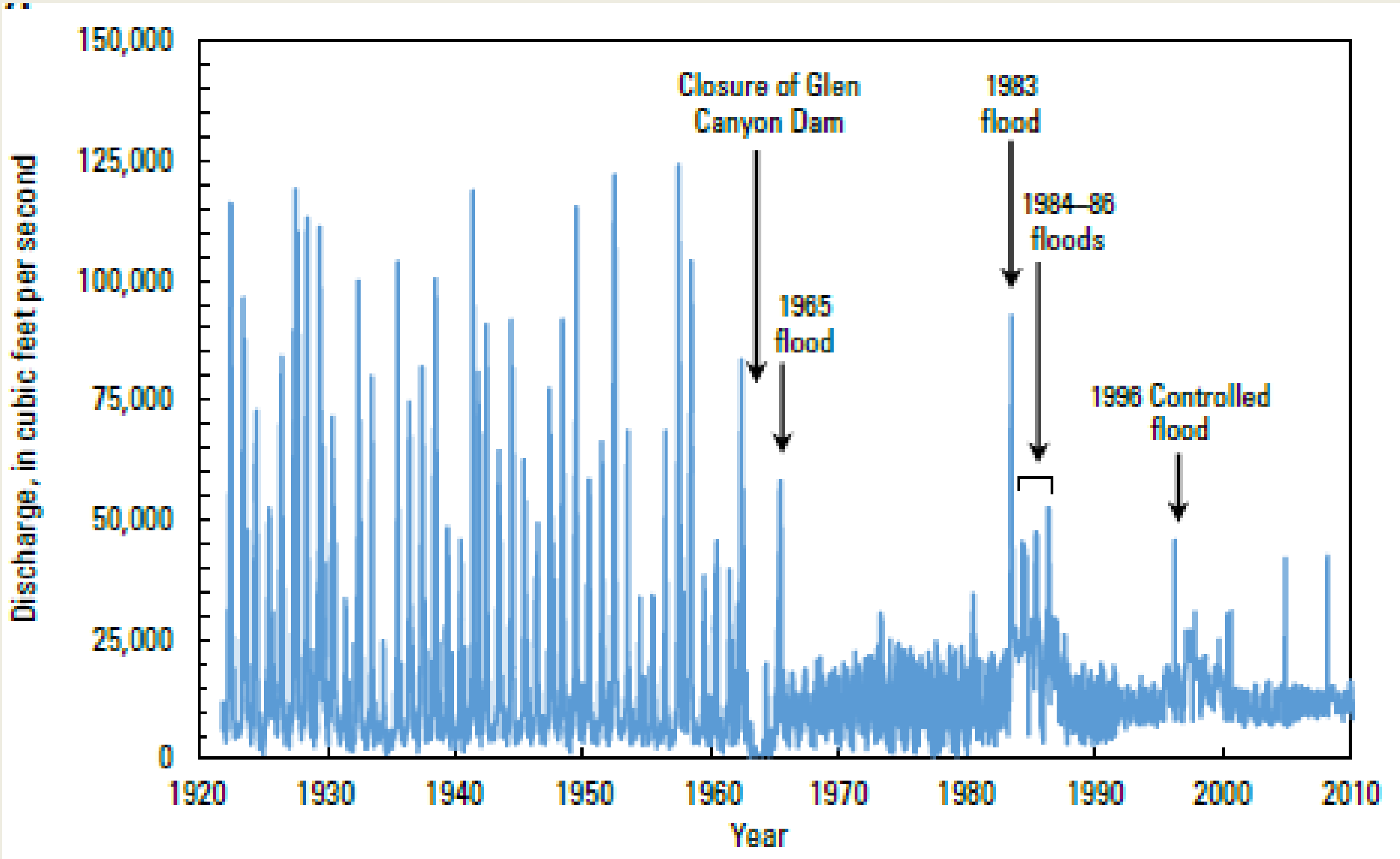


Cardenas Hilltop, RM 71.3

USGS Desert Laboratory Repeat Photography Collection

Background

- Glen Canyon Dam constructed in 1963
- Erosion of sandbars due to lack of sediment replenishment
- Vegetation encroachment due to lack of flooding
- Reduction in size and number of sandbar campsites, a vital recreational resource
- Controlled floods primary management strategy to replenish sandbars



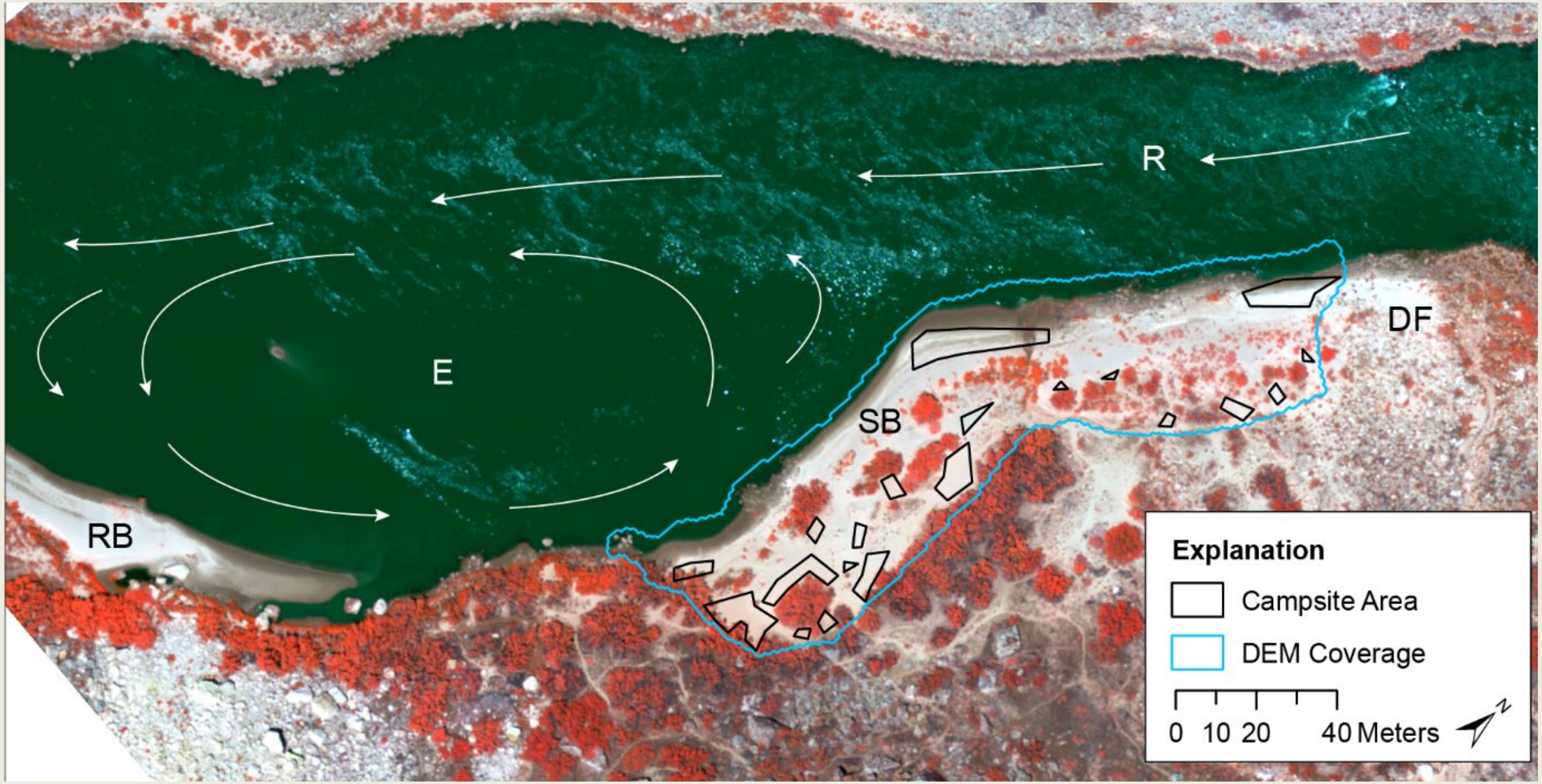
Causes of Campsite Loss

Erosion from daily fluctuations

Vegetation Encroachment

Gullying

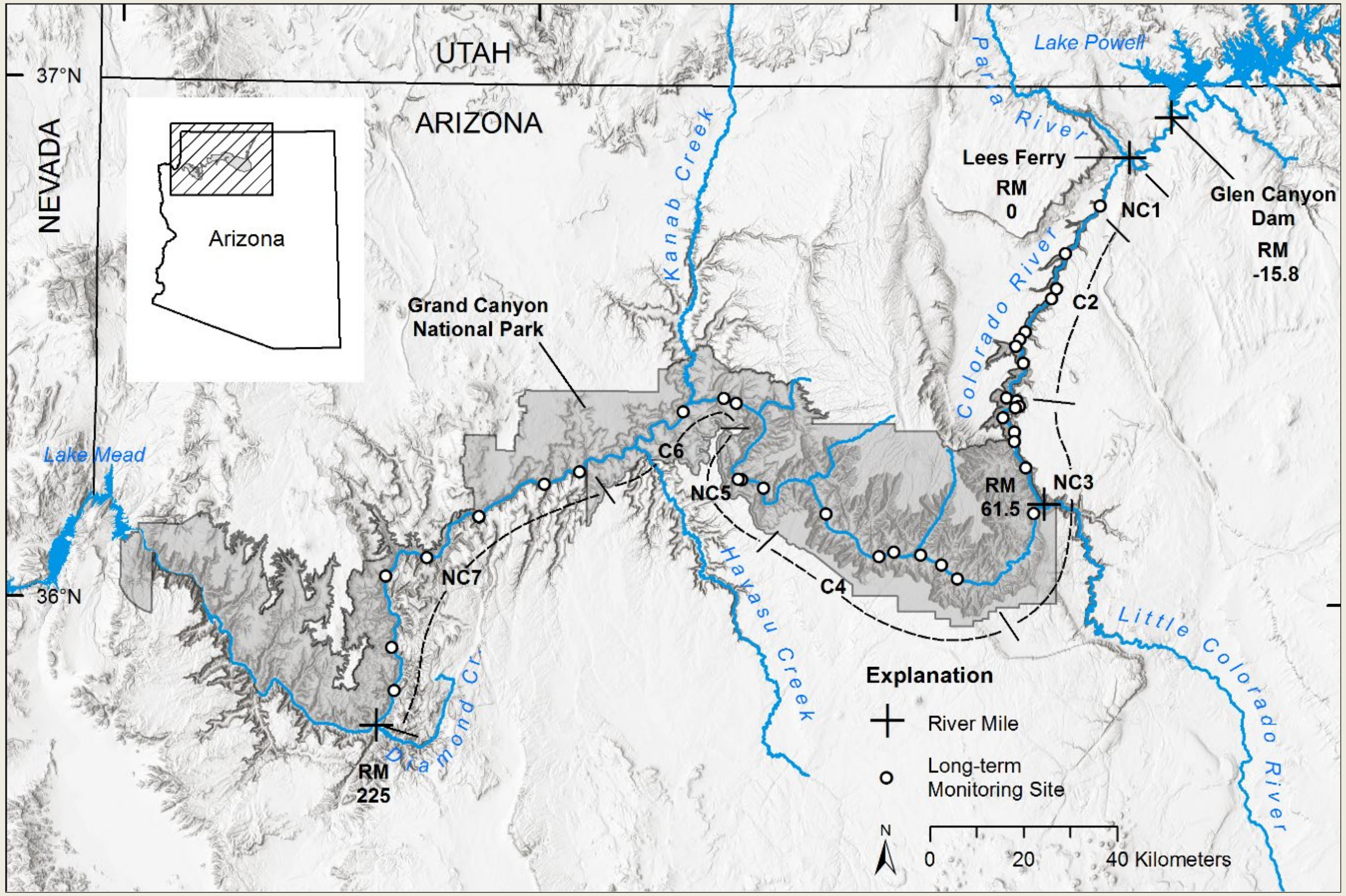
The debris-fan eddy complex



Site 44.5L

- Debris fans form channel constrictions
- Create pools, rapids, and recirculating eddies
- Slower velocities in eddies allow sand deposition
- Separation bars and reattachment bars areas are primary area used as campsites by river runners and hikers

37 Long-Term Monitoring Study Sites



- Sandbar topography and campsite area measured on a near-annual basis
- 1998-present
- Total-station surveys
- 1-m Digital Elevation Models (DEMs)
- Specific criteria define usable campsite area (smooth sand, < 8 degree slope)

Goals

1. Quantify changes in vegetation at campsites
2. Analyze elevation and slope change due to: controlled floods, daily dam releases, and gullying

- What are the geomorphic and vegetation responses to flow regulation?
- Are controlled floods increasing the size of campsite area long-term?

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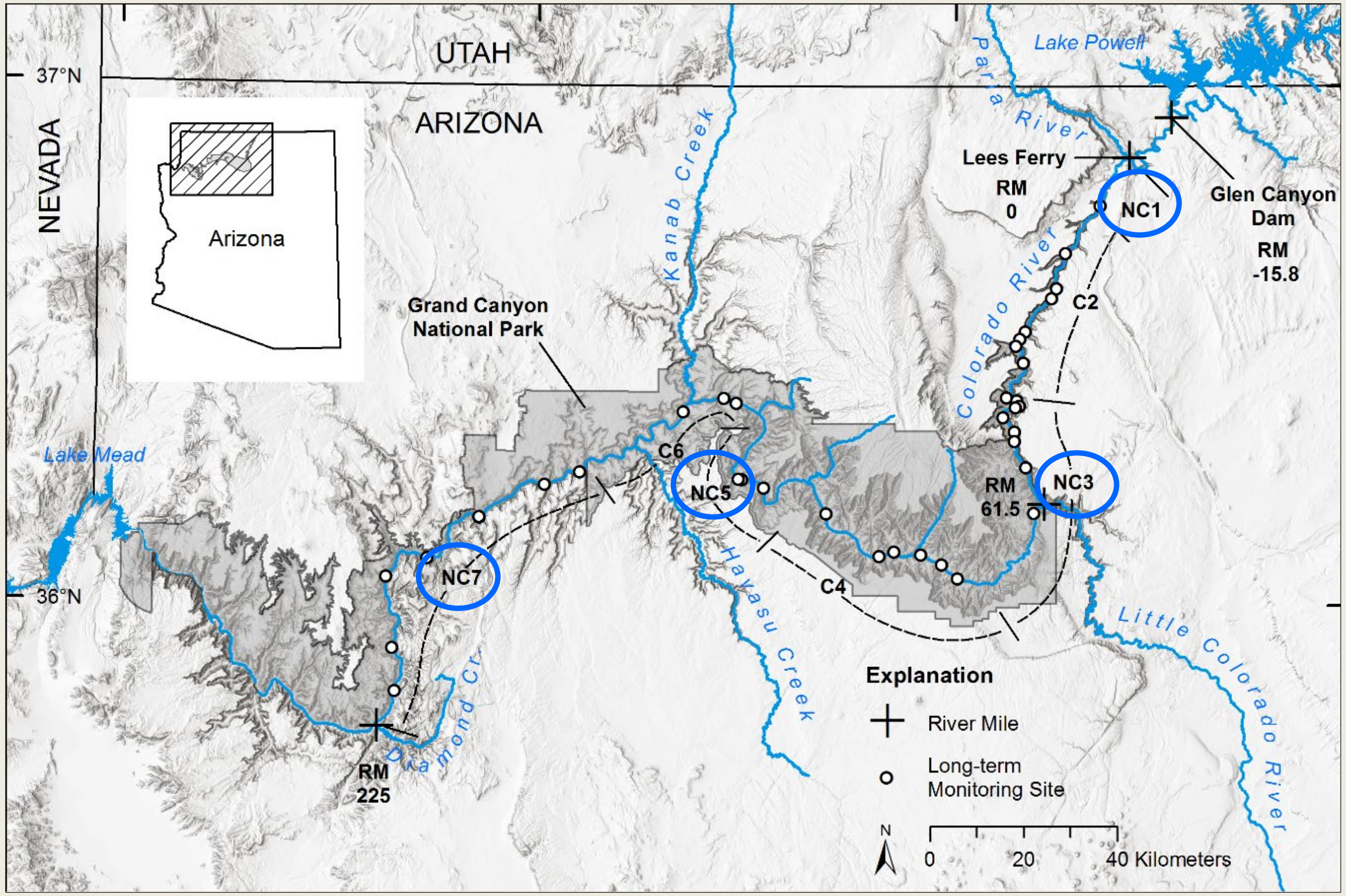

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Non-Critical Reaches = wide sections of canyon, numerous debris-fans

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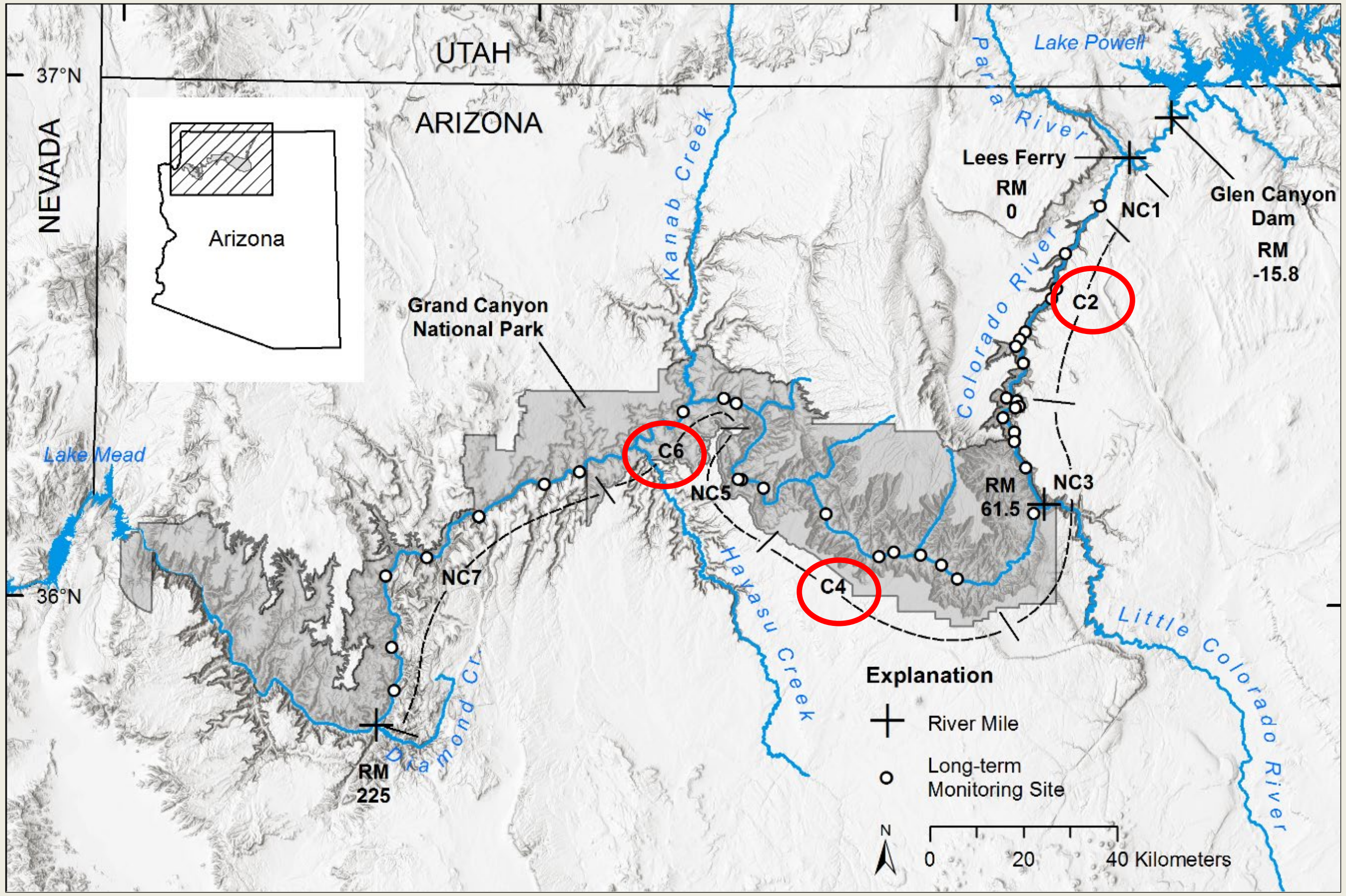

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Critical Reaches = narrow sections of canyon, limited number of campsites

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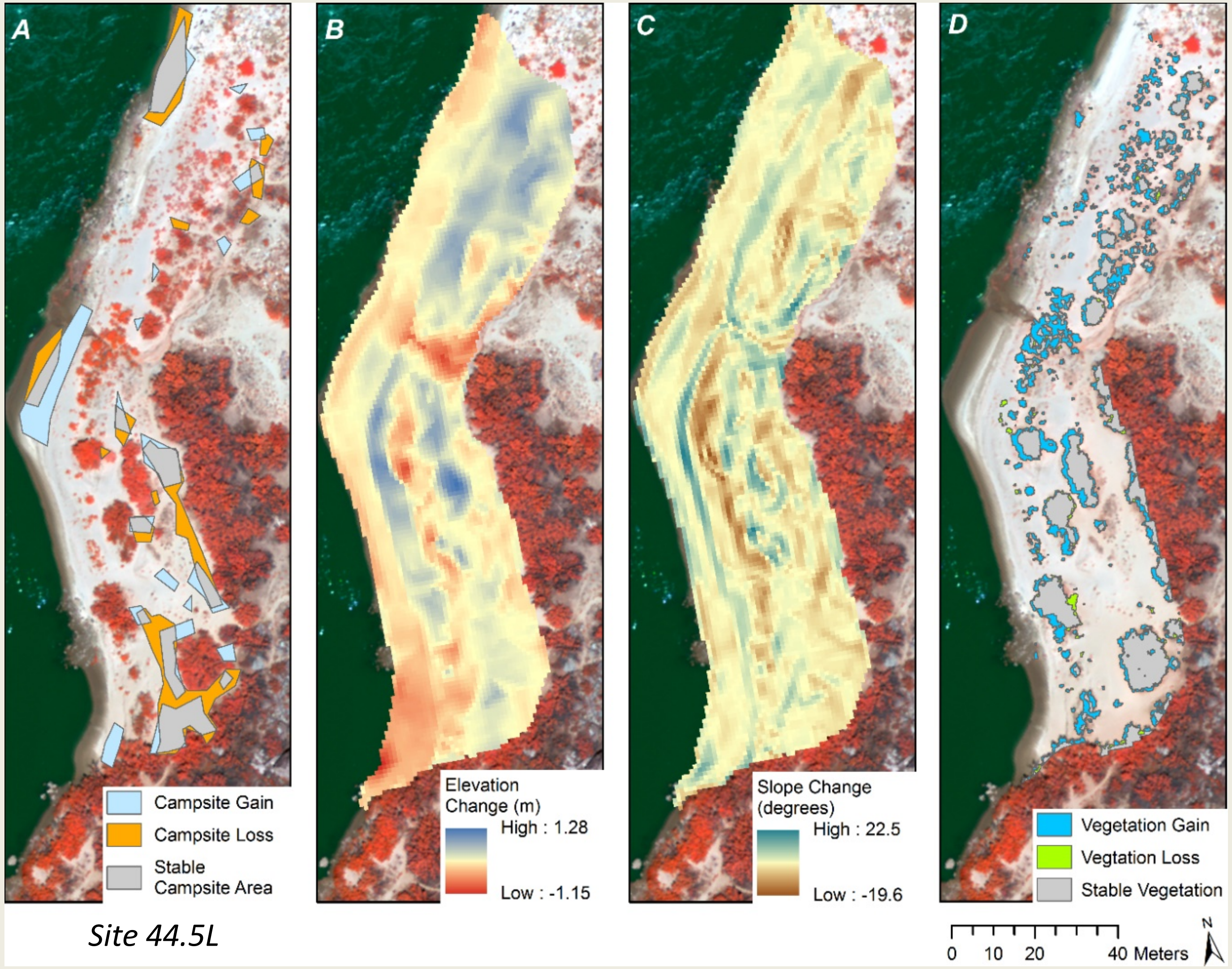


Site 44.5L

Methods

A. Campsite surveys (2002-2016)
B. Elevation change calculated from DEMs of difference
C. Slope change based on 8° threshold
D. Vegetation change using canyon-wide maps of vegetation (May 2002 and 2009)
   - 4-Band orthoimagery (RGB + NIR)
   - 0.20 m resolution
   - Normalized Difference Vegetation Index

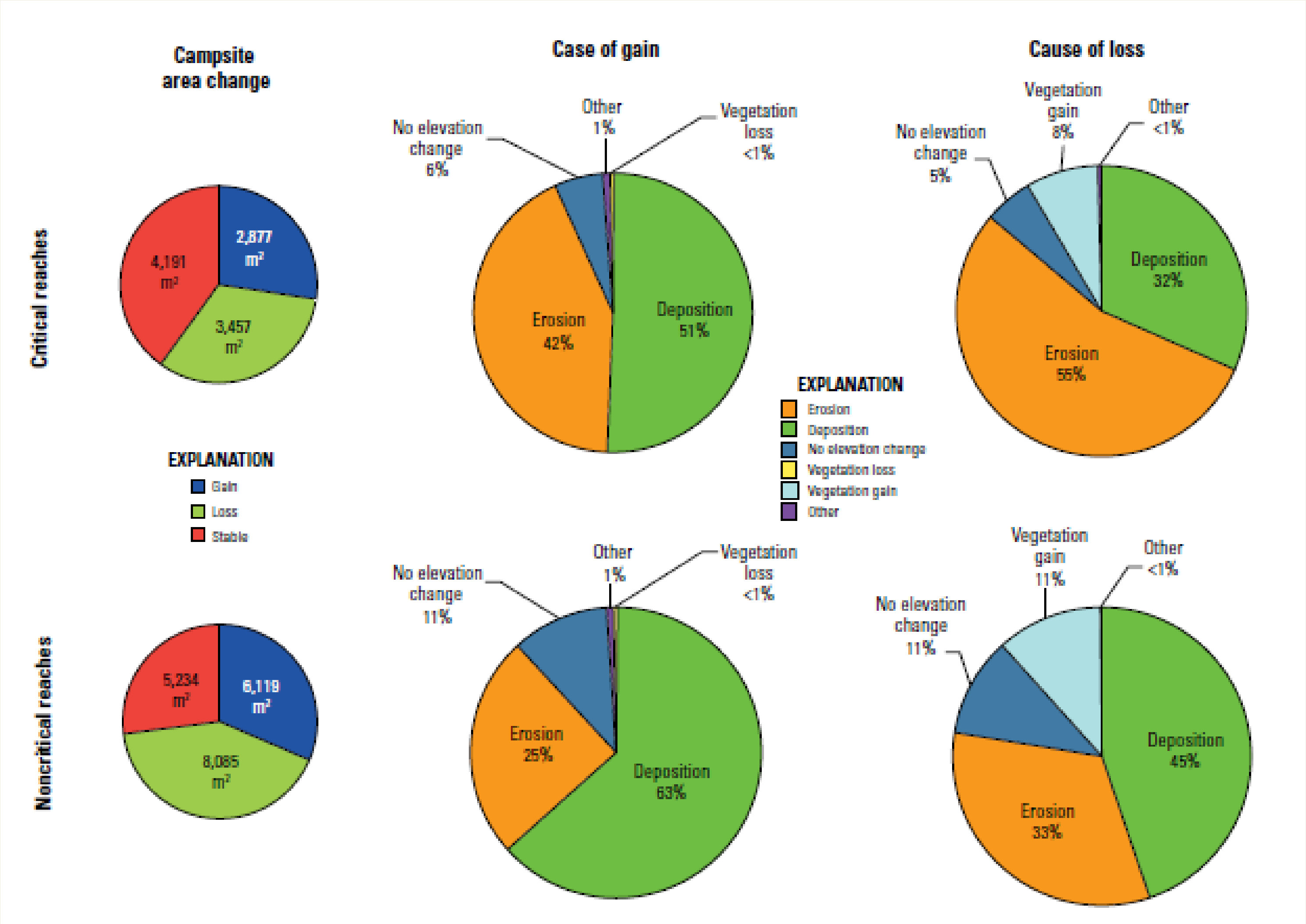
$$\text{NDVI} = \frac{(\text{NIR} - \text{VIS})}{(\text{NIR} + \text{VIS})}$$

E. Gullies detected from flow direction and flow accumulation tools (ArcGIS) using slope rasters

Two Components

1. Determined cause of campsite area changes from 2002-2009 (includes 2004 and 2008 controlled flood)
2. Estimated cause of campsite change past 2009 to 2016 (controlled floods in 2012, 2013, 2014, 2016)

Results (2002-2009)

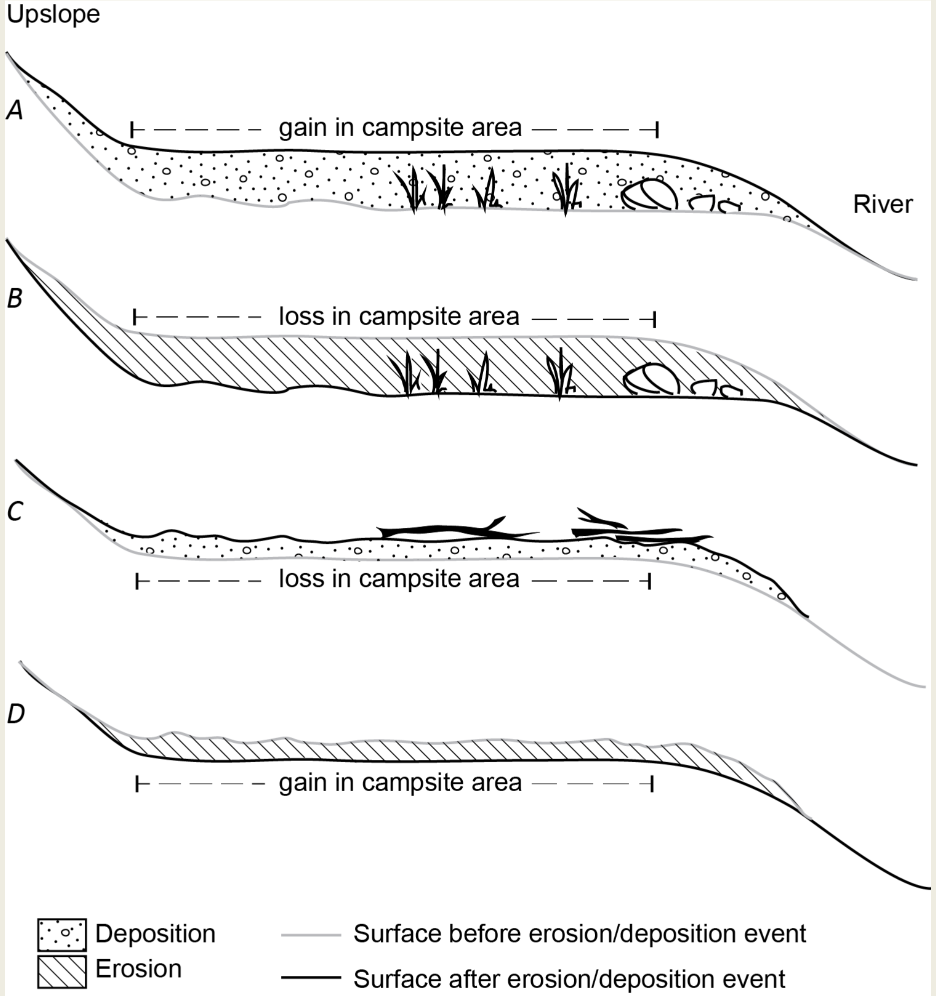


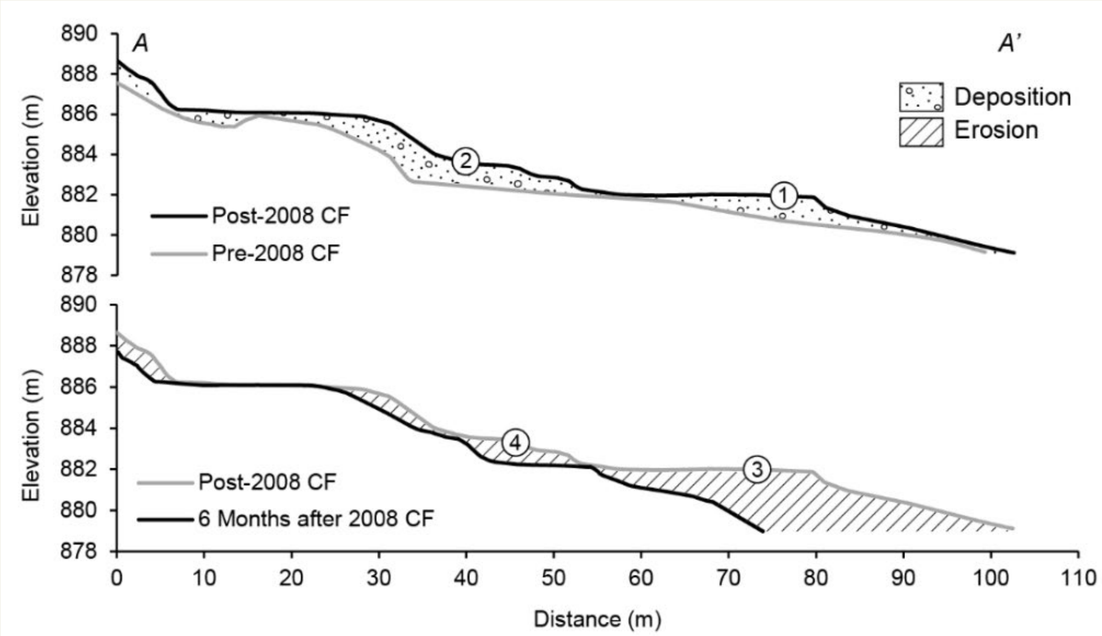
- Net decline of campsite area of 2,547m² (12%), despite two controlled floods
- Erosion and slope change more prevalent in critical reaches (both gains and losses)
- Vegetation expansion more prevalent in non-critical reaches
- Gullying occurred at 5 sites, accounted for < 1% of overall loss (important locally, but not overall)

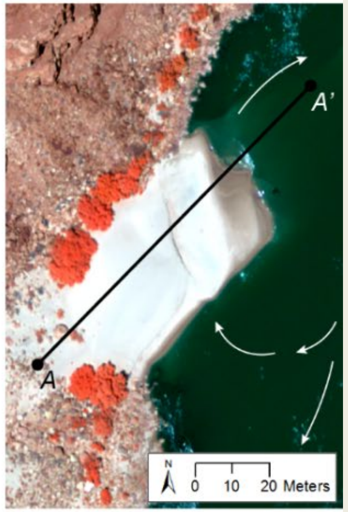
Two drivers of campsite change

- Short-term gains and losses associated with controlled floods and flood deposit erosion
- Long-term one directional loss of due to vegetation encroachment

Specific Mechanisms of Topographic Change (2002-2009)







Site 22.1R

Elevation Change and slope change

1. Deposition→ creates flat area → campsite gain
2. Deposition→ creates steep area → campsite loss
3. Erosion→ removes flat area)→ campsite loss
4. Erosion→ removes steep area→ campsite gain

Lateral Cutbank Retreat (items 3–4)

Elevation Change with no slope change

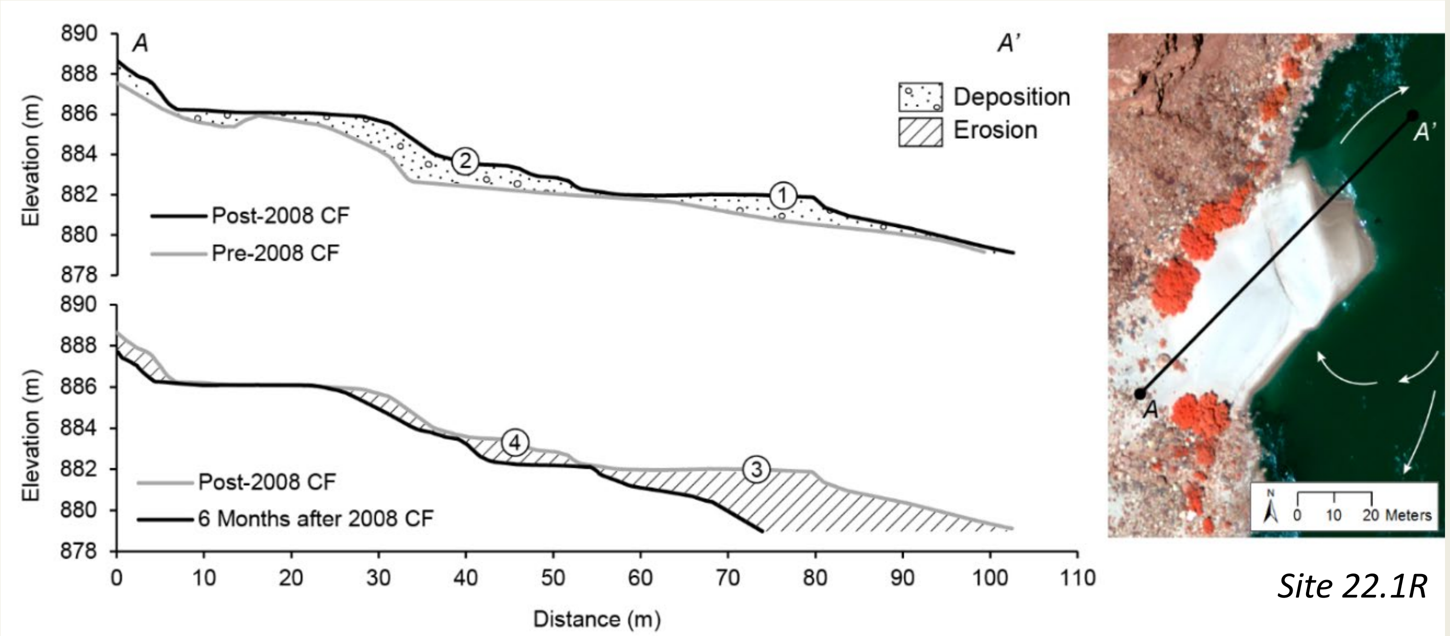
A. Deposition → burial of vegetation/boulders → campsite gain
B. Erosion → exposure of vegetation/boulders → campsite loss
C. Deposition → presence of driftwood/debris → campsite loss
D. Erosion → sandbar smoothing→ campsite gain

Specific Mechanisms of Topographic Change (2002-2009)

Pre-2008 Controlled Flood

Post-2008 Controlled Flood

3 months after 2008 Controlled Flood



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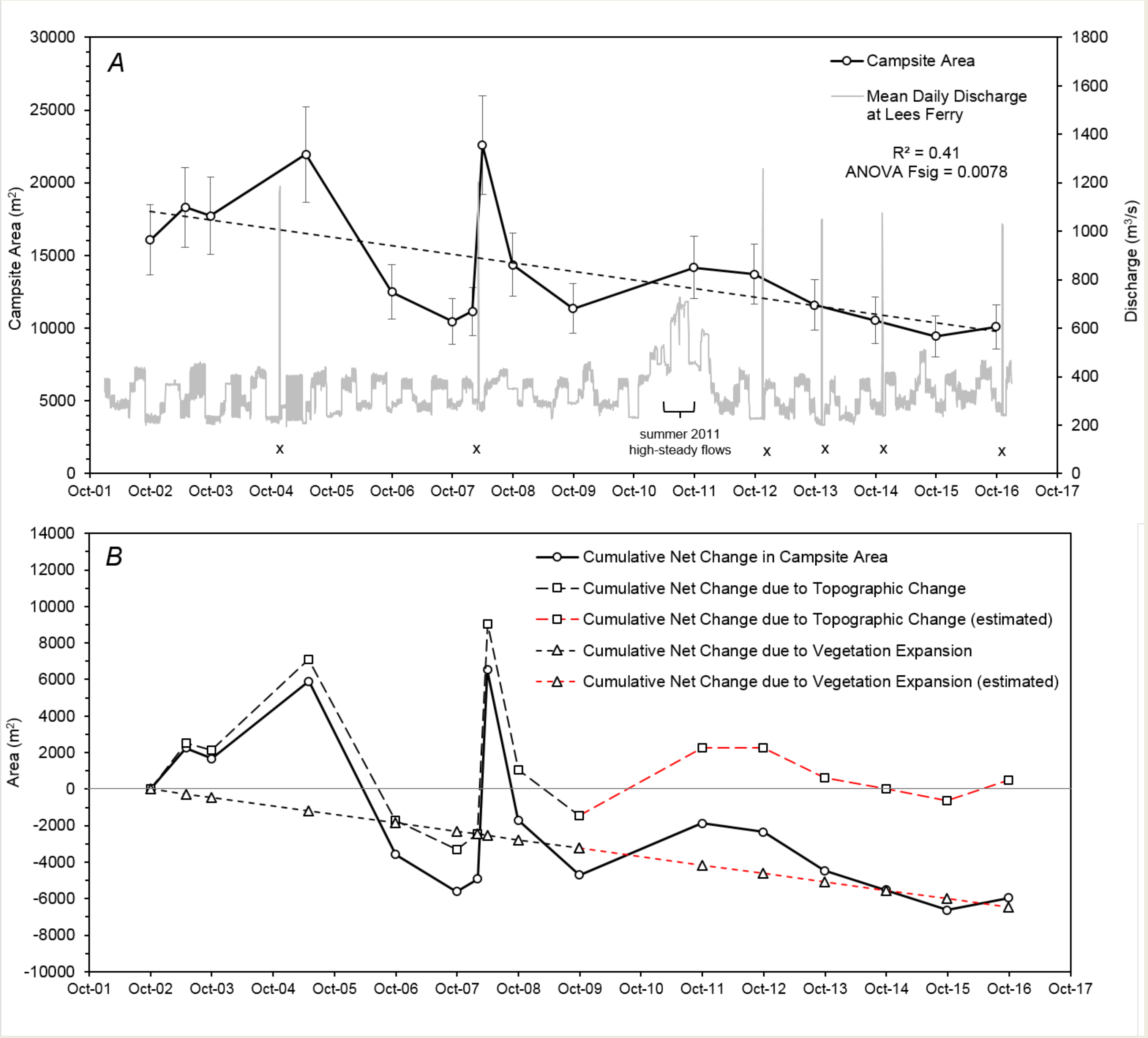
} *Lateral Cutbank Retreat* (items 3–4)

- ***Controlled floods both create and destroy campsite area***
- ***Not a direct correlation between increases in sandbar size and campsite size***



Estimating Cause of Campsite Change (2002-2016)

- Campsite area declined by 37%
- 6 Controlled Floods
- Avg. vegetation expansion rate of 413 m^2/year
- *Gains in campsite area from topographic change essentially negligible*
- *Vegetation expansion basically outpacing the short term gains associated with controlled floods*

Conclusions

What are the geomorphic and vegetation responses to flow regulation?

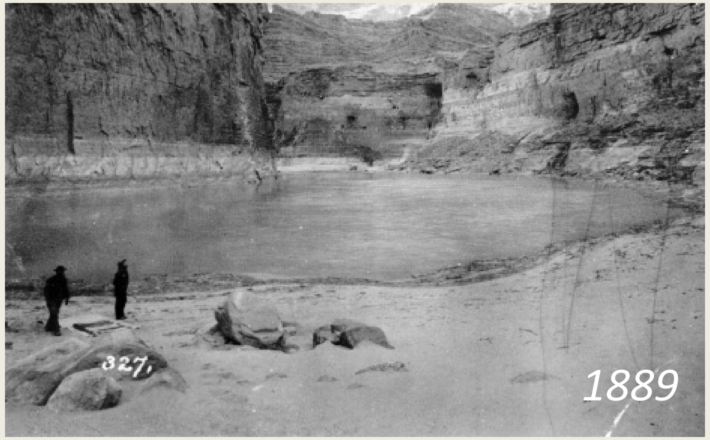
- Native and non-native vegetation continues to expand
- Gains from controlled floods often short-lived due to fluvial mainstem erosion (daily fluctuating dam releases)

Are controlled floods increasing the size of campsite area long-term?

- Despite the use of more frequent floods......not exactly
- Sandbars maintaining or increasing in volume (Grams et al., 2015;2018) , but not direct relationship (Hazel et al., 2008)

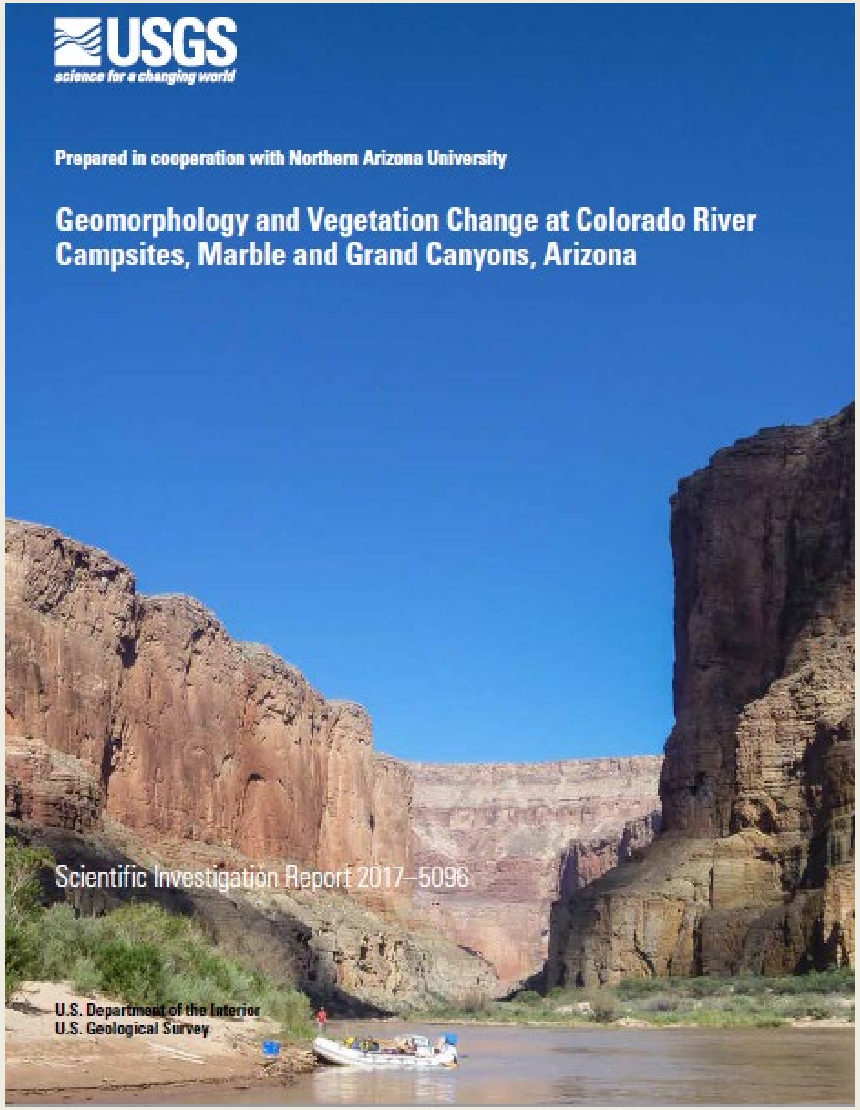
Recommendations

- Manual vegetation removal (particularly sites in critical reaches)
- Update vegetation expansion rates with 2013 imagery



South Canyon RM 32.2, looking downstream

USGS Desert Laboratory Repeat Photography Collection



Publications and Contact

- USGS Scientific Investigation Report (2018)
  https://doi.org/10.3133/sir20175096
- USGS Data Release (2018)
  https://www.sciencebase.gov/catalog/item/59a5d3dae4b024f204d408b5
- River Research and Applications article (September 2018)
  Quantifying geomorphic and vegetation change at sandbar campsites in response to flow regulation and controlled floods, Grand Canyon National Park, Arizona
  https://doi.org/10.1002/rra.3349

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Questions?

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