Terrace Stratigraphy, Geomorphology, And Climate in Cataract Canyon as a Control for Analogous Grand Canyon Settings

Andre R. Potochnik

Kate S. Thompson

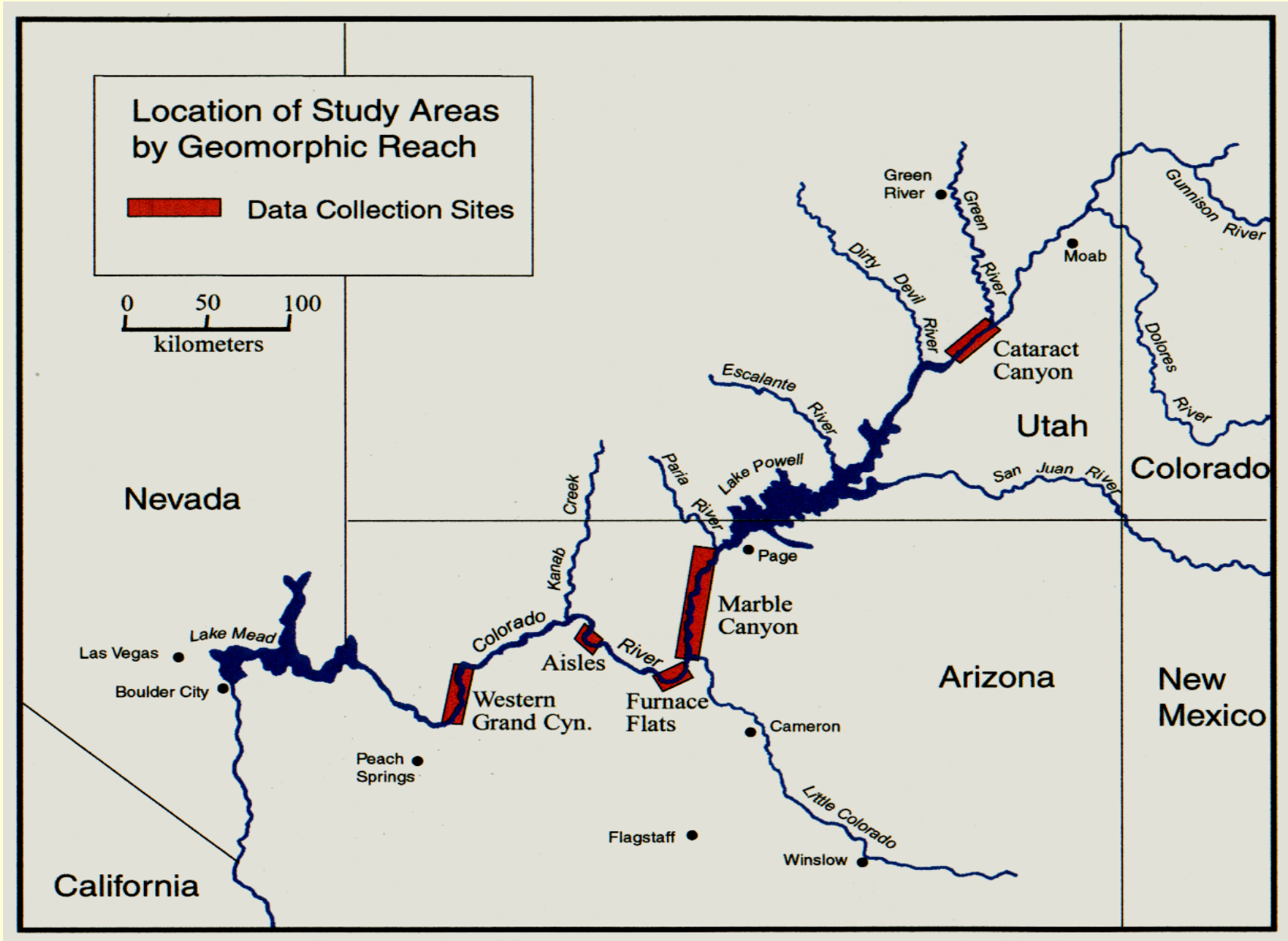
Gary R. O'Brien

Lynn A. Neal

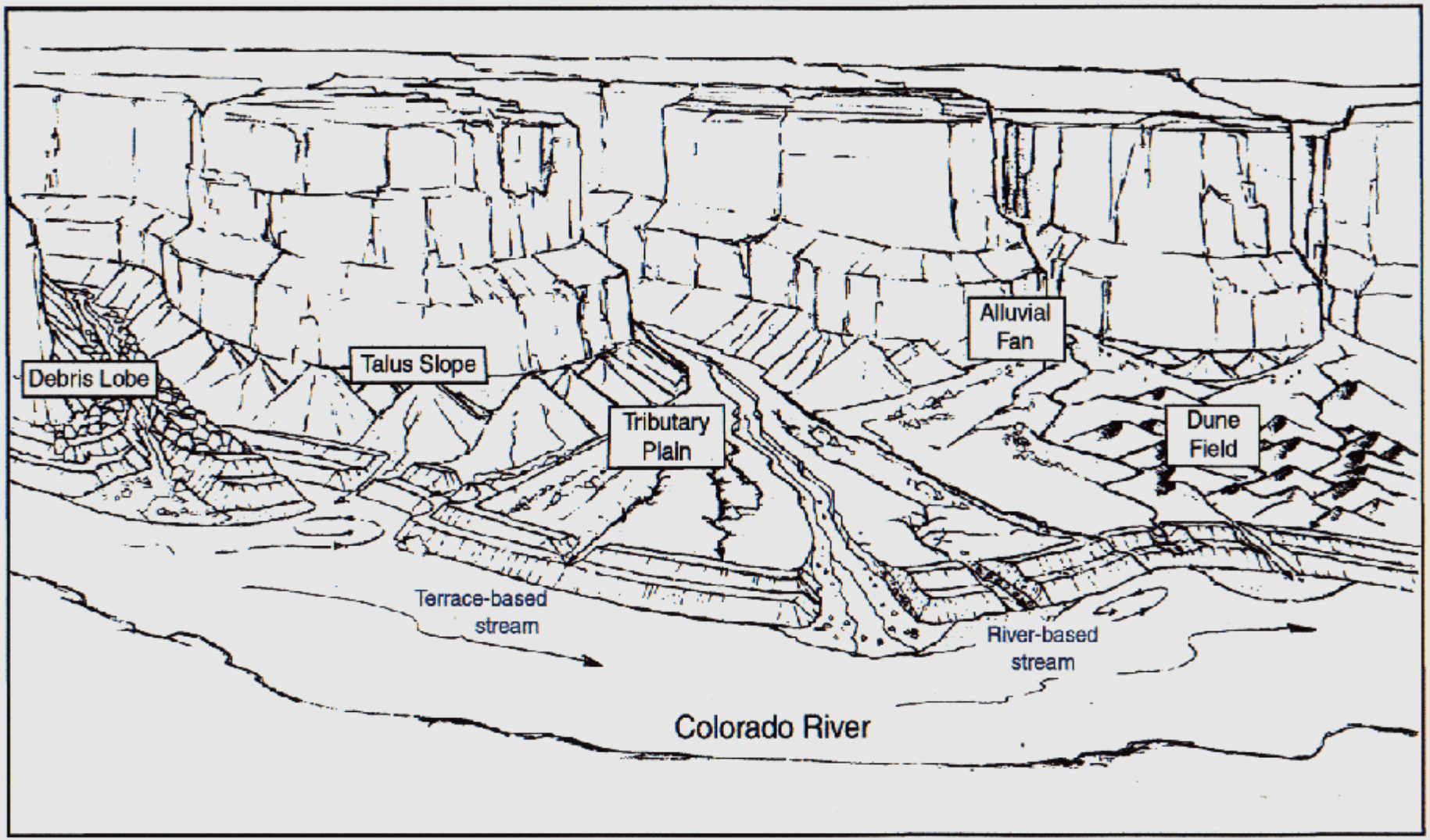
Research Questions for Cataract Canyon Study

- Is Cataract Canyon analogous to Grand Canyon?
- Are terrace gully erosion rates similar?
- Do large annual river floods mitigate gully erosion?
- How can Cataract Canyon inform Grand Canyon in the post dam period?

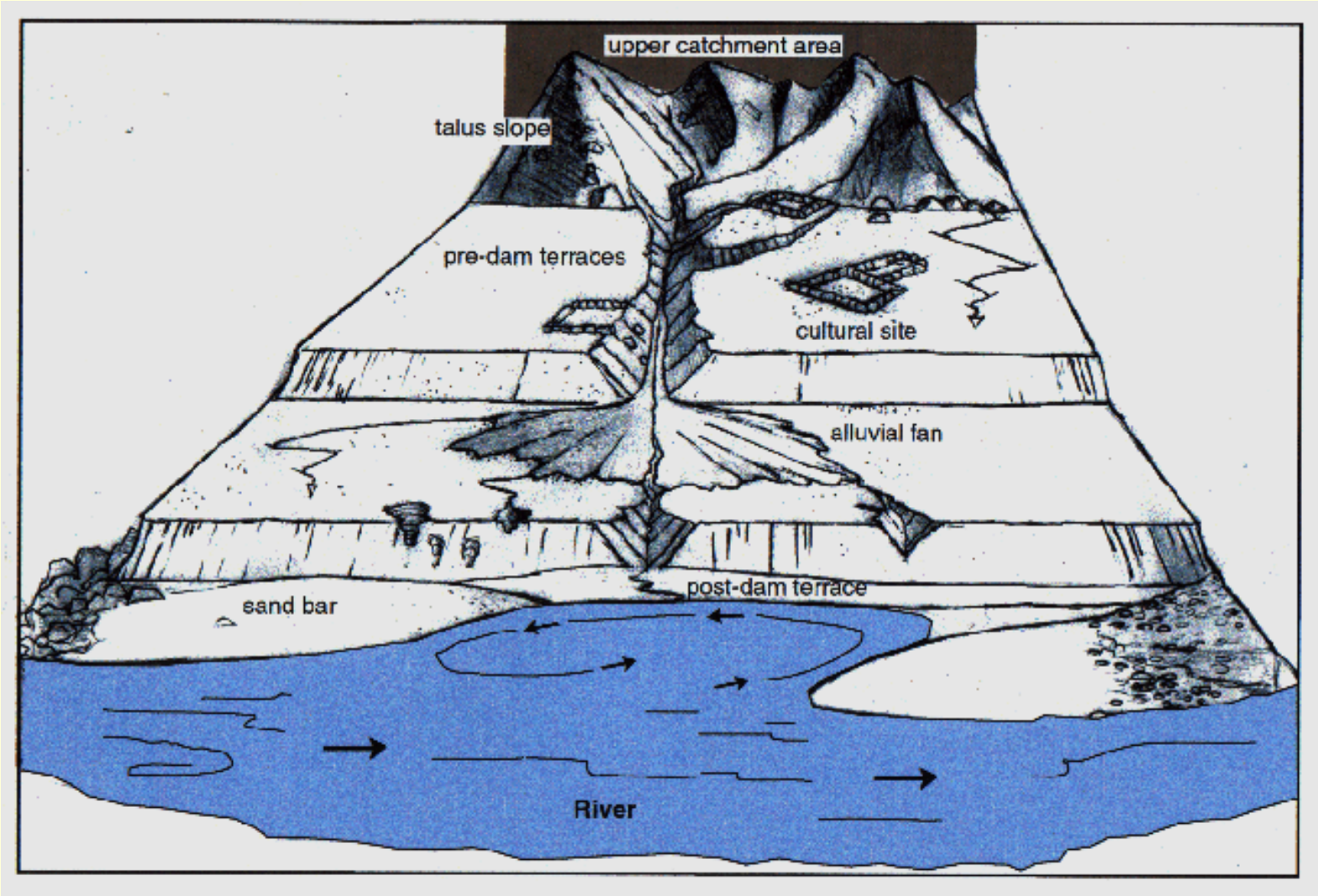
Study Locations



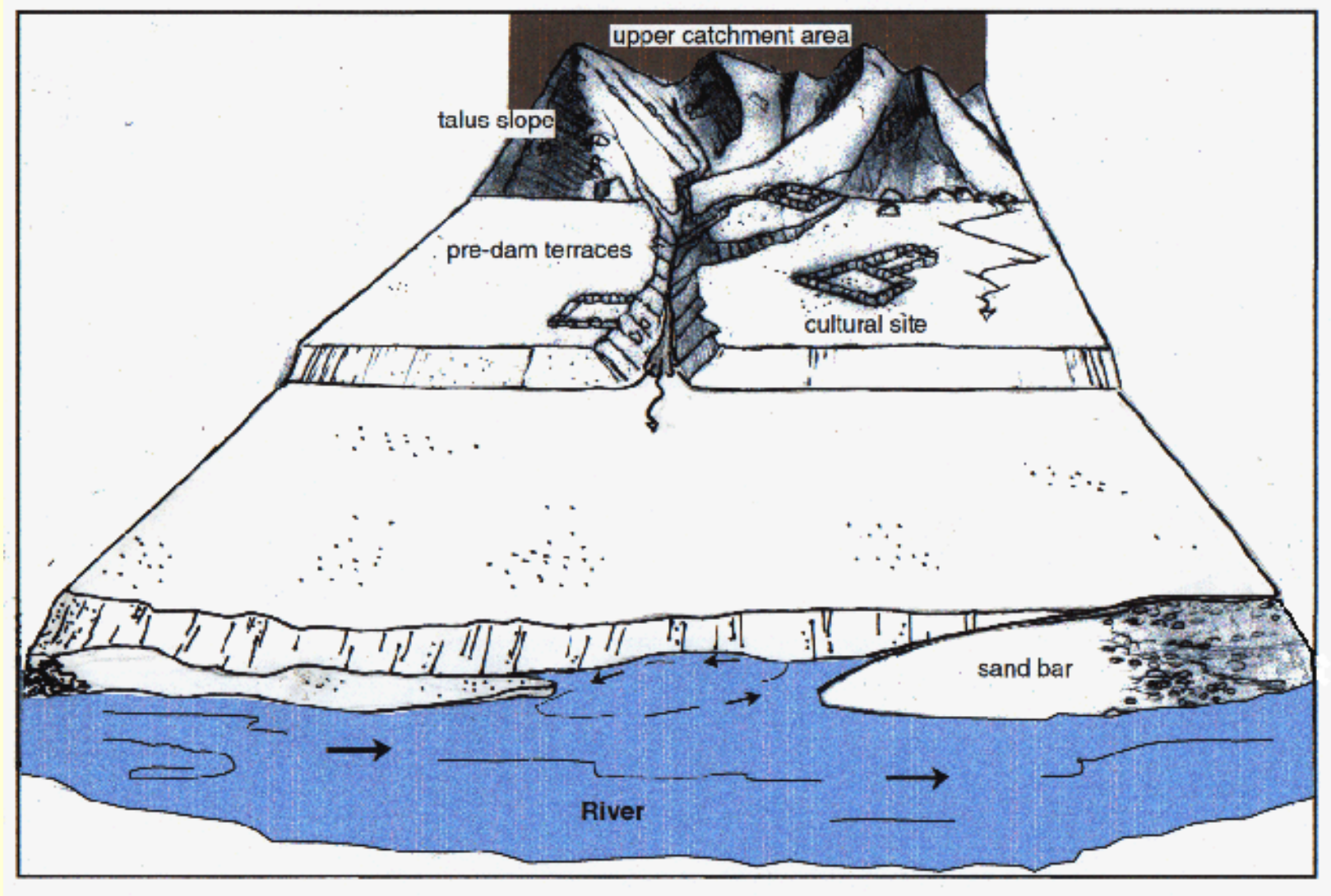
Geomorphic Settings



Processes Driving and Resisting Erosion



Process Restoring Erosion



Geology

Cataract and Grand Canyons have:

- Mostly undeformed, generally flat-lying or gently tilted sedimentary rocks
- Cliff-bench topography of canyon walls
- Mostly shale, sandstone, limestone
- Large tributary canyons
- Small catchments between tributaries
- Sandy fluvial terrace sequences

Climate

Parameter	Cataract Cyn.	Furnace Flats
•Mean annual precipitation (mm)	220	233
•Mean temp, monsoon season (C)	22.2	23.8
•Mean precipitation, monsoon season (mm)	86	97
•#precipitation events > 25mm/day (1964-1995)	6	8
•% months of monsoon season 50mm precip. (1964-1995)	9.1	9.0

Sediment and Flow History

Parameter	Cataract Canyon (CR + GR)	Furnace Flats (CR+GR+SJR)
• Mean water yield (maf/yr)1926-1986	9.5	11.2
• Mean sed. yield (m-tons/yr) 1926-1986	27.0	52.4
• 1957 flood peak (cfs)	101,000	125,000
• Mean annual flood (cfs)	63,000	80,600

River Geomorphology

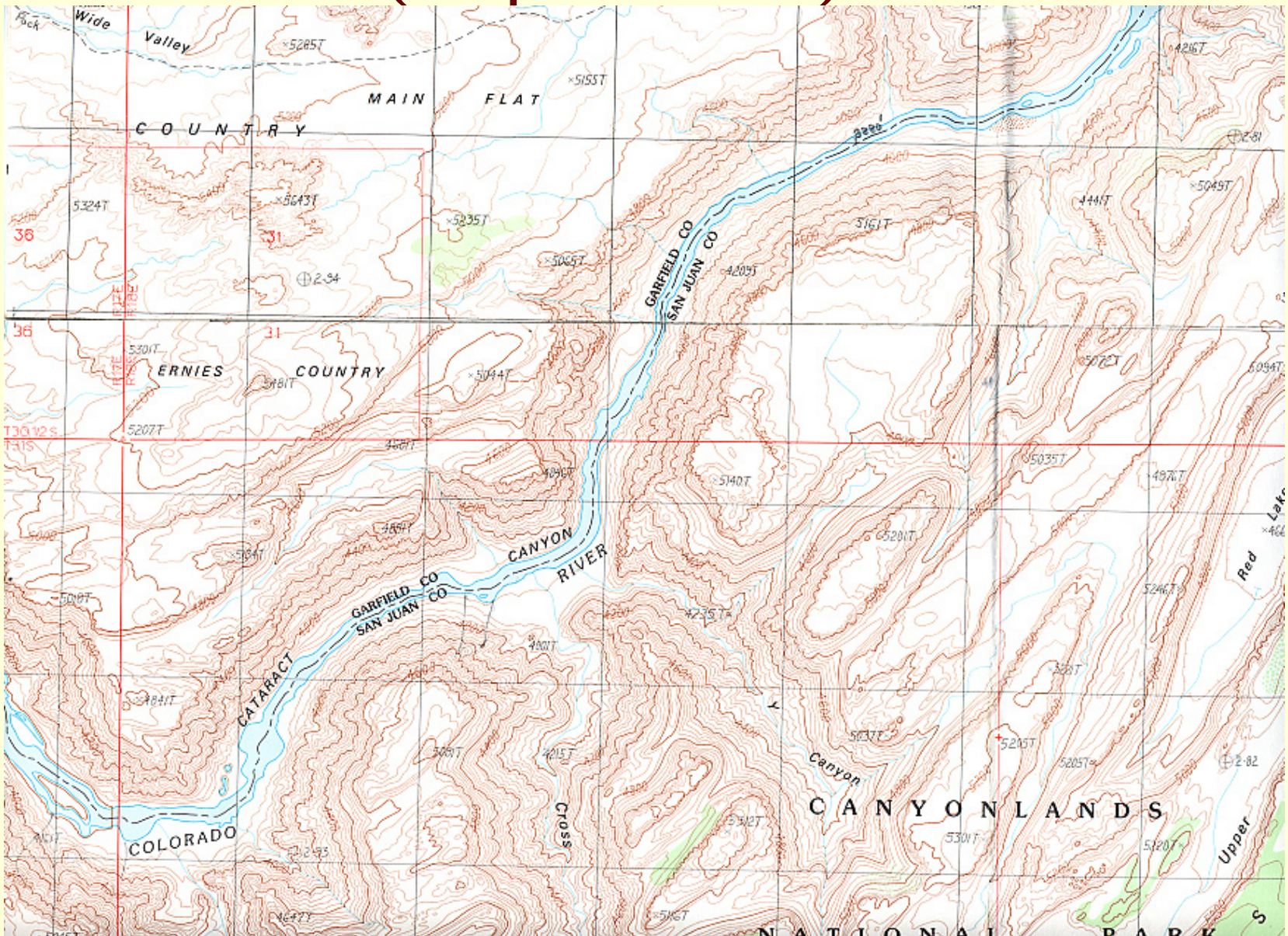
Parameter	Cataract Canyon (CR + GR)	Furnace Flats (CR+GR+SJR)
Reach length (km)	11	13
River gradient (m/km)	2.42	1.95
Elevation (m)	1158	807
Terraces above 40k cfs	5	5
Pre-dam terraces	3	4

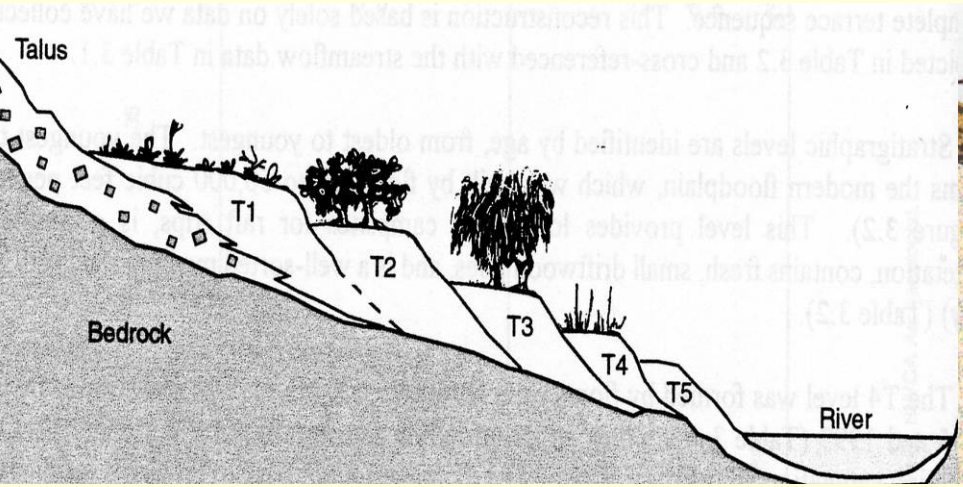
Grand Canyon Type Reach ("furnace flats")

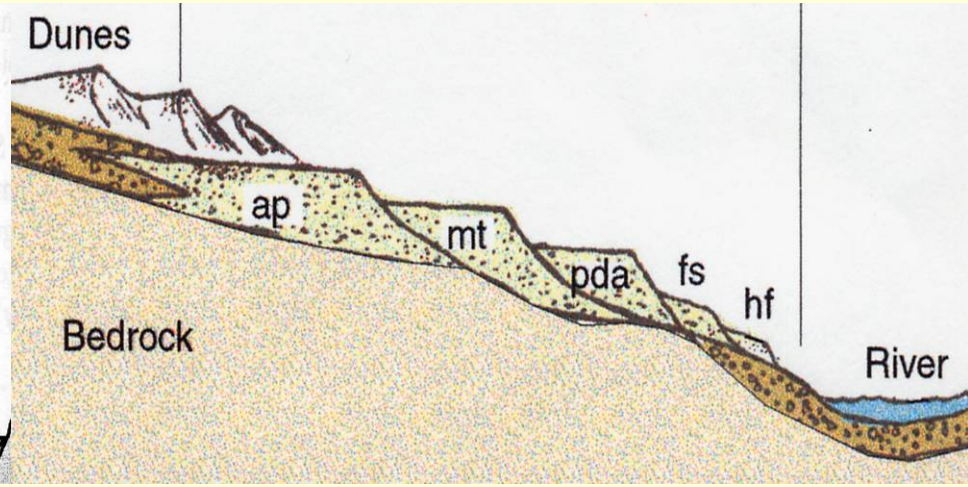
Cataract Canyon
Control Reach (Rapids 4-12)

Grand Canyon Type Reach ("furnace flats")

Cataract Canyon Control Reach (Rapids 4-12)







Terrace Sequences

Cataract Canyon

T1: desert scrub/arch, 1884
T2: old Hackberry, 1921 (154k)
T3: old Tamarisk, 1984 (114k)
T4: young Tam,1995 (70k)
T5: 1999 flood plain (47k)

Grand Canyon

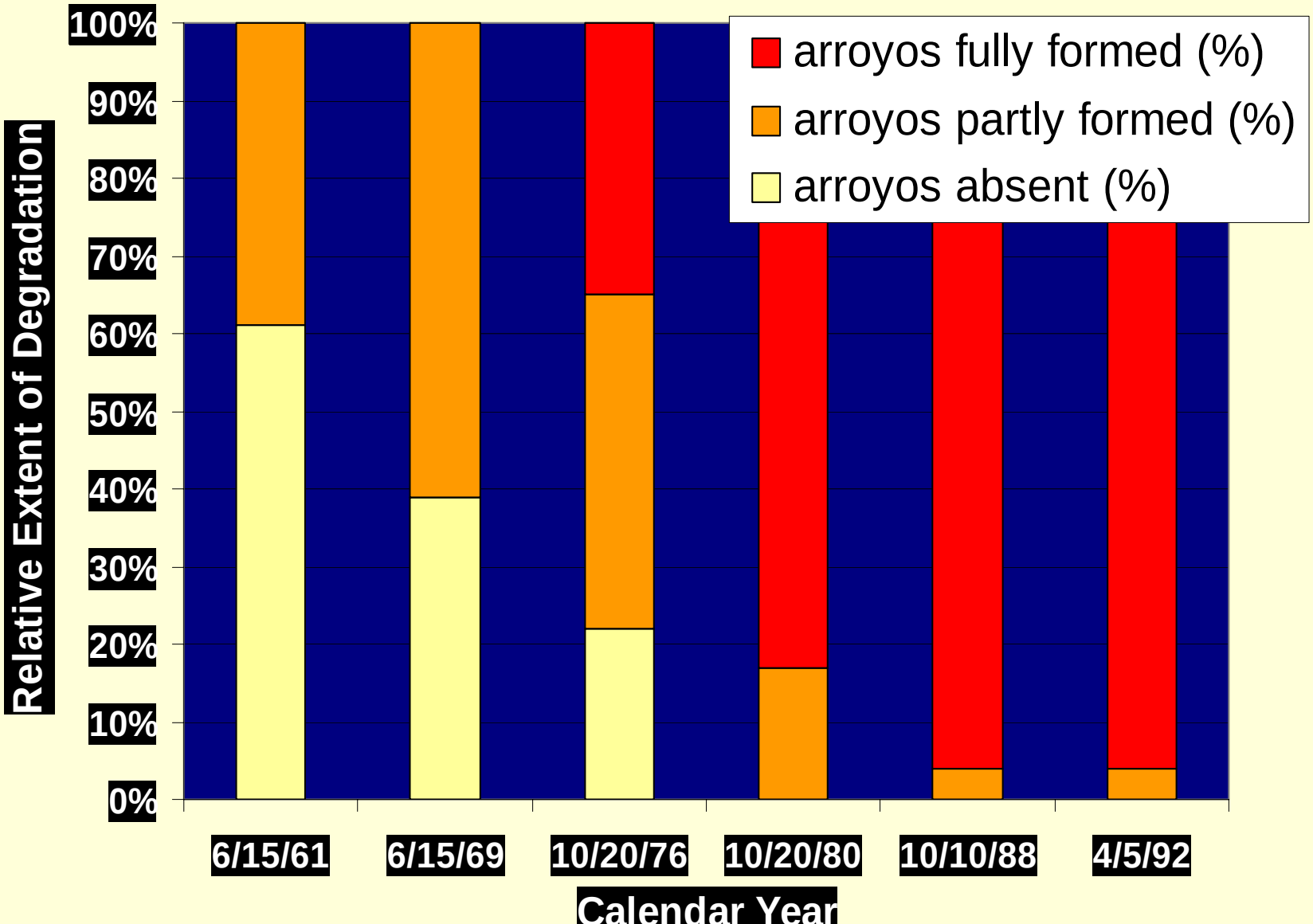
Ap/sa: desert scrub/arch, 1884
Mt: old Mesquite, 1921 (170k)
Pda: old Tamarisk, 1957 (125k)
Fs: 1983 flood release (97k)
Hf: 1996 BHBF (45k)

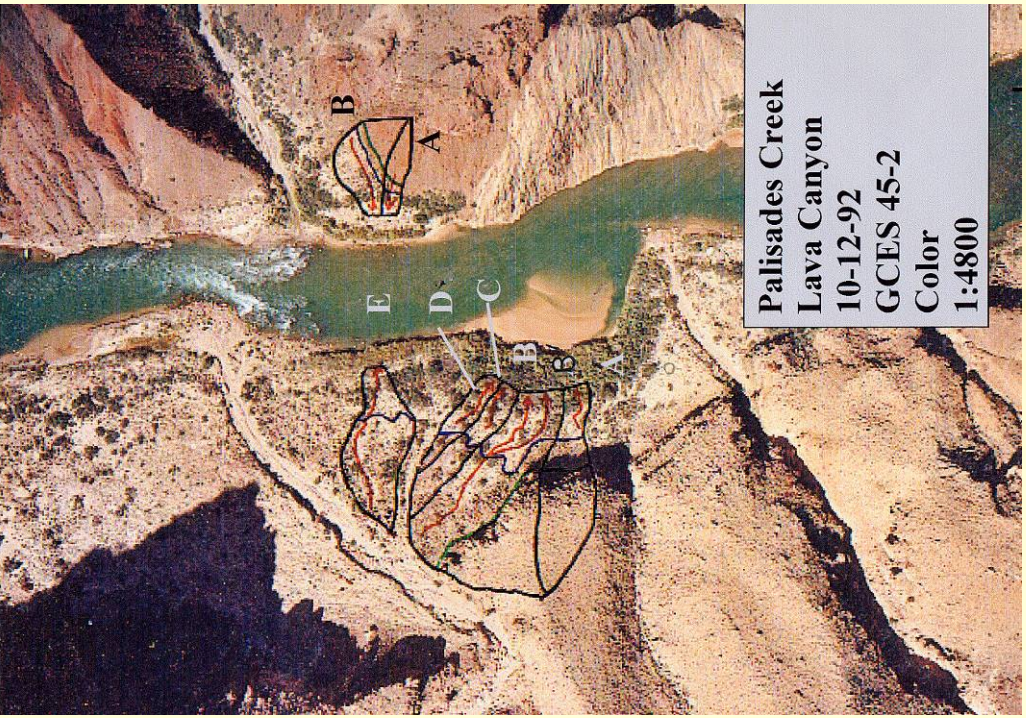
Null Hypothesis: Degree of gully erosion has remained unchanged from the pre-dam to post-dam period

- **Test 1 - Use air photos to determine the degree of channel lengthening since 1965**
- **Test 2 - Compare amount of gully erosion in Cataract Canyon (control section) to Furnace Flats section in Grand Canyon**

Channel Lengthening Over Time

n = 23

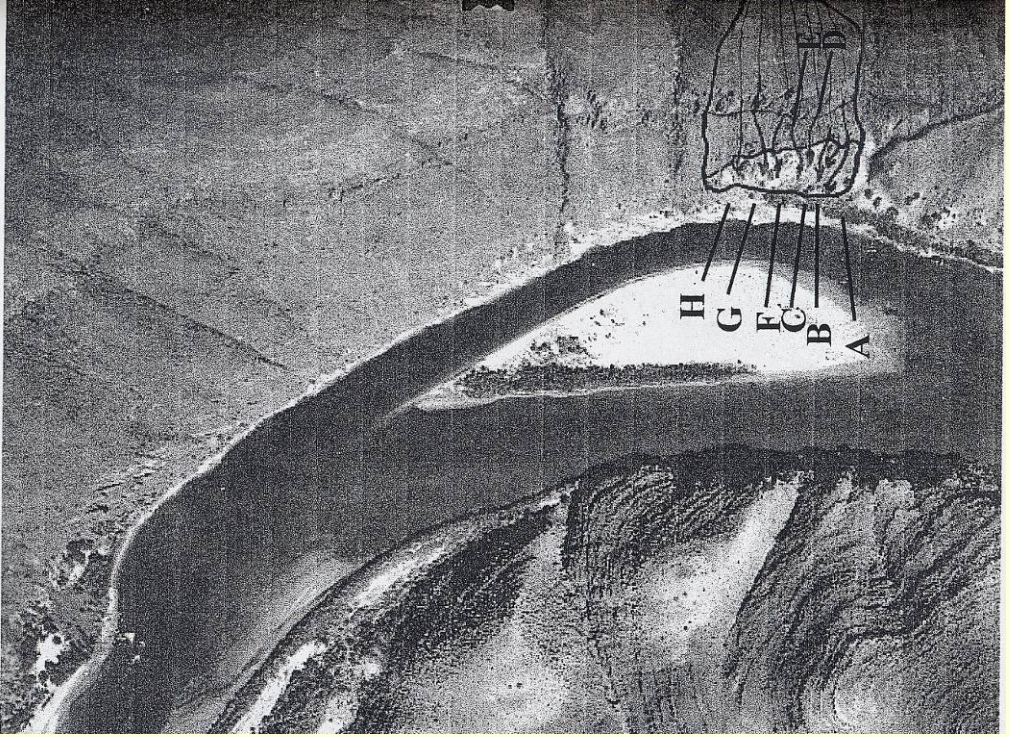


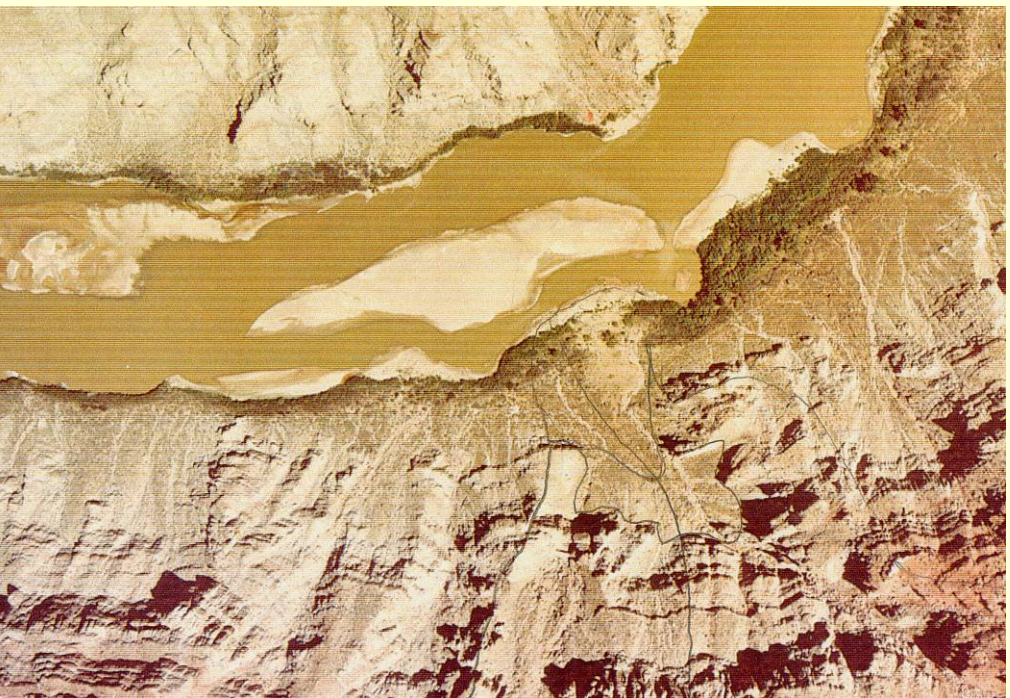


Paired Catchments #1

- Grand Canyon
- Palisades Creek debris lobe/talus slope setting
- 21,701 m^2

- Cataract Canyon
- Cross Canyon talus slope setting
- 46,220 m^2



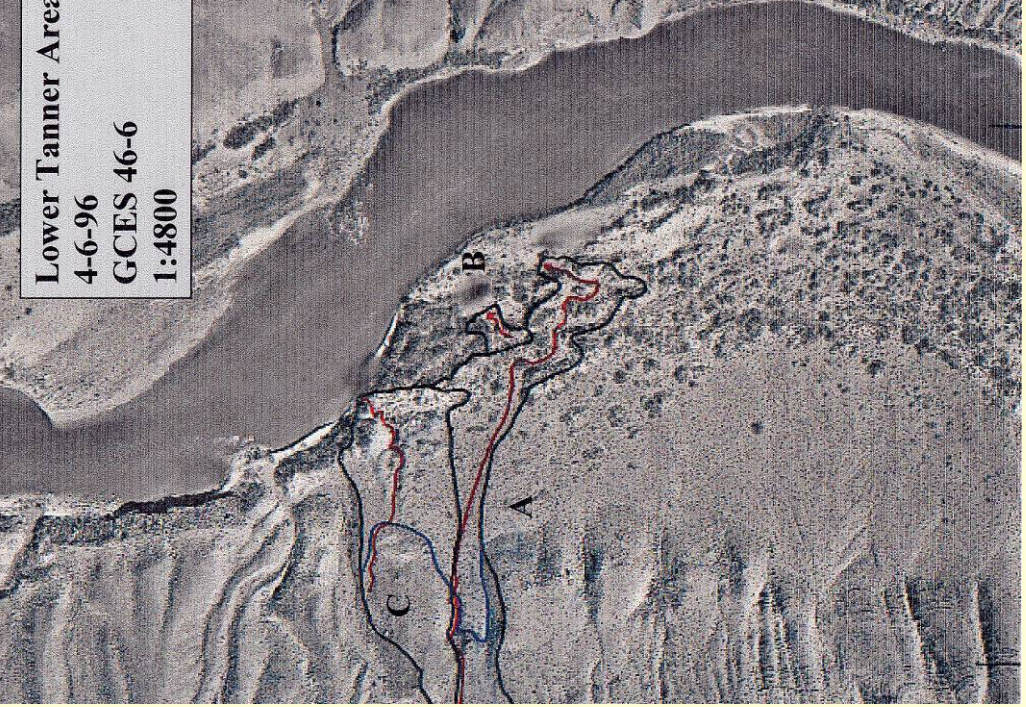


Paired Catchments #2

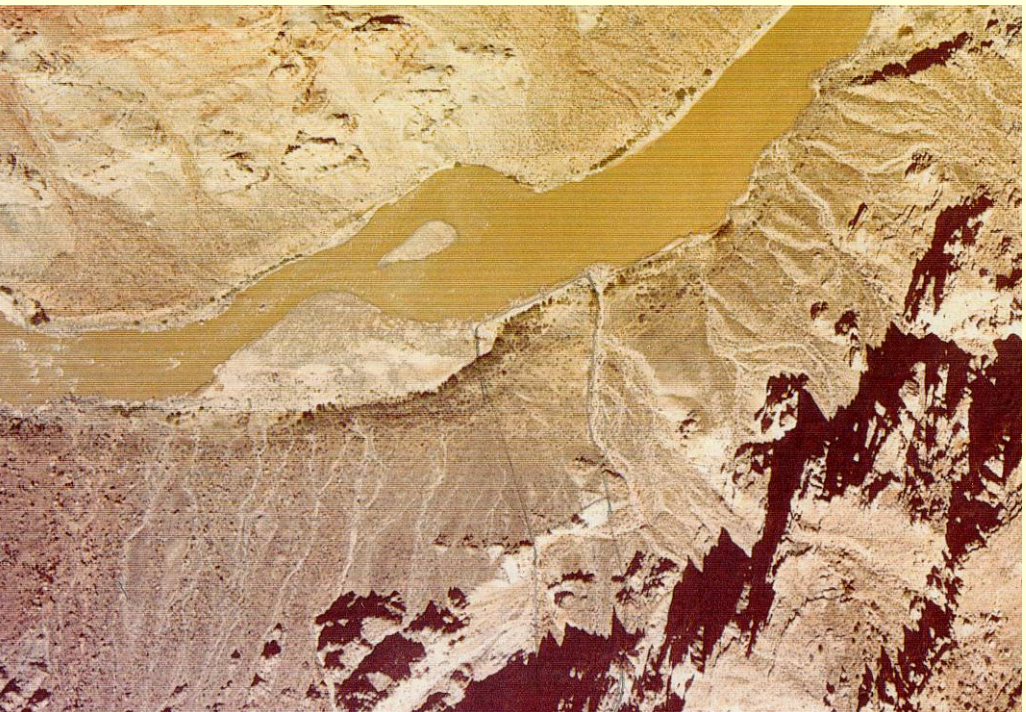
- Grand Canyon
- Upper Unkar
- Talus Slope setting
- 21,759 m^2

- Cataract Canyon
- Rapid 12
- Alluvial fan setting
- 227,995m^2

Paired Catchments #3



- Grand Canyon
- Lower Tanner
- Alluvial fan/eolian setting
- 10,500 m^2



- Cataract Canyon
- Rapid 4
- Tributary plain setting
- 10,222 m^2

Gully Density/Depth of 3 Paired Catchments

Sites compared	Length of Area (m)	Number of catchments	Gully density	Mean gully depth
#1				
Palisades Ck	**42**	**3**	**0.07**	**0.68**
Cross Cyn	**42**	**2**	**0.05**	**0.83**
#2				
Upper Unkar	**112**	**8**	**0.07**	**0.74**
Rapid 12	**108**	**4**	**0.04**	**0.73**
#3				
Tanner Cyn	**112**	**4**	**0.04**	**2.85**
Rapid 4	**83**	**3**	**0.04**	**0.20**

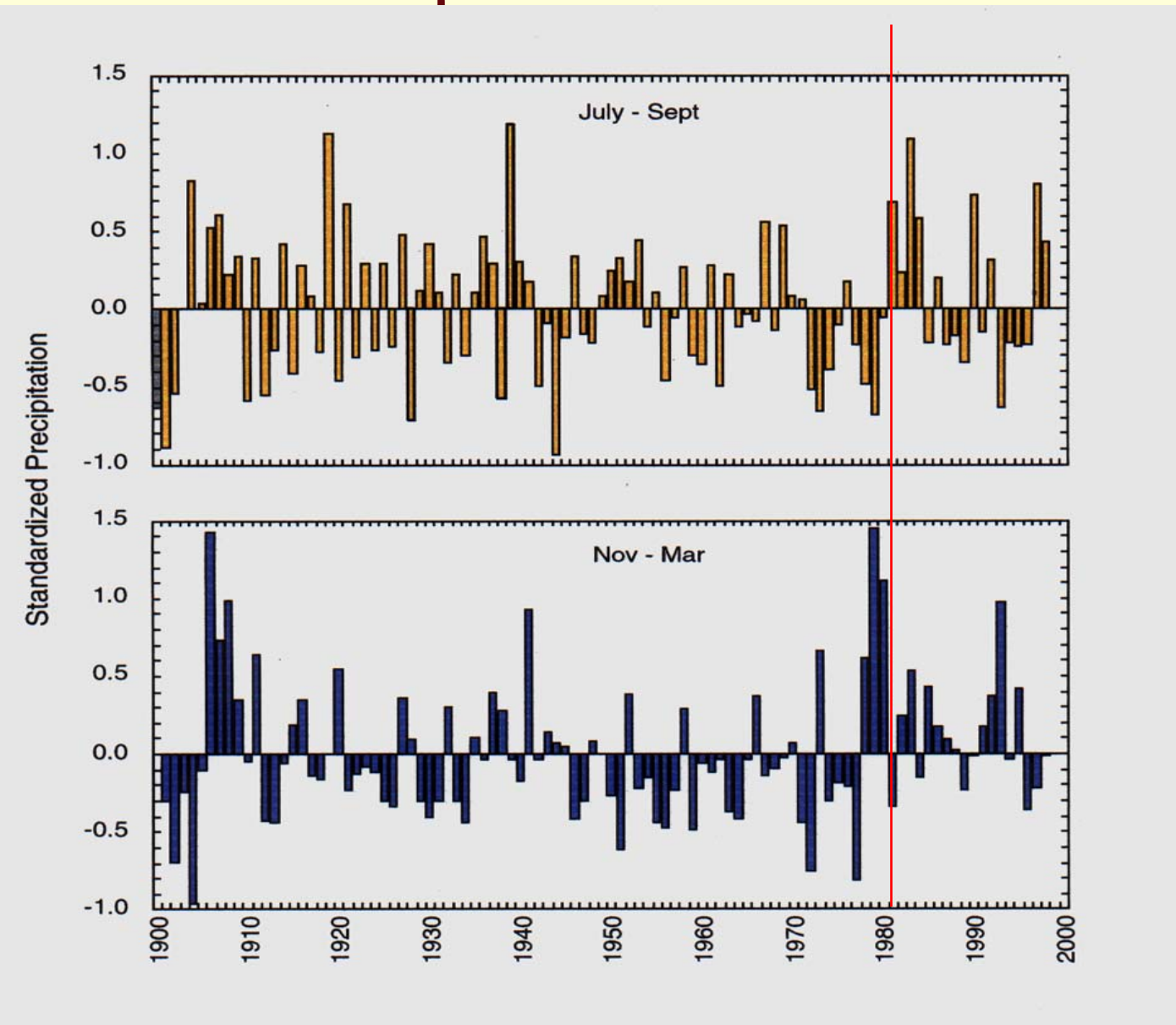
Degree of Gully Incision

Landform	Grand Canyon	Cataract Canyon
Mean gully depth ap/T1 terrace (m)	2.45 (n=15)	0.56 (n=9)
Range of gully depths (m)	0.5-4.0	0.12-0.85
River-based gullys	53	22
Drainage density (upper terrace)	0.06	0.04

Climatic Variation Hypothesis: High precipitation anomalies in the post-dam period increases severity of gully erosion

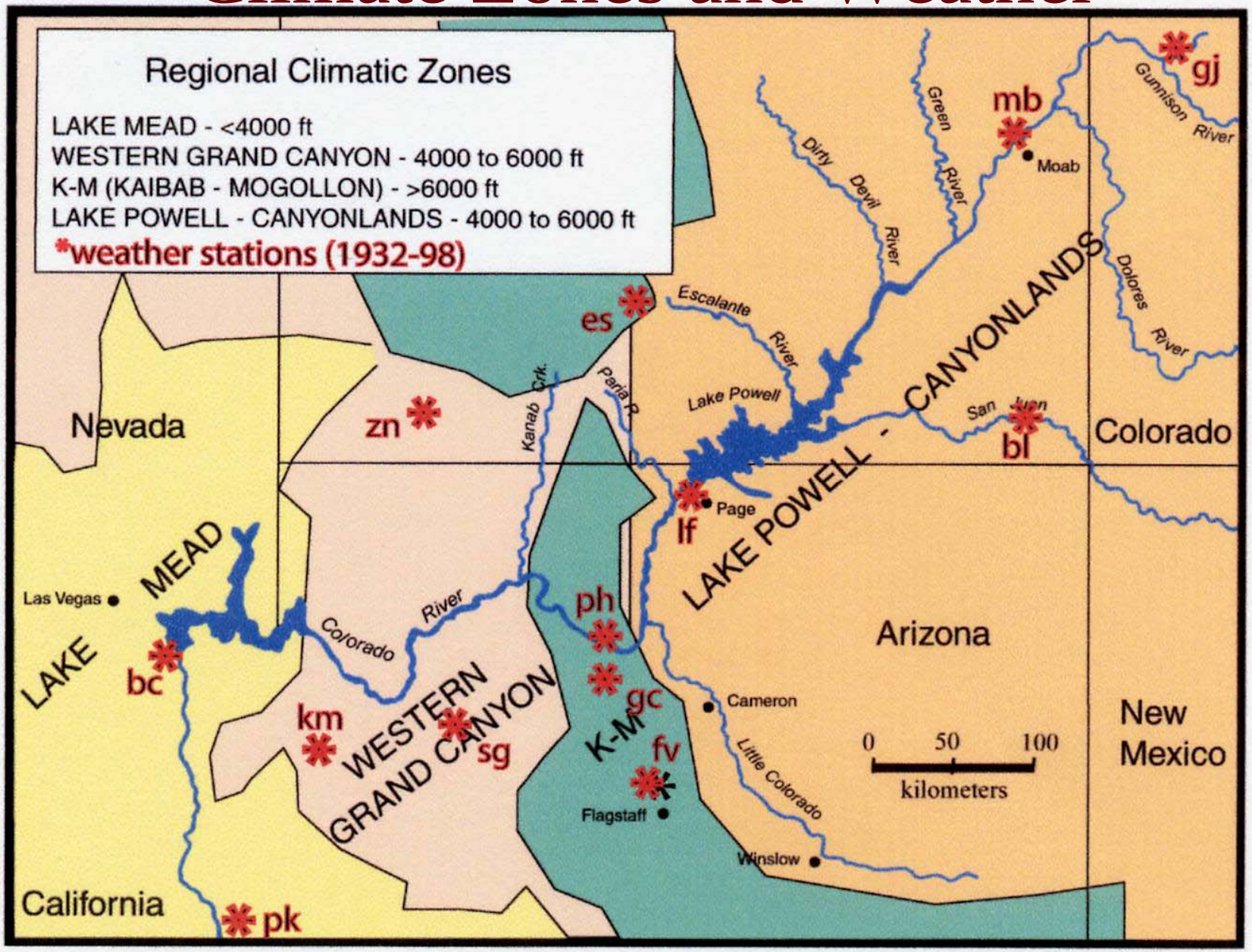
- Test 1 - Evaluate previous research on variation of 20th century precipitation
- Test 2 - Investigate variation in monsoon season rainfall at equivalent time periods before and after closure of the dam

Decadal Variation in 20th Century Precipitation-Colorado Plateau



Webb, et.al. In preparation

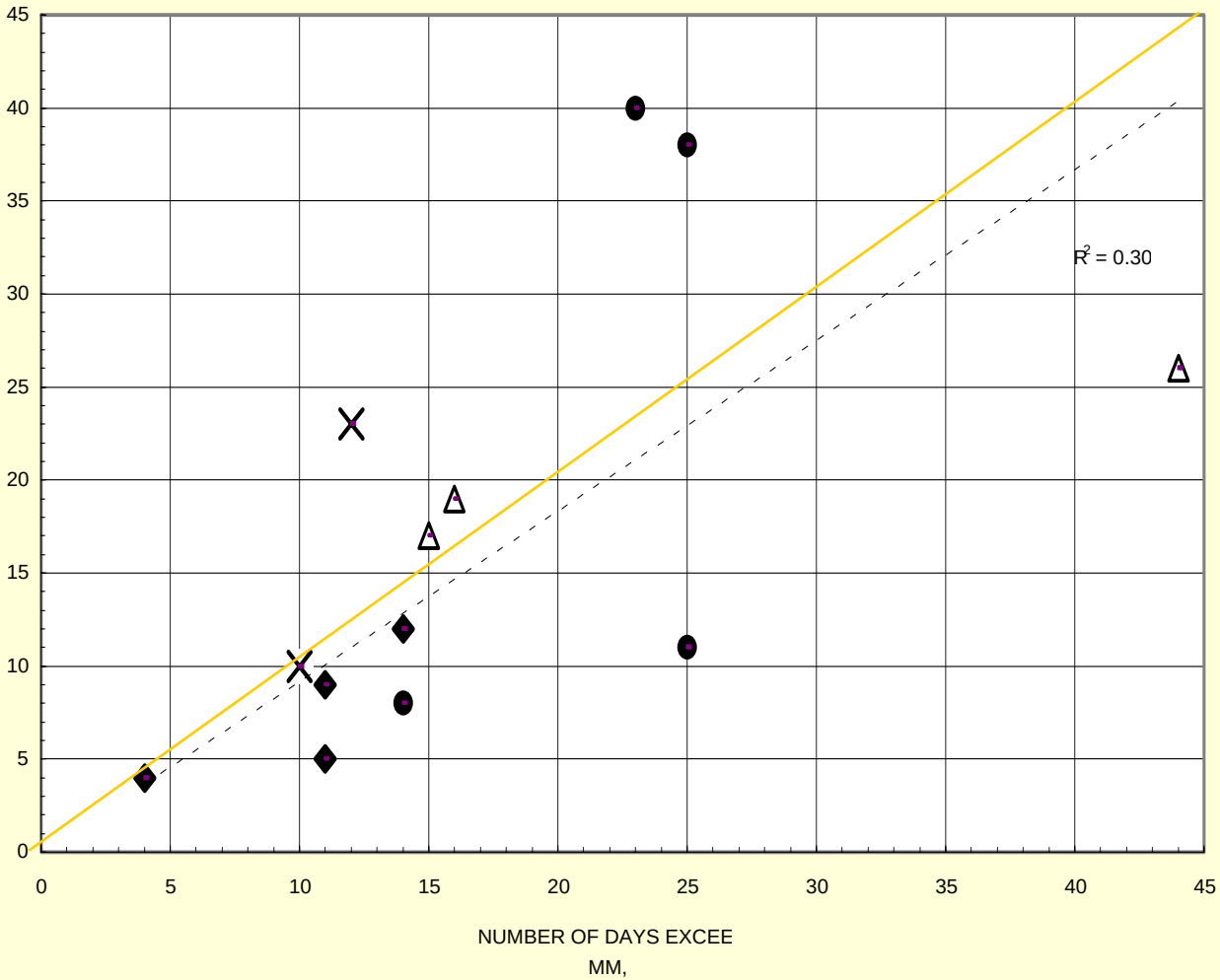
Climate Zones and Weather



Monsoon Precipitation

for 13 Weather Stations, Colorado River Corridor (>25 mm/day)

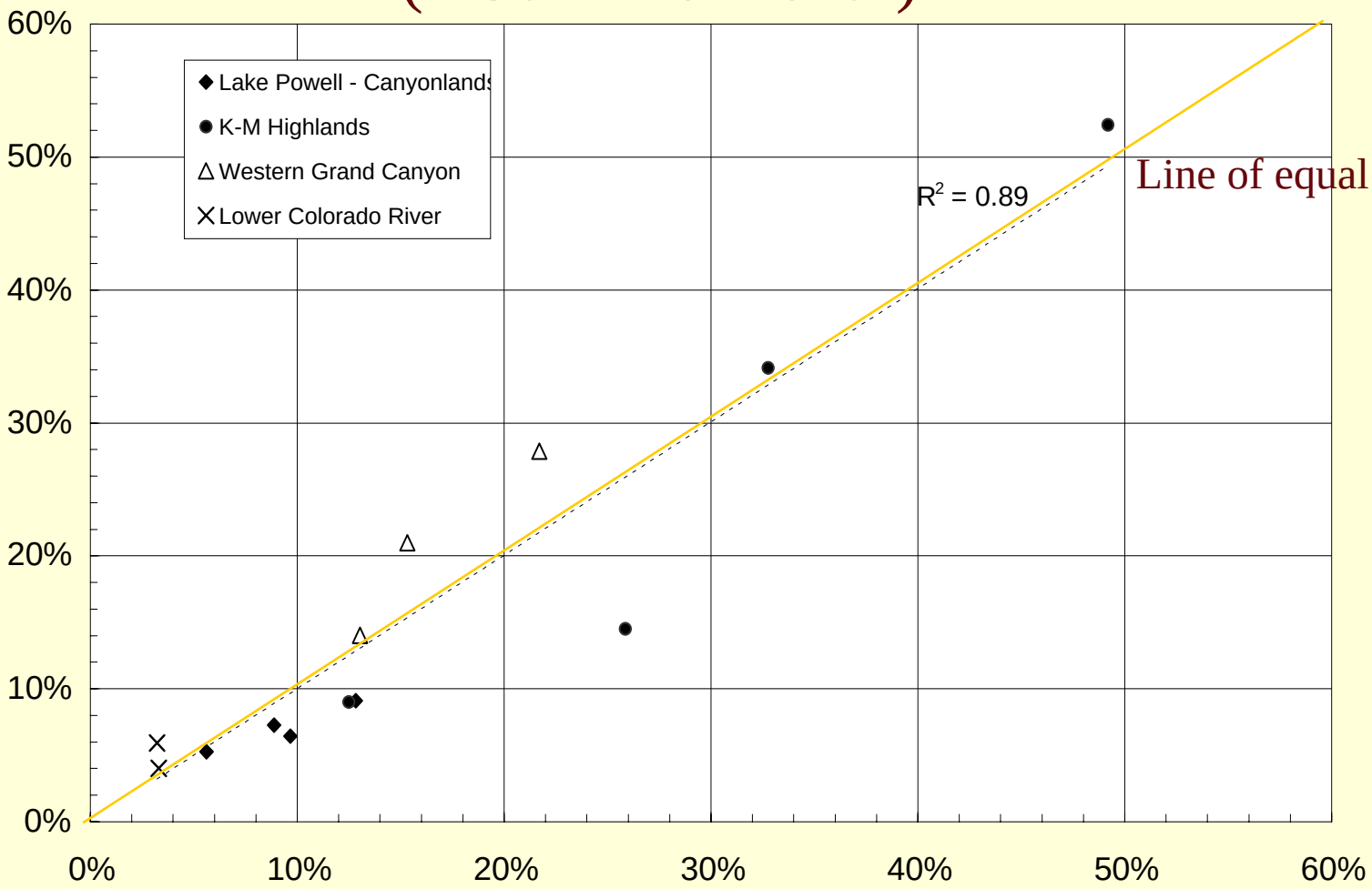
Line of equal events



Monsoon Precipitation

for 13 Weather Stations,Colorado River Corridor

(> 50 mm / month)

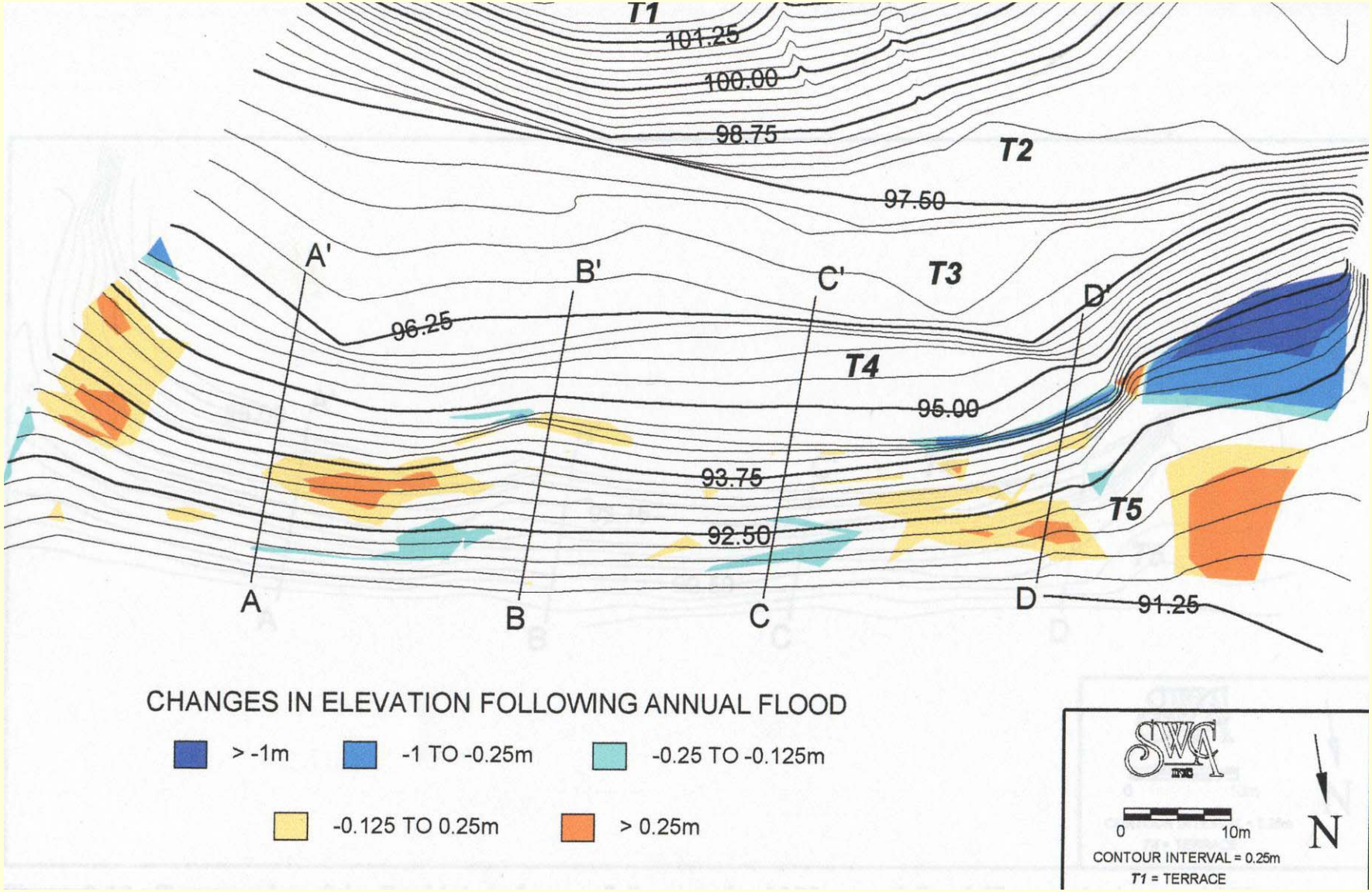


Base-Level Hypothesis:
Reduction of sediment supply and large annual floods (post-dam) increases rate of gully erosion

- Test 1 - Report on rebuilding of high-elevation sand bars in Cataract Canyon
- Test 2 - Assess catchment and river processes at each study site in Grand Canyon

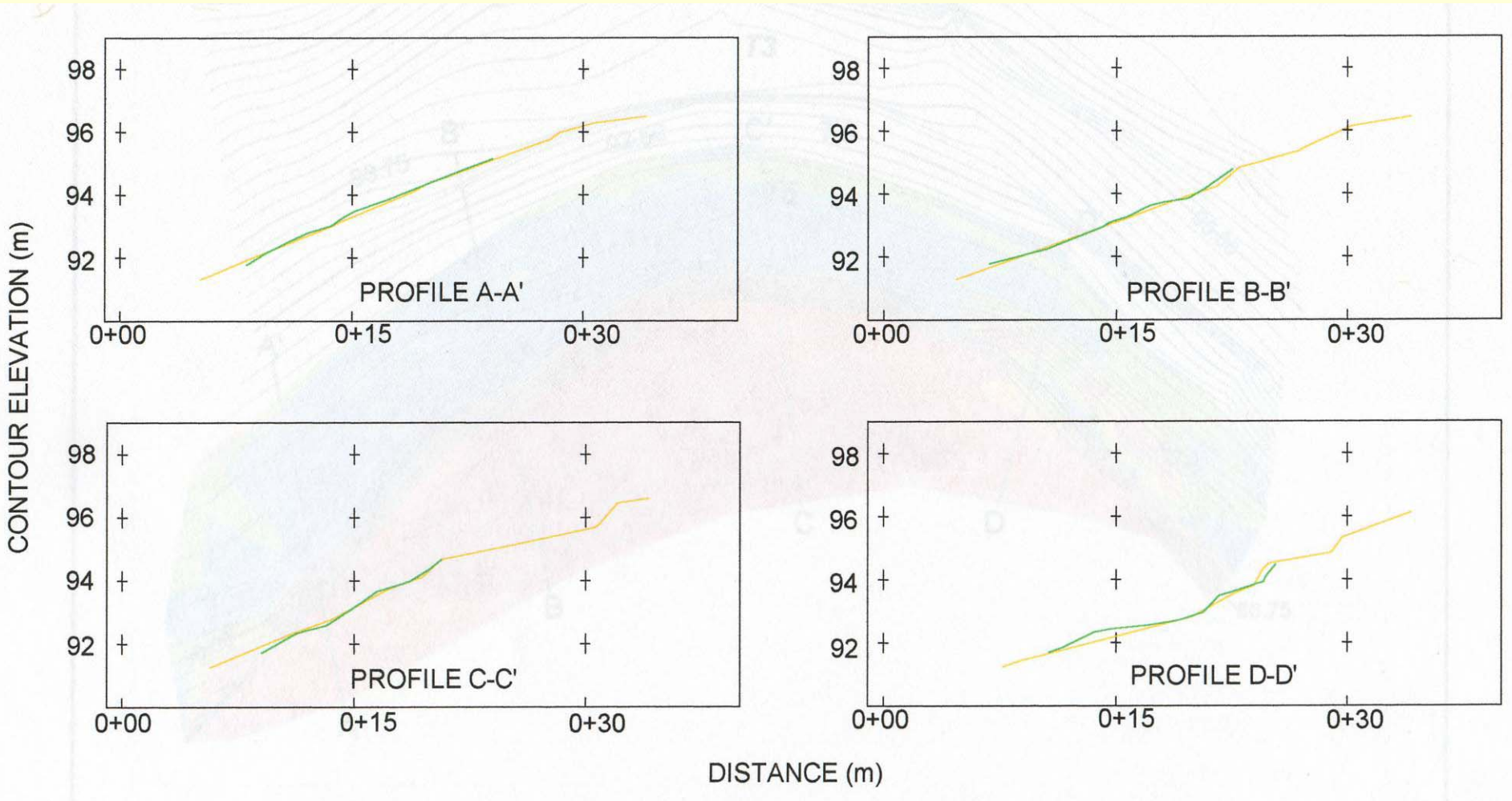
Rapid #4

1999 post flood survey-plan view



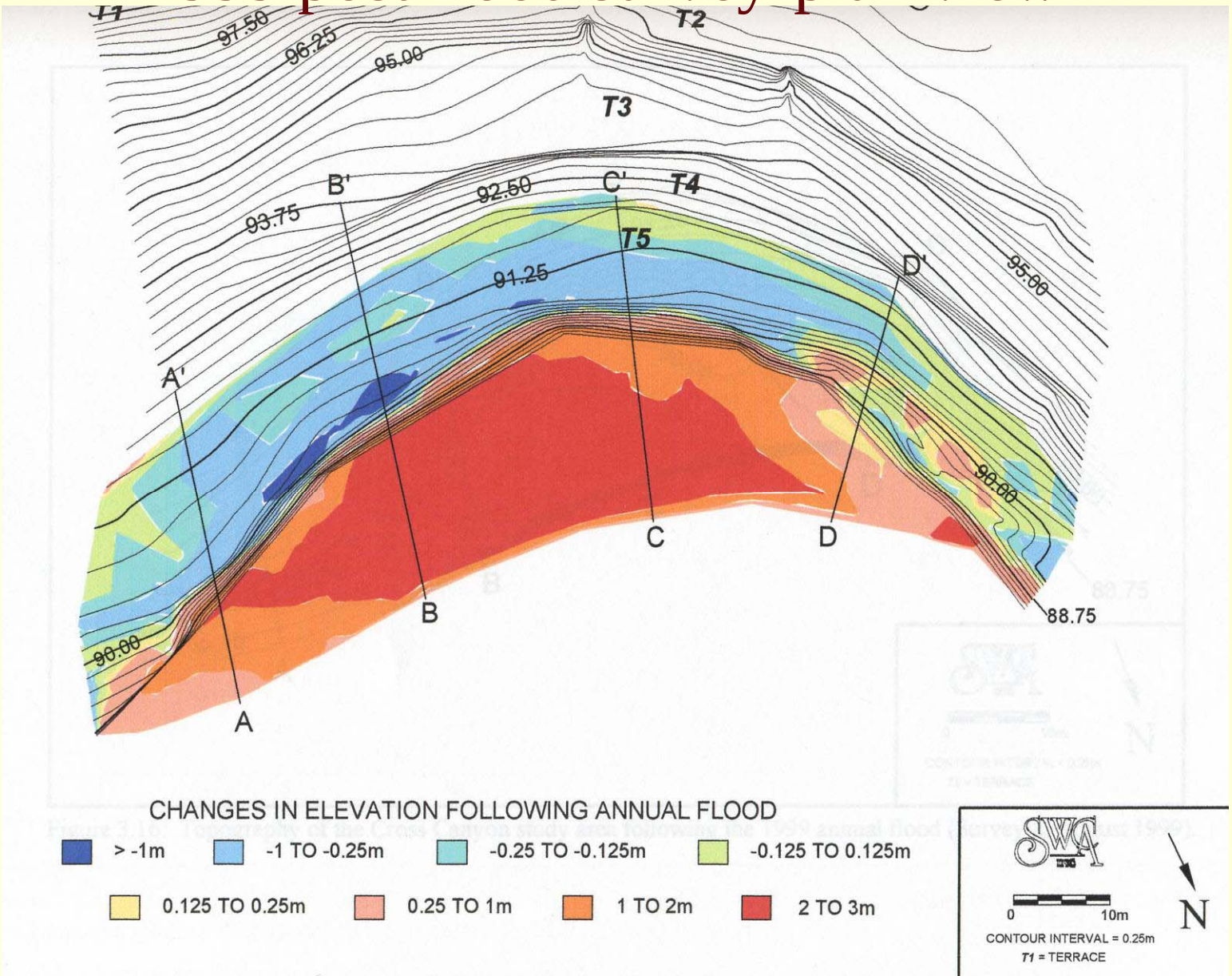
Rapid #4

1999 post flood survey-section views



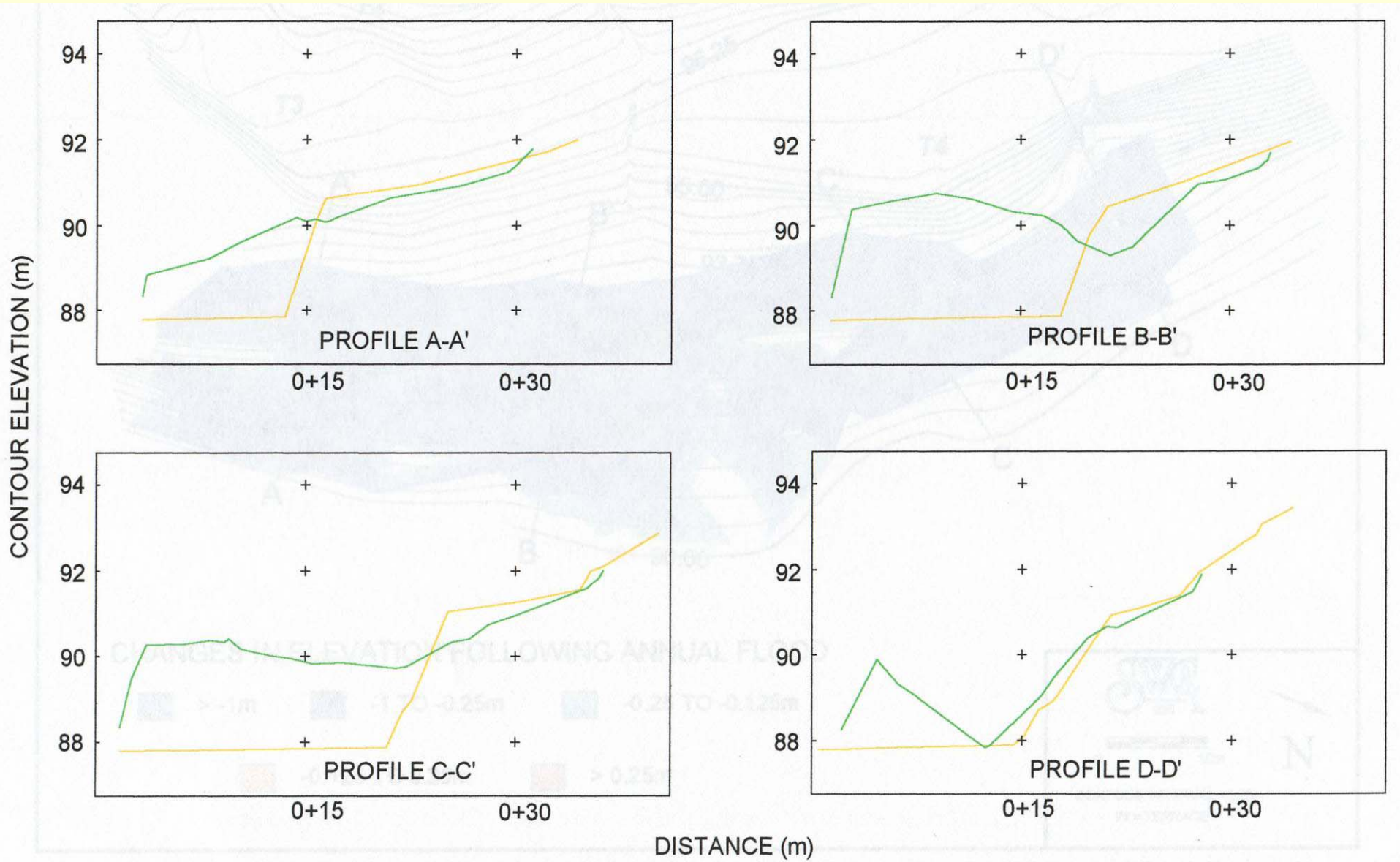
Cross Canyon

1999 post flood survey-plan view



Cross Canyon

1999 post flood survey-section view

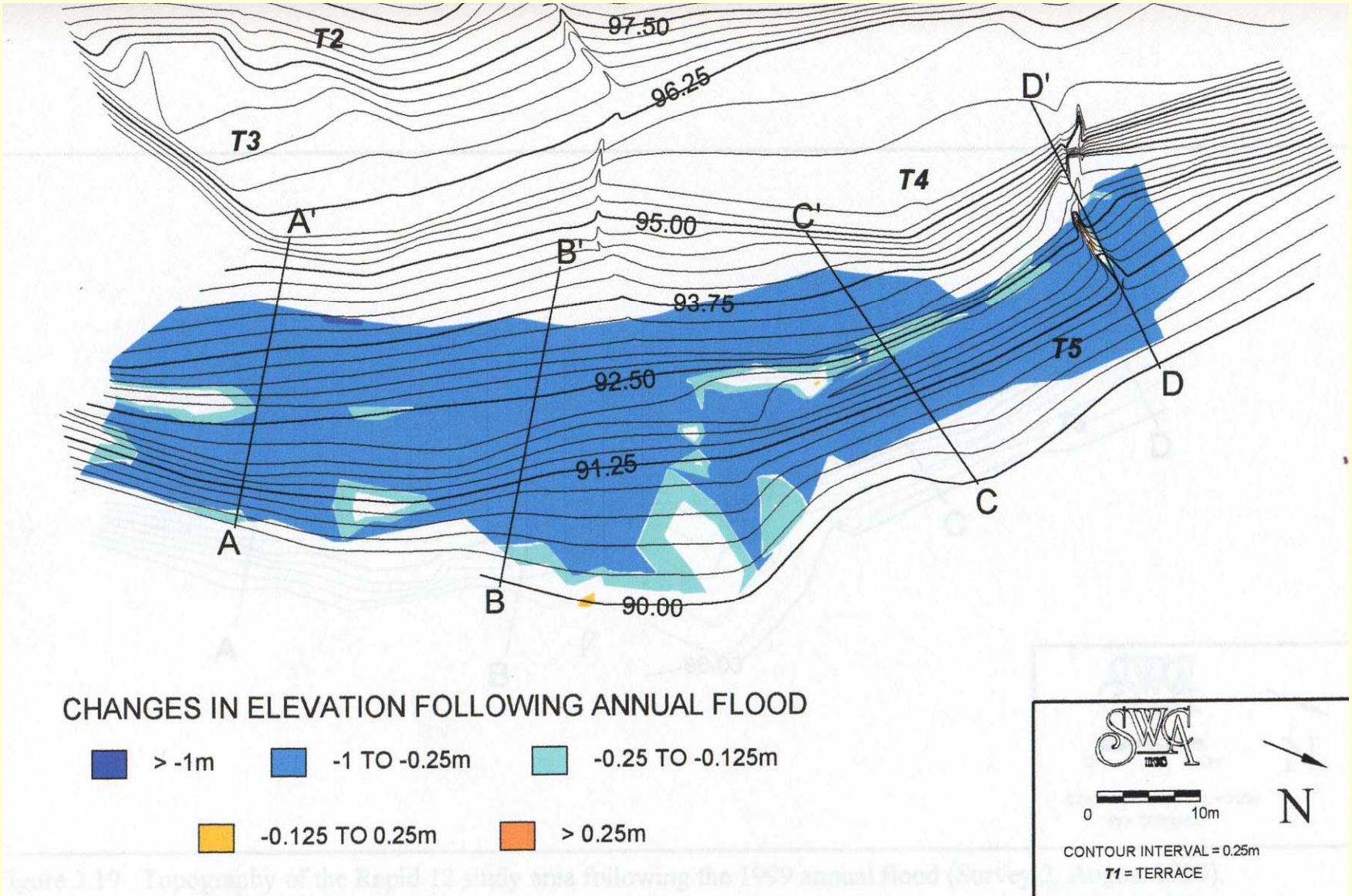


Cross Canyon
March 1999
Pre-flood

Cross Canyon
August 1999
Post-flood

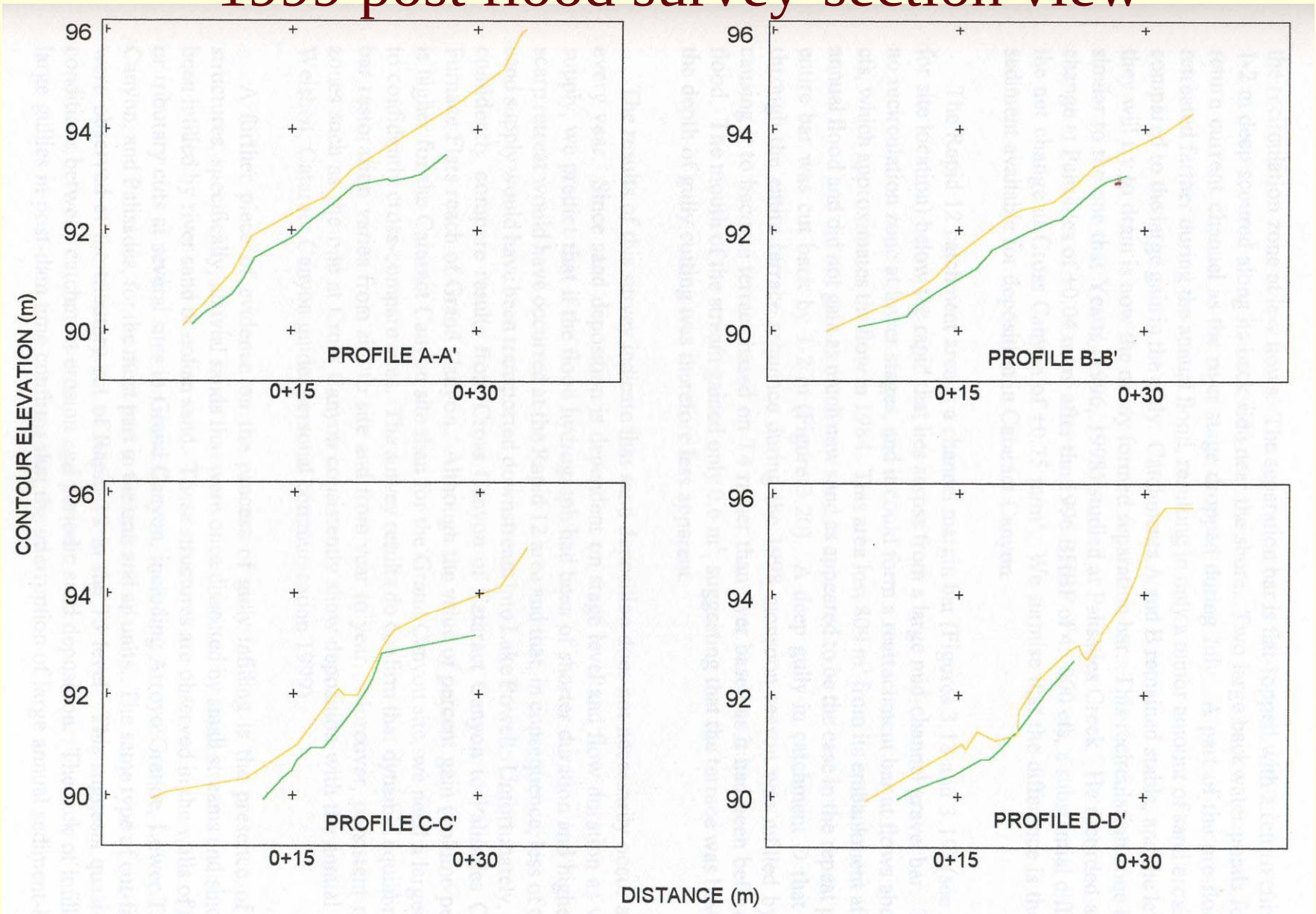
Rapid #12

1999 post flood survey-plan view



Rapid #12

1999 post flood survey-section view



Rapid 12
March 1999
Pre-flood

Rapid 12
August 1999
Post-flood

Sand Volume Gained/Lost at Three Cataract Canyon Catchments

Study site	sand vol. cut (m3)	sand vol. fill (m3)	net sand volume change (m3)	ratio of change vol./area
Rapid 4	-187.6	+145.5	-42.1	-0.02
Cross Cyn.	-400.9	+2677.6	+2276.7	+0.75
Rapid 12	-811.2	+1.9	-809.3	-0.42

Granite Park
1963
1000 cfs
(Belknap collection)

Granite Park
1996
8000 cfs
(Lisa Leap photo)

Old Unkar Camp
1960
(Belknap collections)

Old Unkar Camp
1998

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- Is Cataract Canyon analogous to Grand Canyon?
- Are terrace gully erosion rates similar?
- Do large annual river floods mitigate gully erosion?
- How can Cataract Canyon inform Grand Canyon in the post dam period?

Results

- Cataract Canyon does inform Grand Canyon pre-dam alluvial processes.
- Null hypothesis is negated.
- Climate variability hypothesis is partly supported.
- Base level hypothesis is substantiated through infilling of gullies and buttressing of terraces by 1999 annual flood in Cataract Cyn.

Recommendations

- Refine and monitor geomorphic analogue catchments in Grand and Cataract Canyons.
- Establish and monitor critical geomorphic parameters in Grand Canyon archeologic areas.
- Refine models of archeology and sediment transport to better understand relationships of fine sediment to cultural resources.