

Alluvial Bar Morphology and Dynamics in the Middle Rio Grande: Application to Habitat Restoration for the Rio Grande Silvery Minnow

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WORK CONDUCTED FOR:

- **New Mexico Interstate Stream Commission**
- **Middle Rio Grande ESA Collaborative Program**

WHAT IS A BAR ?



?

“Discrete alluvial feature formed by deposition and modified by erosion”

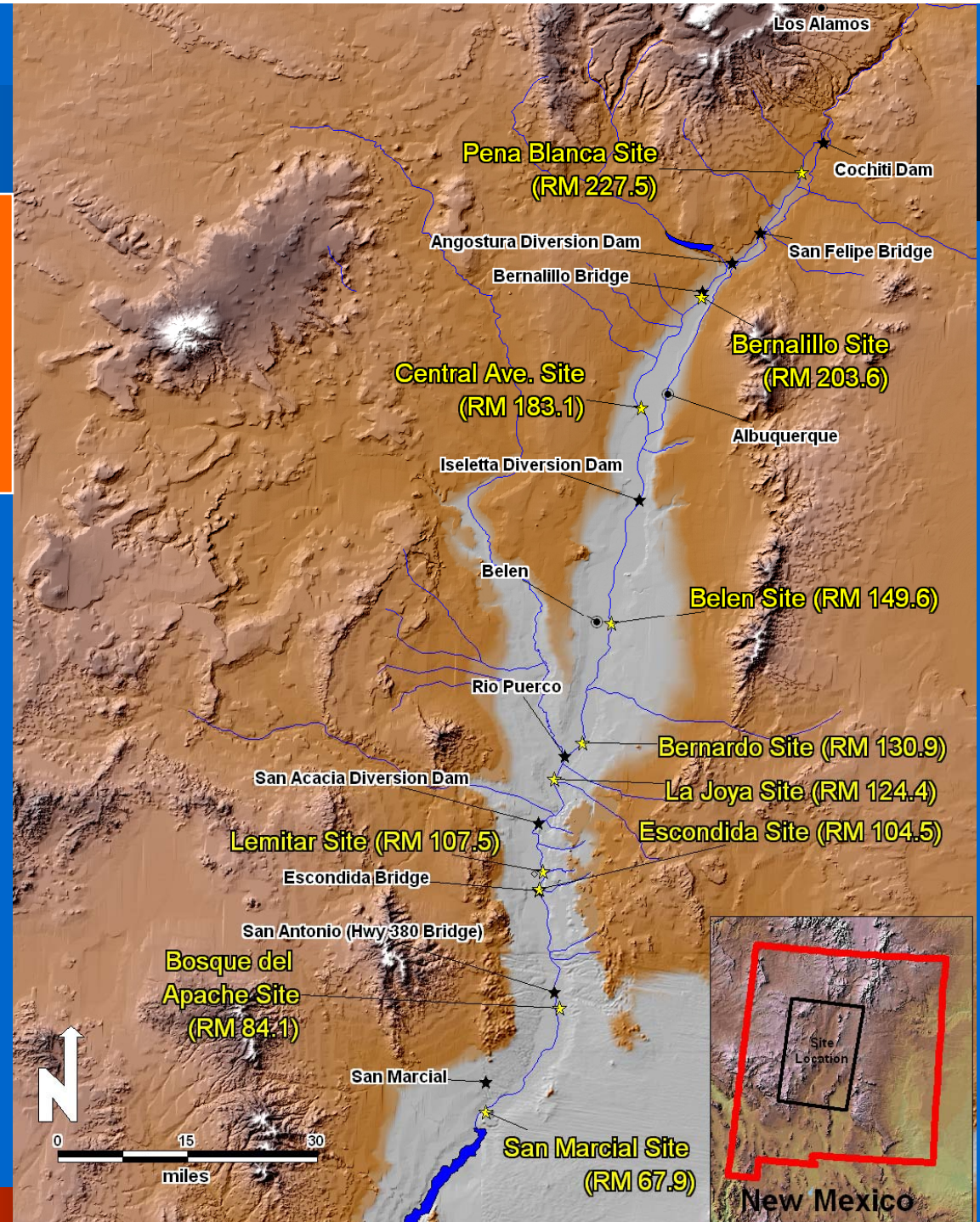
- Can be mid-channel or bank-attached
- Can be subaerial or subaqueous
- Can be stationary or mobile
- Can be vegetated or unvegetated

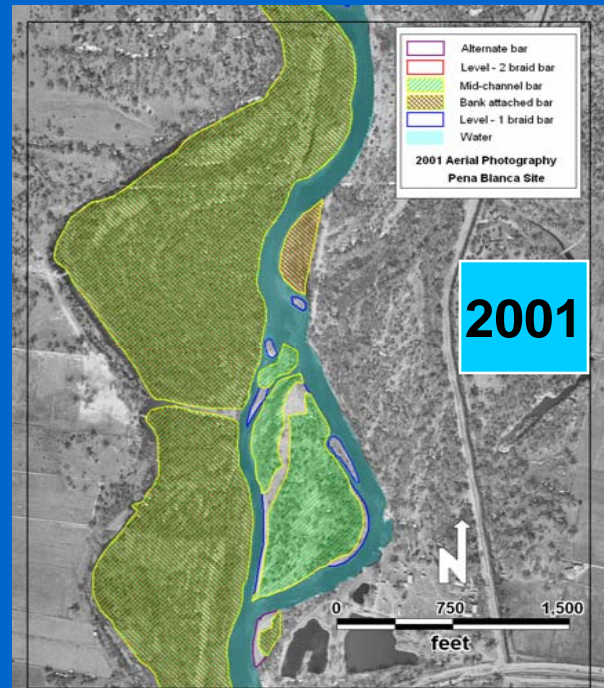
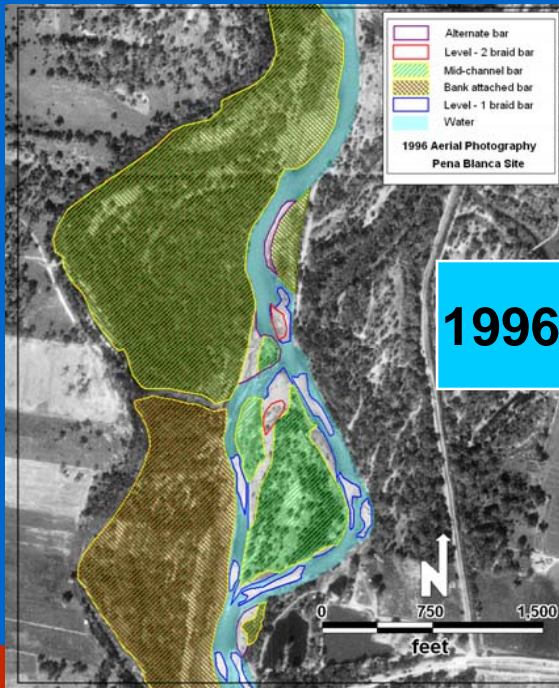
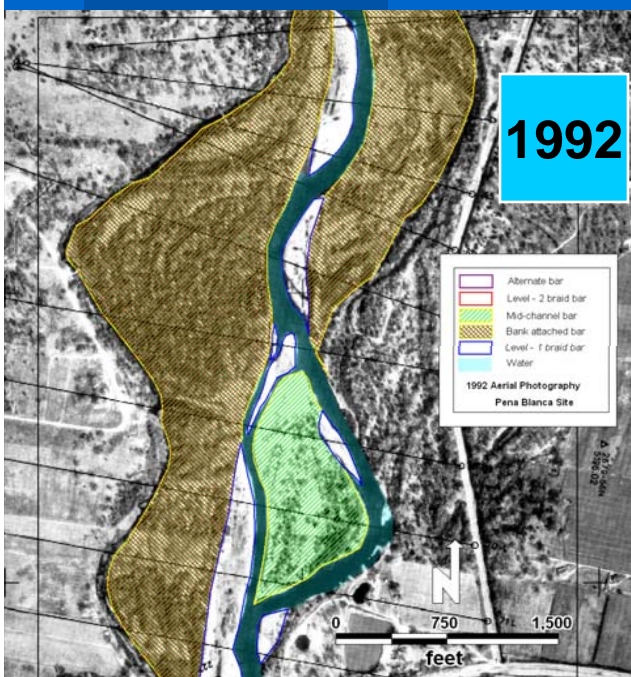
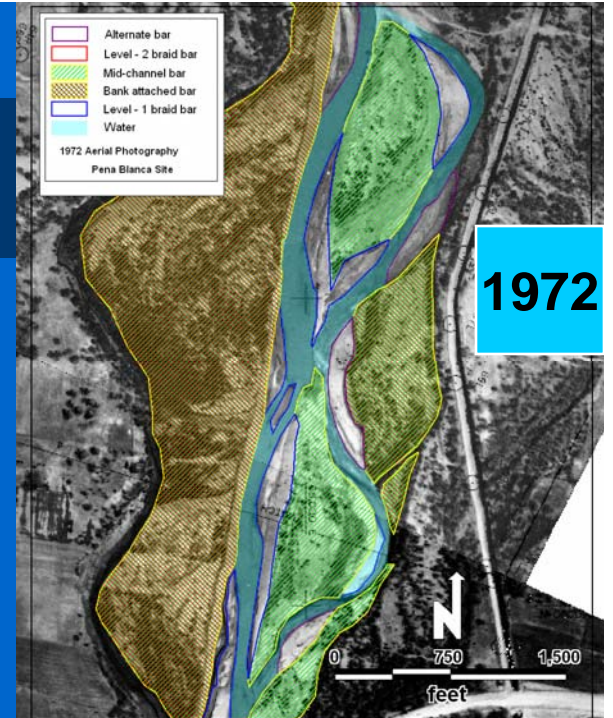
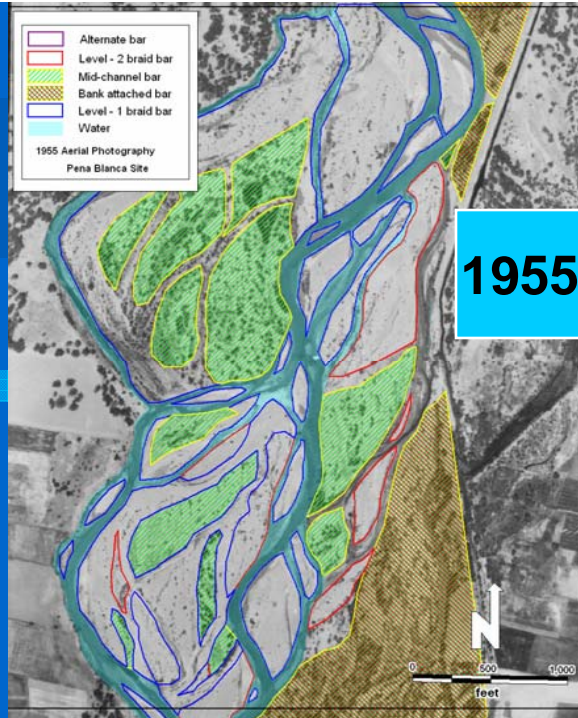
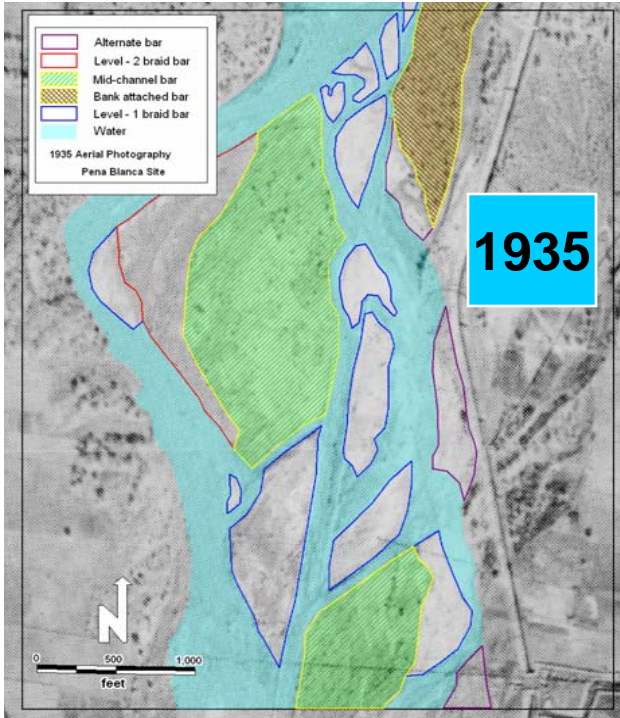


PROJECT OBJECTIVES

- Evaluate bar changes over time in response to changes in flow, sediment supply and channel morphology
- Develop a bar classification
- Relate fluvial processes to bar types
- Apply results to river/habitat restoration

9 STUDY SITES





Modified Braiding Index (Germanoski, 1989)

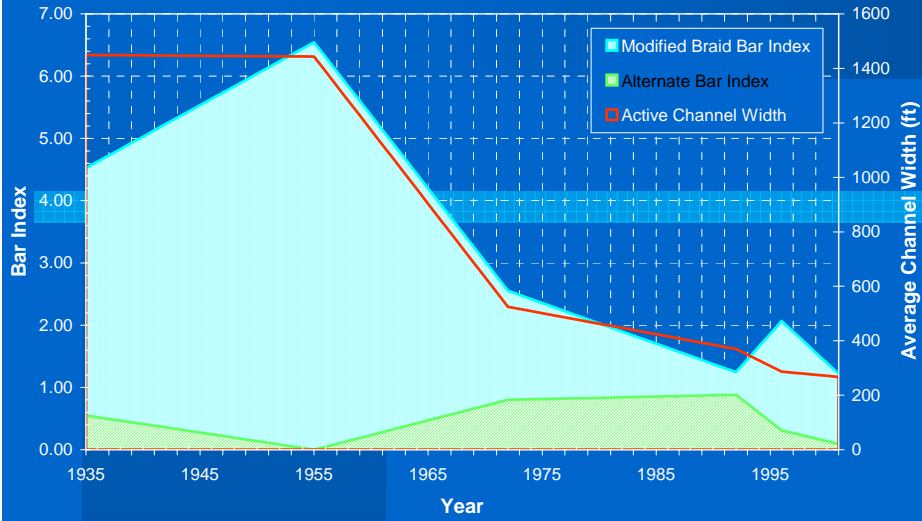
$$MBI = \frac{2(\sum L_{BraidBar})}{L_{Channel}} + \frac{n_{bars}}{L_{Channel}}$$

EXPECTED MBI RESPONSES

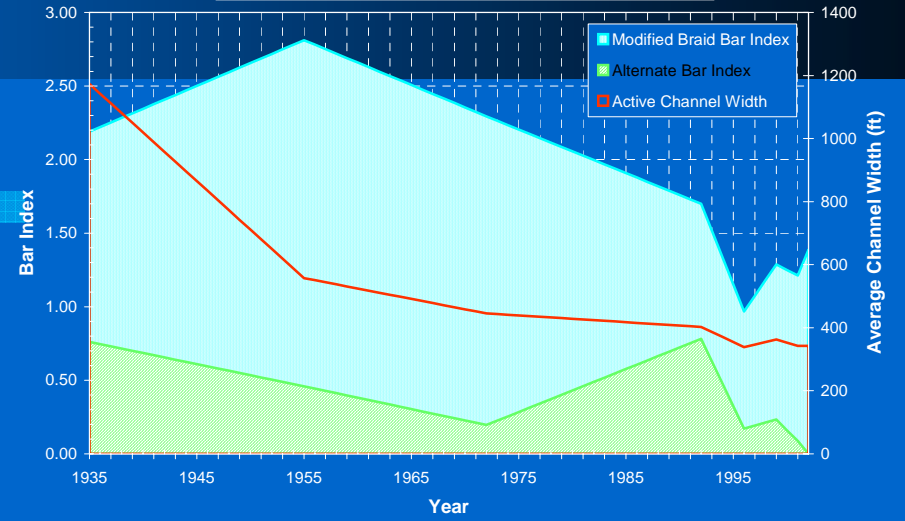
(Germanoski and Schumm, 1993;
Germanoski and Harvey, 1993)

- If D_{50} increases, and there is sediment supply: $>$ MBI
- If D_{50} increases, and there is no sediment supply: $<$ MBI
- If the bed aggrades: $>$ MBI
- If the bed degrades: $<$ MBI

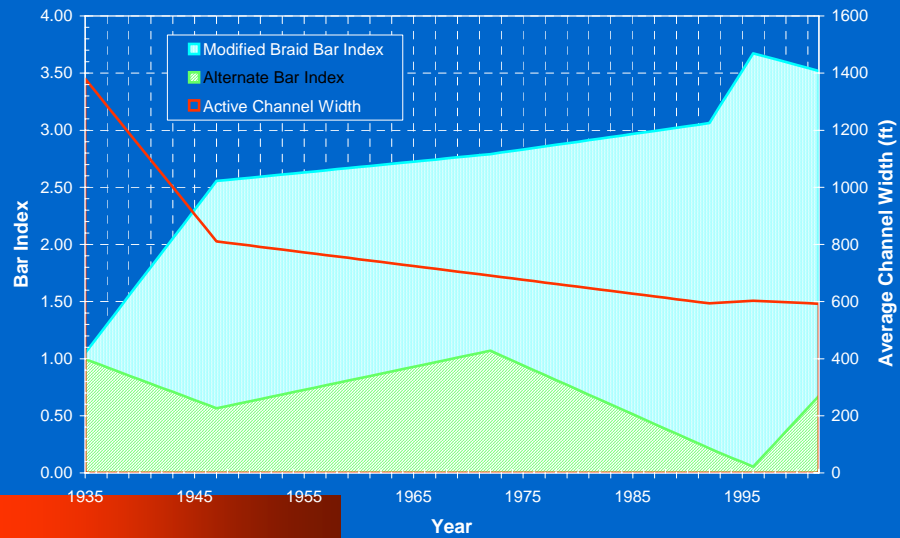
Pena Blanca



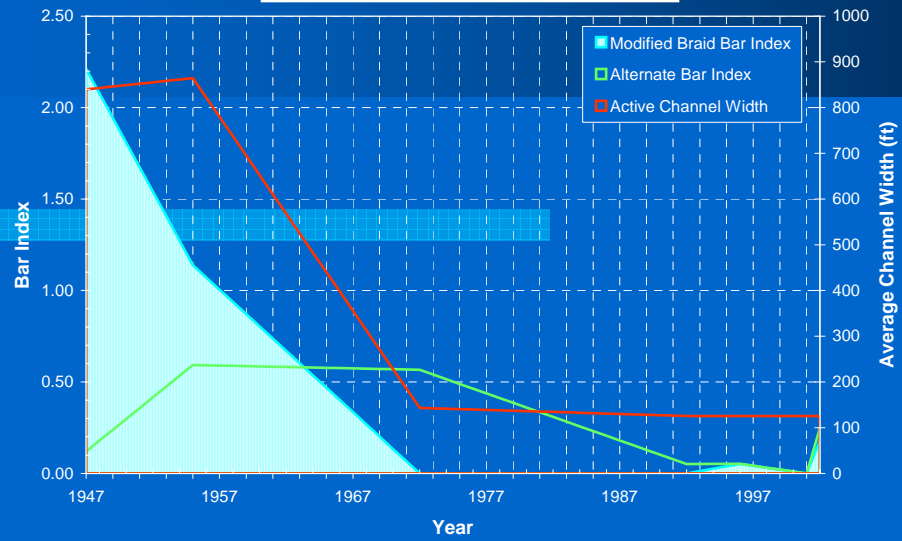
Central Avenue



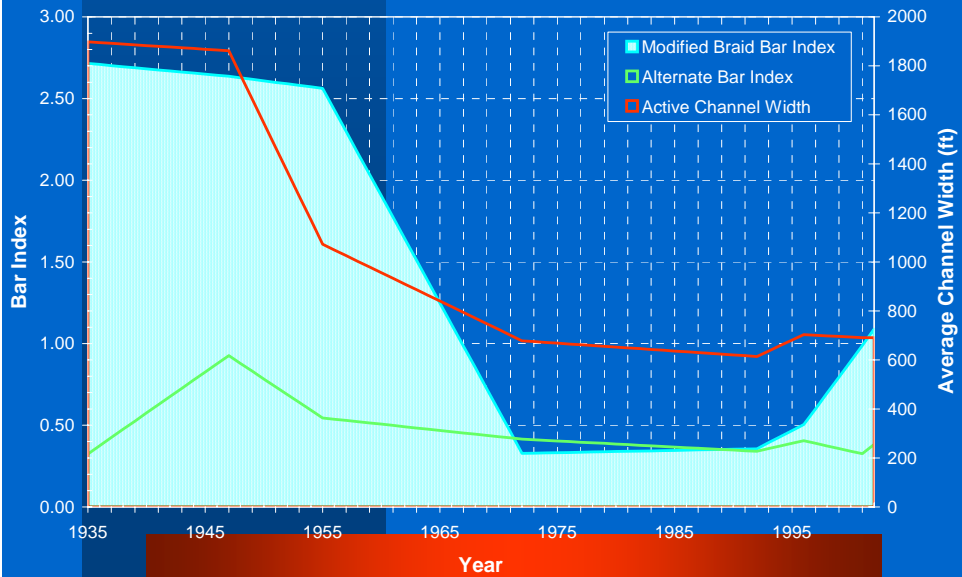
Bernardo



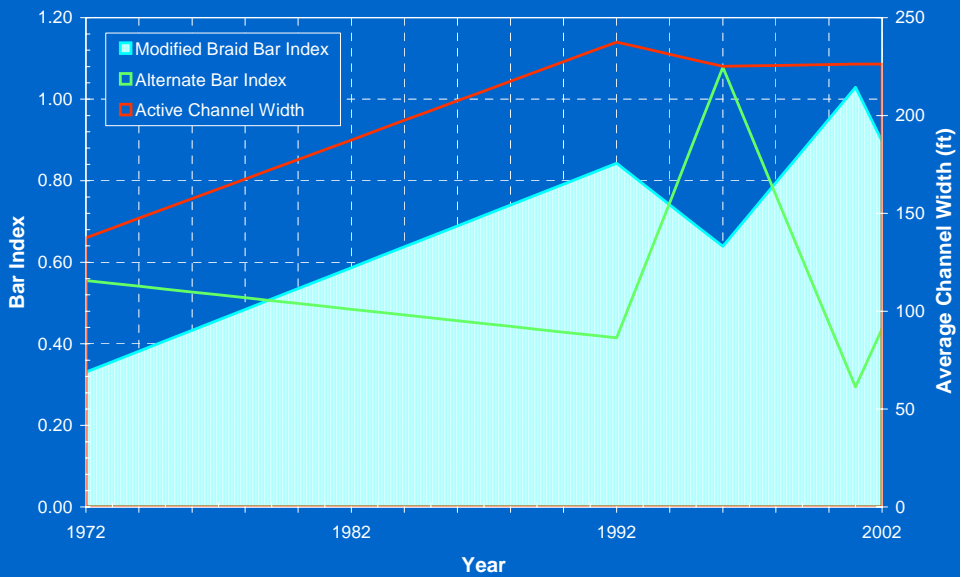
Escondida



Bosque del Apache

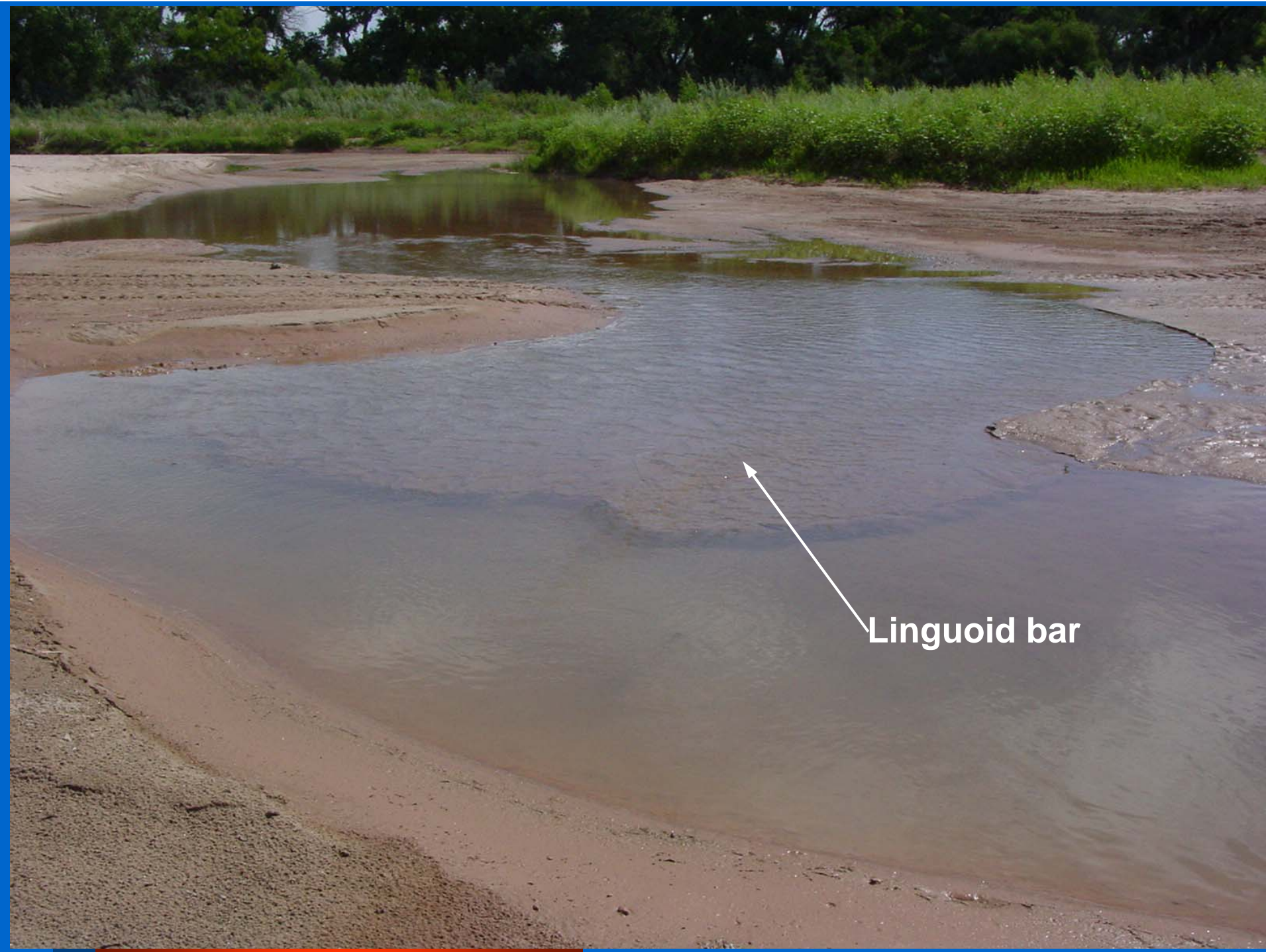


San Marcial



Hierarchical Bar Classification for the Middle Rio Grande

Bar Type	Location	Elevation	Subaqueous or Subaerial	Perennial Vegetation
Linguoid	Mid-channel	Bed	Subaqueous	No
Braid	Mid-channel	Level-1,2	Subaerial	No
Alternate	Bank-attached	Level-1	Subaerial	No
Mid-channel	Mid-channel	Level-1,2	Subaerial	Yes
Bank-attached	Bank-attached	Level-1,2	Subaerial	Yes

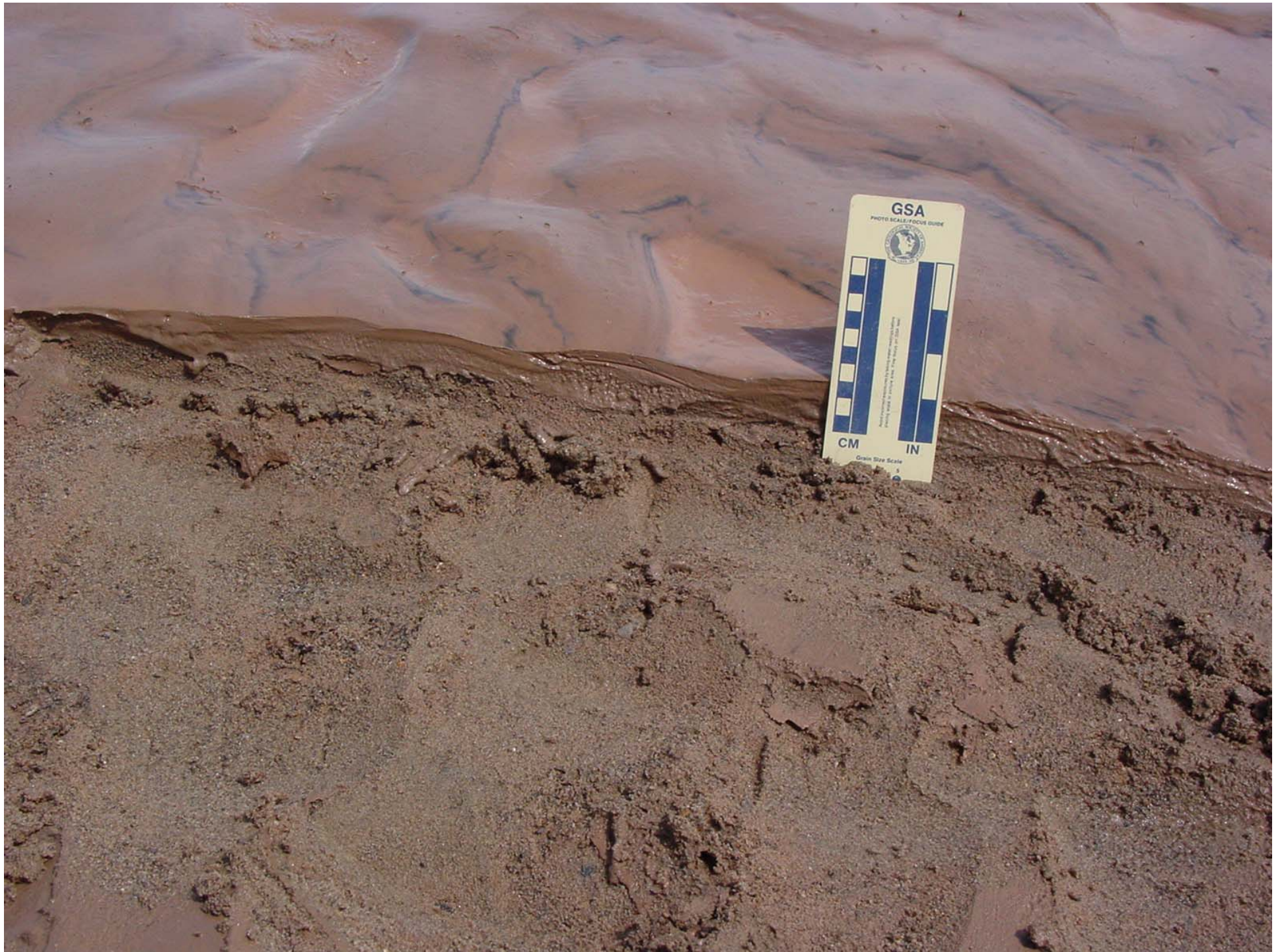


Linguoid bar



L-1 braid bars





GSA
PHOTO SCALE/FOCUS GUIDE

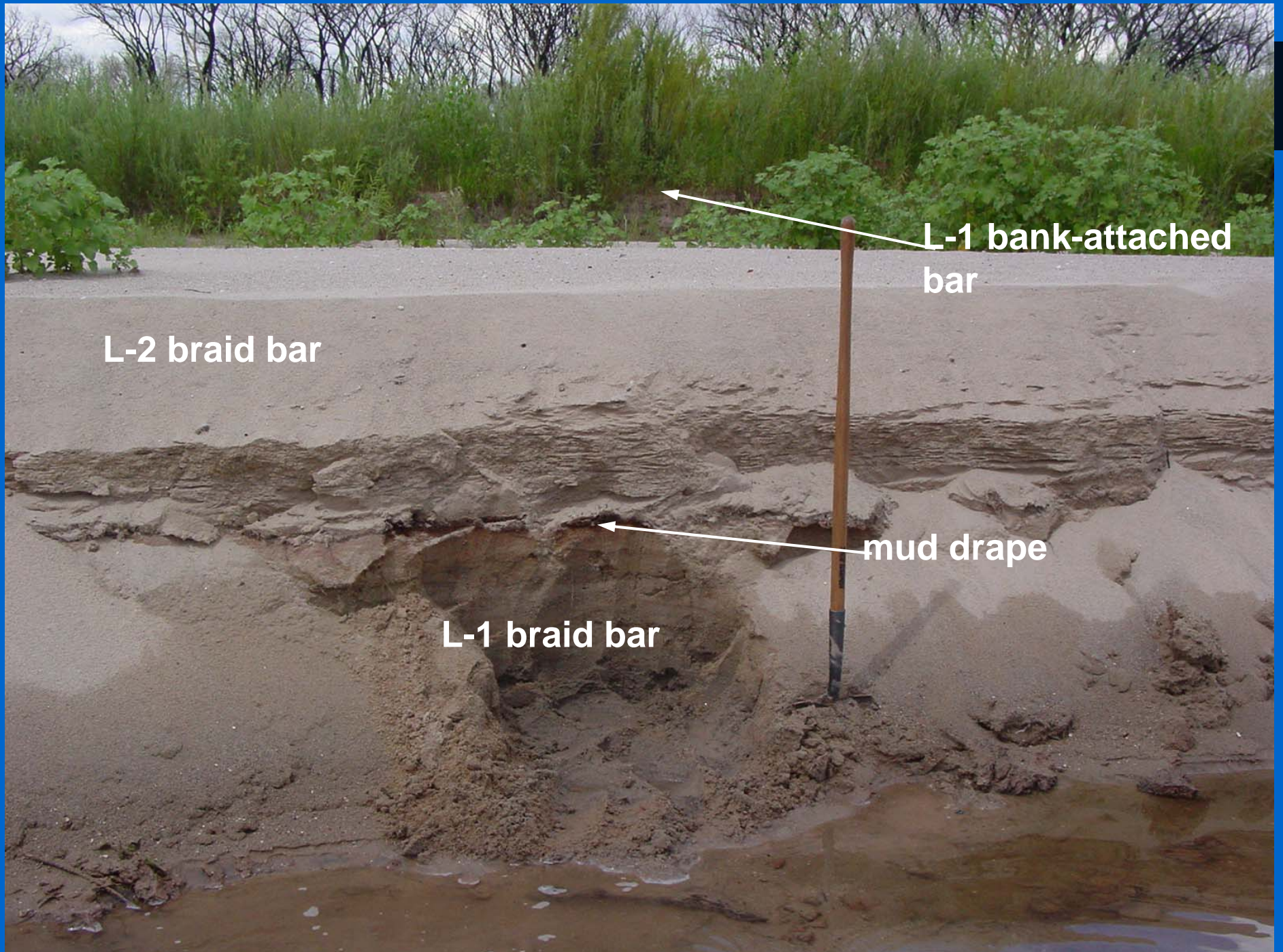


Always use this scale in photographs taken with a camera. Accuracy is within 1% for lengths up to 10 cm. Accuracy is within 2% for lengths up to 10 in.

CM **IN**

Grain Size Scale

1
2
3
4
5

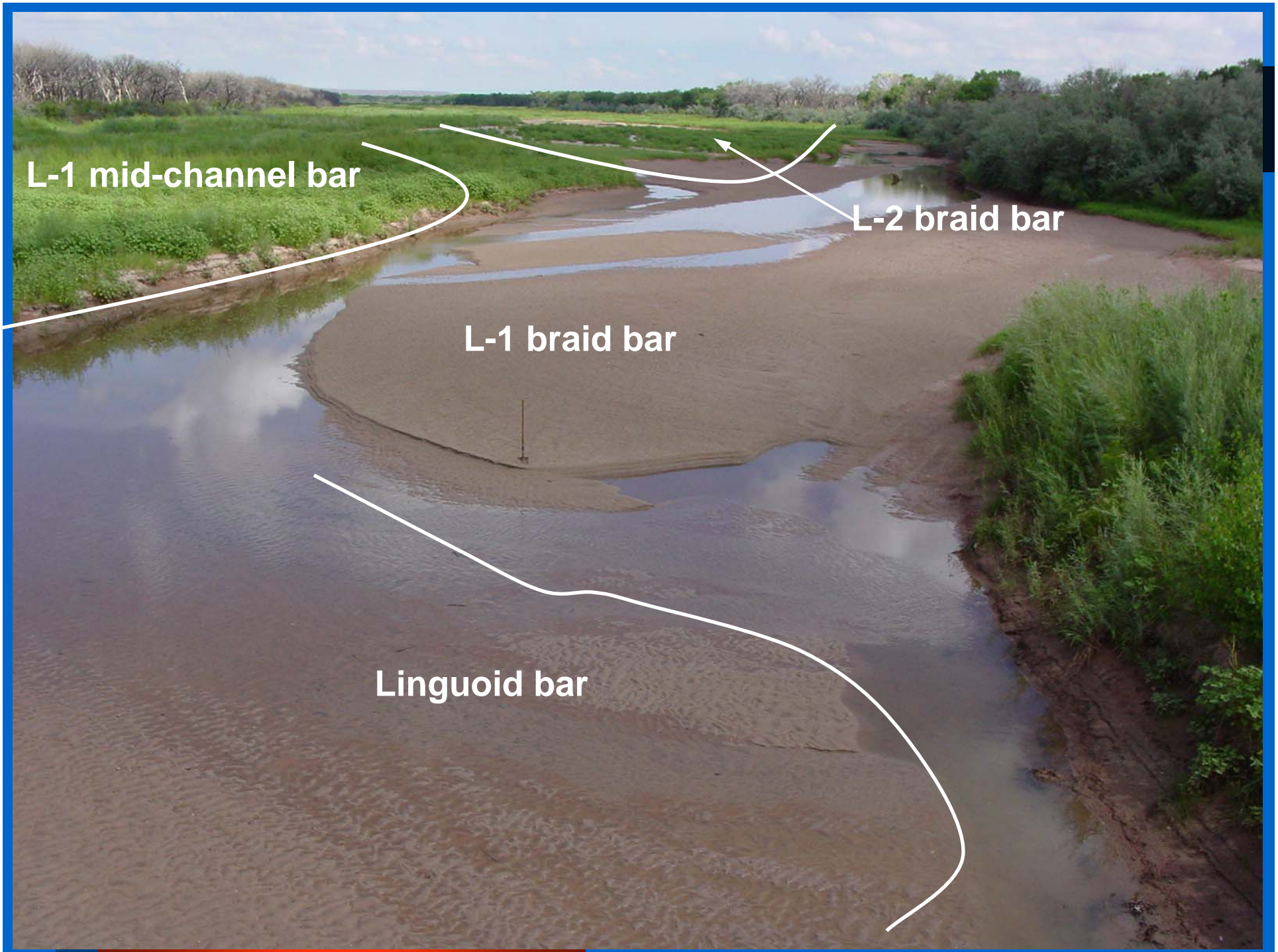


L-2 braid bar

L-1 bank-attached bar

mud drape

L-1 braid bar

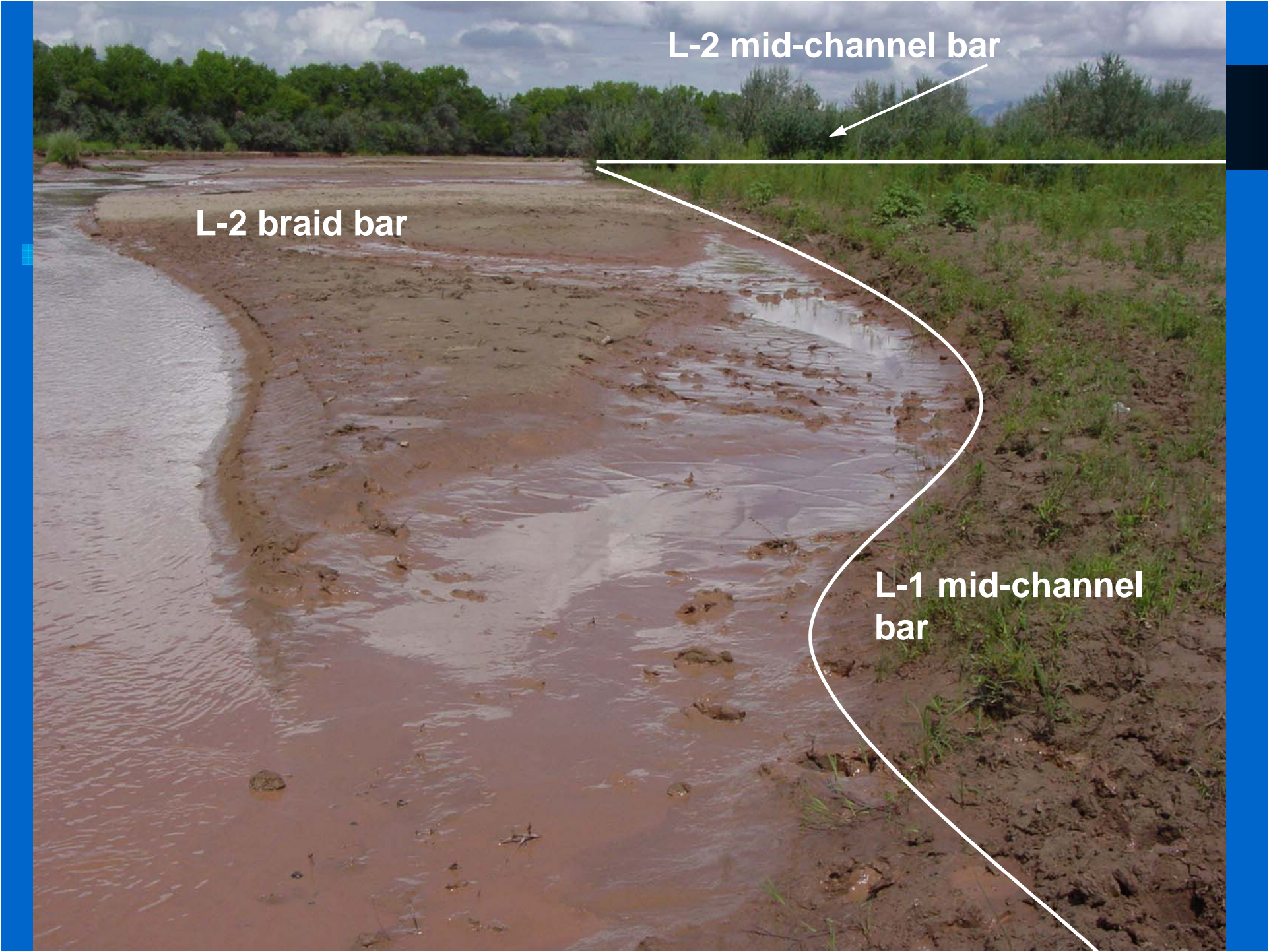


L-1 mid-channel bar

L-2 braid bar

L-1 braid bar

Linguoid bar



L-2 mid-channel bar

L-2 braid bar

L-1 mid-channel bar

L-2 mid-channel bar



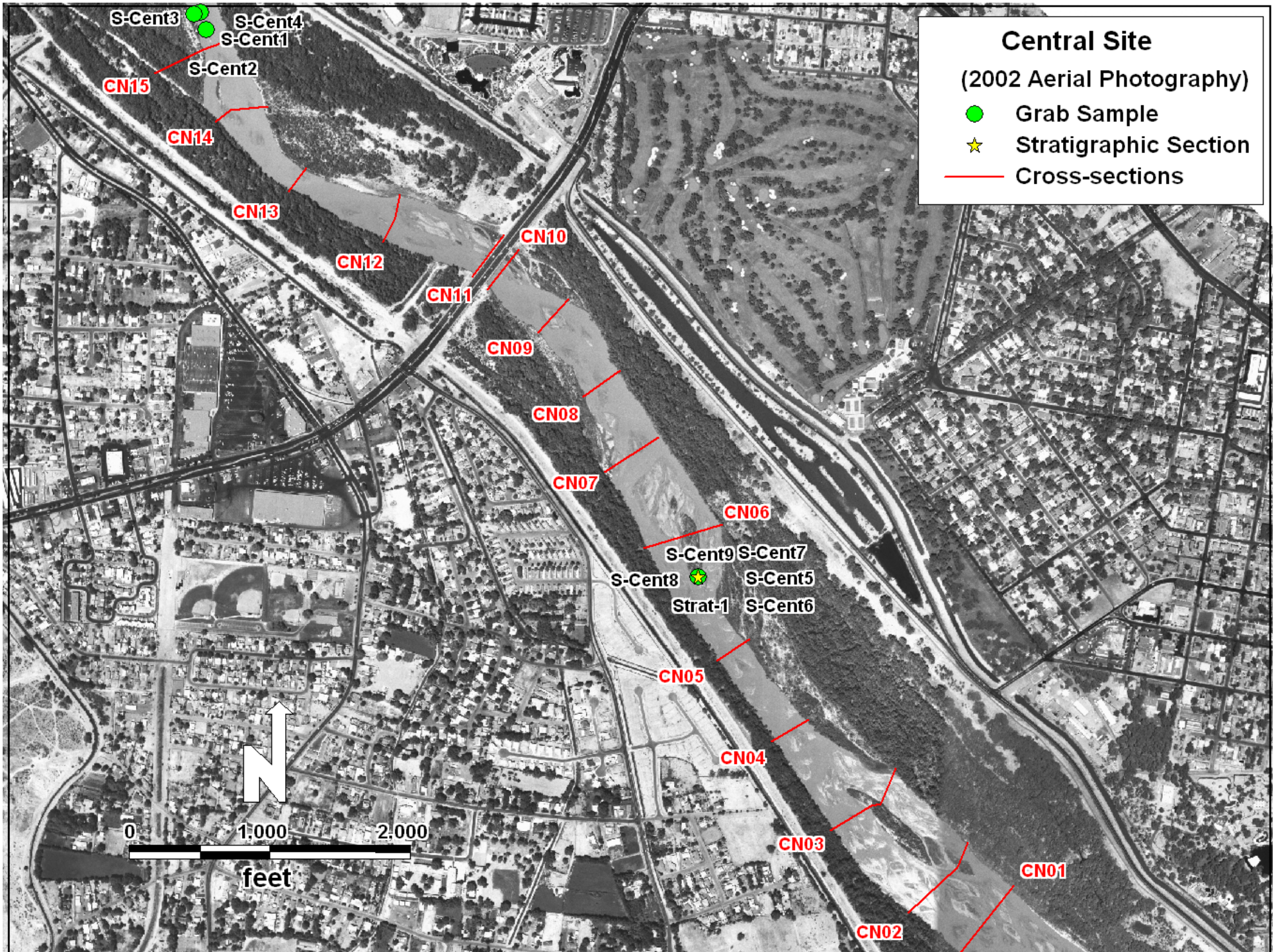


L-2 bank-attached bar

L-1 bank-attached bar

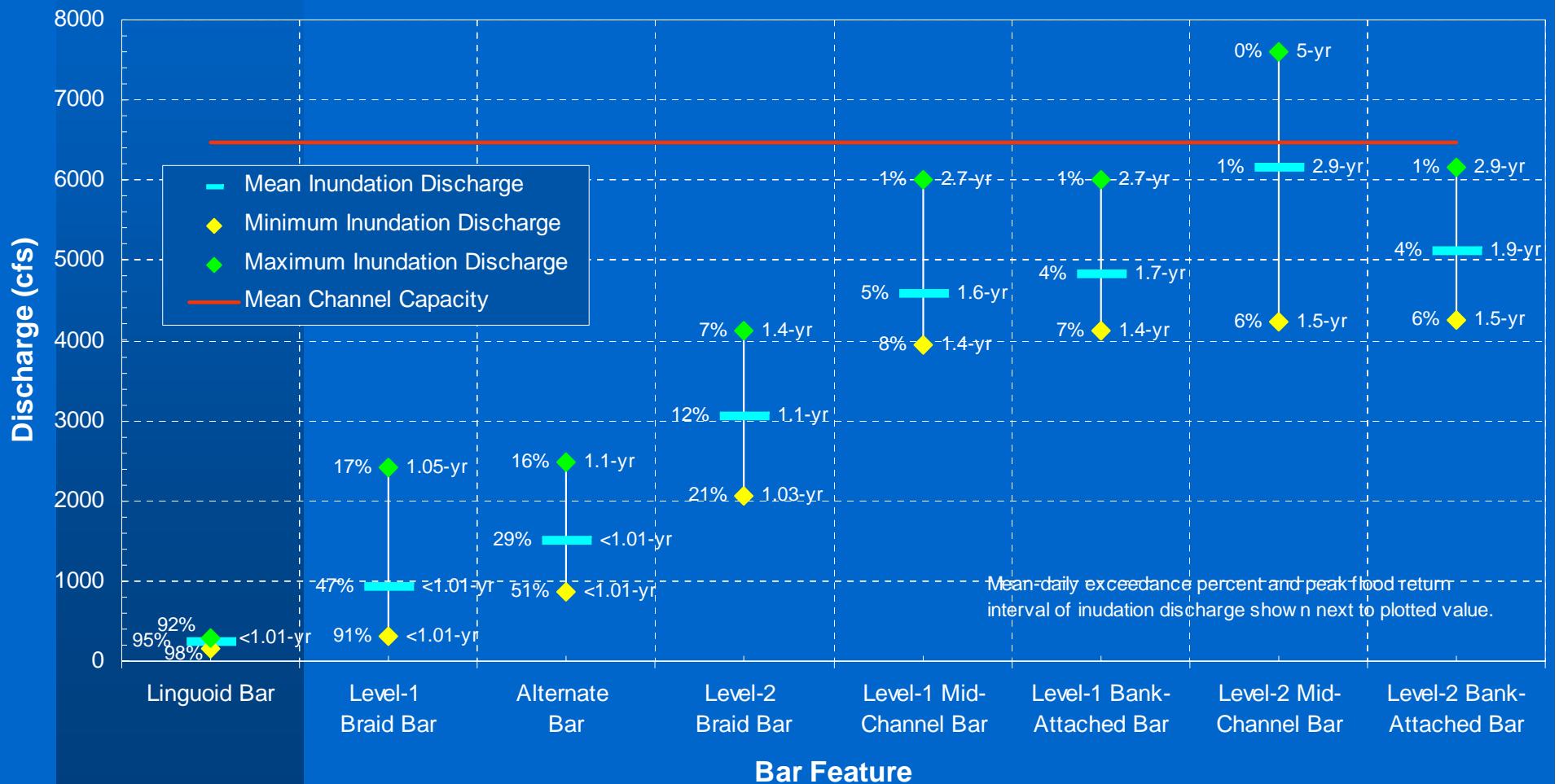
HYDRAULIC ANALYSIS

- **One-dimensional HEC-RAS models**
 - **Fixed-bed analysis**
 - **Calibrated to gauged flow at time of survey and 2005 peak flow (Tetra Tech. (2005))**



Central Site

Bar Inundation Analysis



BAR INUNDATION FREQUENCY & DURATION

Table ES-1. Summary of frequency and duration of inundation of the classified bar types at sites without excessive aggradation or degradation.*

Bar Type	Inundation Recurrence Interval	Days per Year of Inundation	Percent of Year Inundated
Level 1 braid bars	< 1 year	290	80%
Alternate bars	< 1 year	290	80%
Level 2 braid bars	< 1 year	146	<40%
Level 1 mid-channel bars	1.5 years	90	25%
Level 1 bank-attached bars	1.5 years	90	25%
Level 2 mid-channel bars	2 years	36	<10%
Level 2 bank-attached bars	2 years	36	<10%

*excluding the Pena Blanca, Bernalillo, Escondida and San Marcial sites.

BARS AND SHEAR STRESS

Table ES-2: Comparison of maximum in-channel shear stresses to the prevalence of bars in the sand-bed sites.

Site Names	Maximum In-Channel Shear Stresses (lb/ft ²)	Prevalence of Active Bars
Central Avenue	<0.1	moderate to high number of active bars
Bosque del Apache, San Marcial	0.1	high number of active bars
Bernardo, La Joya, Lemitar	0.12 - 0.15	active bars are present
Belen	0.2	moderate number of active bars
Escondida	0.3	virtually no active bars

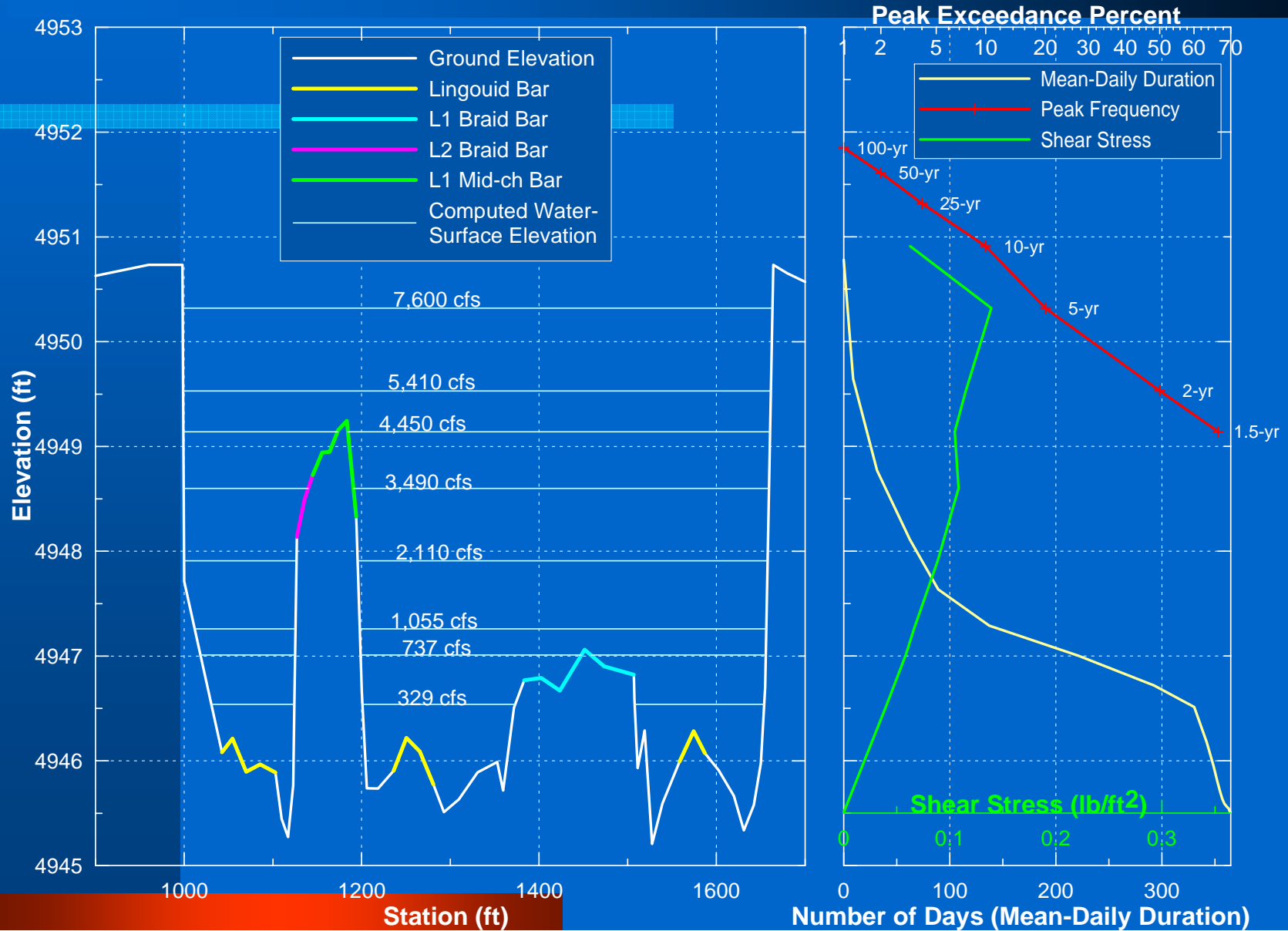
BARS AND VEGETATION

- Shear stress limit for vegetation establishment ~ < 1 psf
- Shear stress limit for vegetation removal ~ > 6 psf



9 4 2005

Central Site – Cross Section 2



BARS AND DEPOSITION

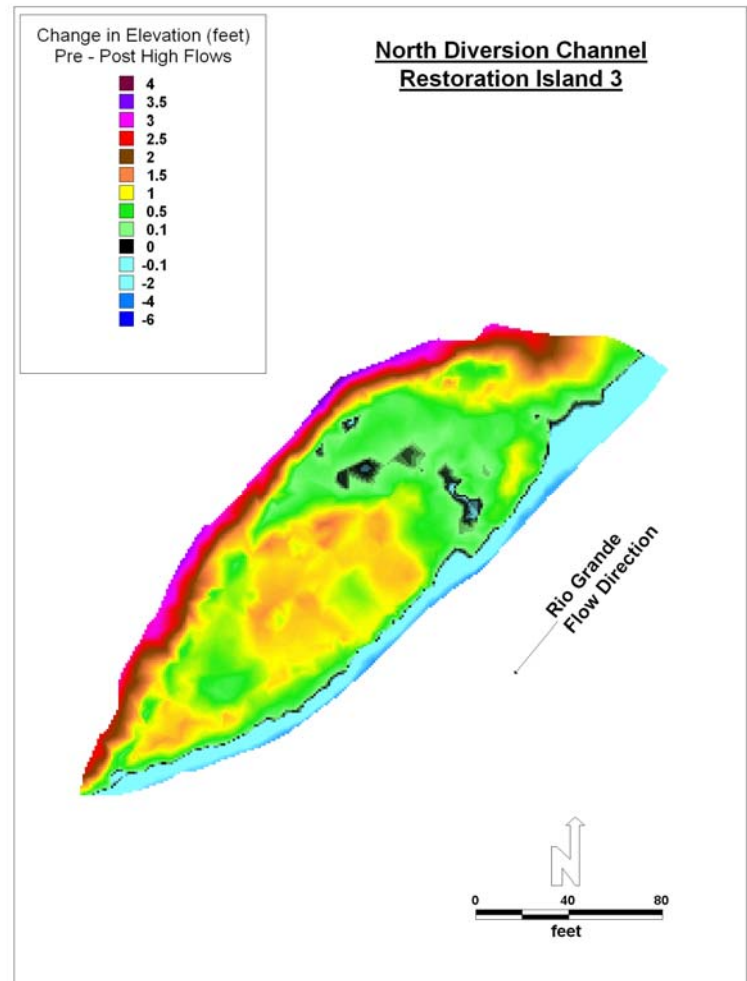
- Based on surveys of L1 and L2 bars in Albuquerque Reach, pre- and post-2005 high flows
- Comparison based on 0.5 ft contour-interval topographic mapping

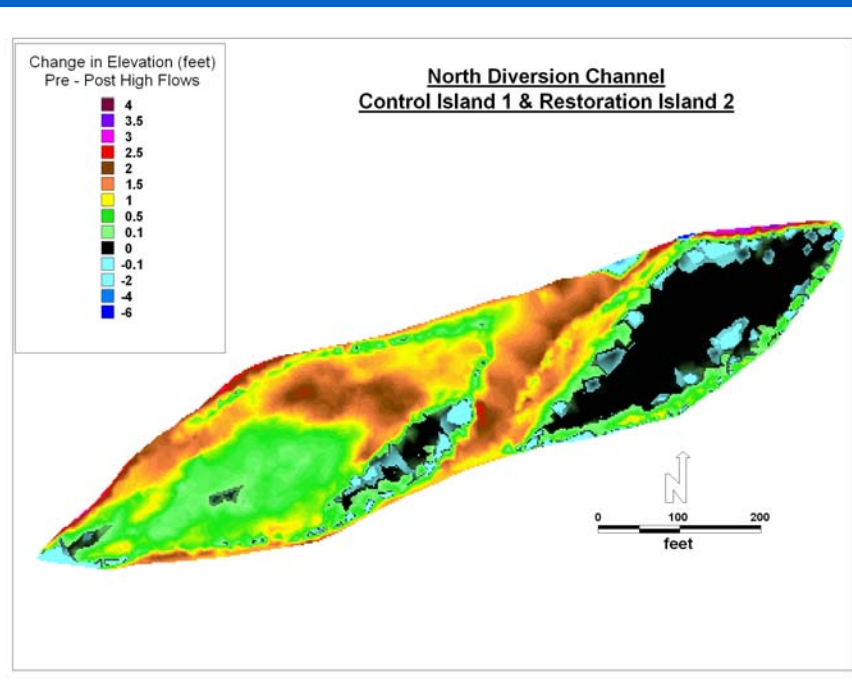
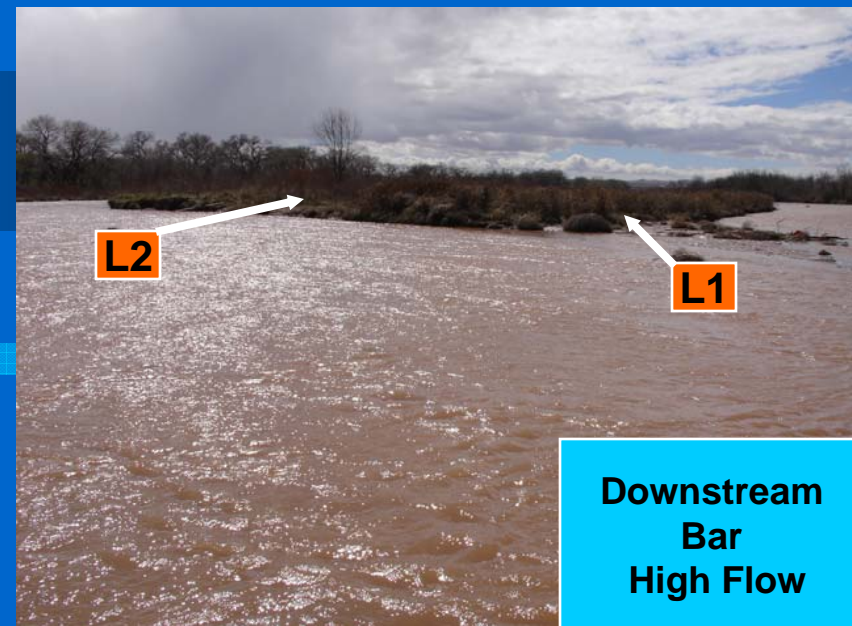
POST-HIGH FLOW SEDIMENT DEPOSITION 2005



L1

29 3 2005





BARS AND DEGRADATION

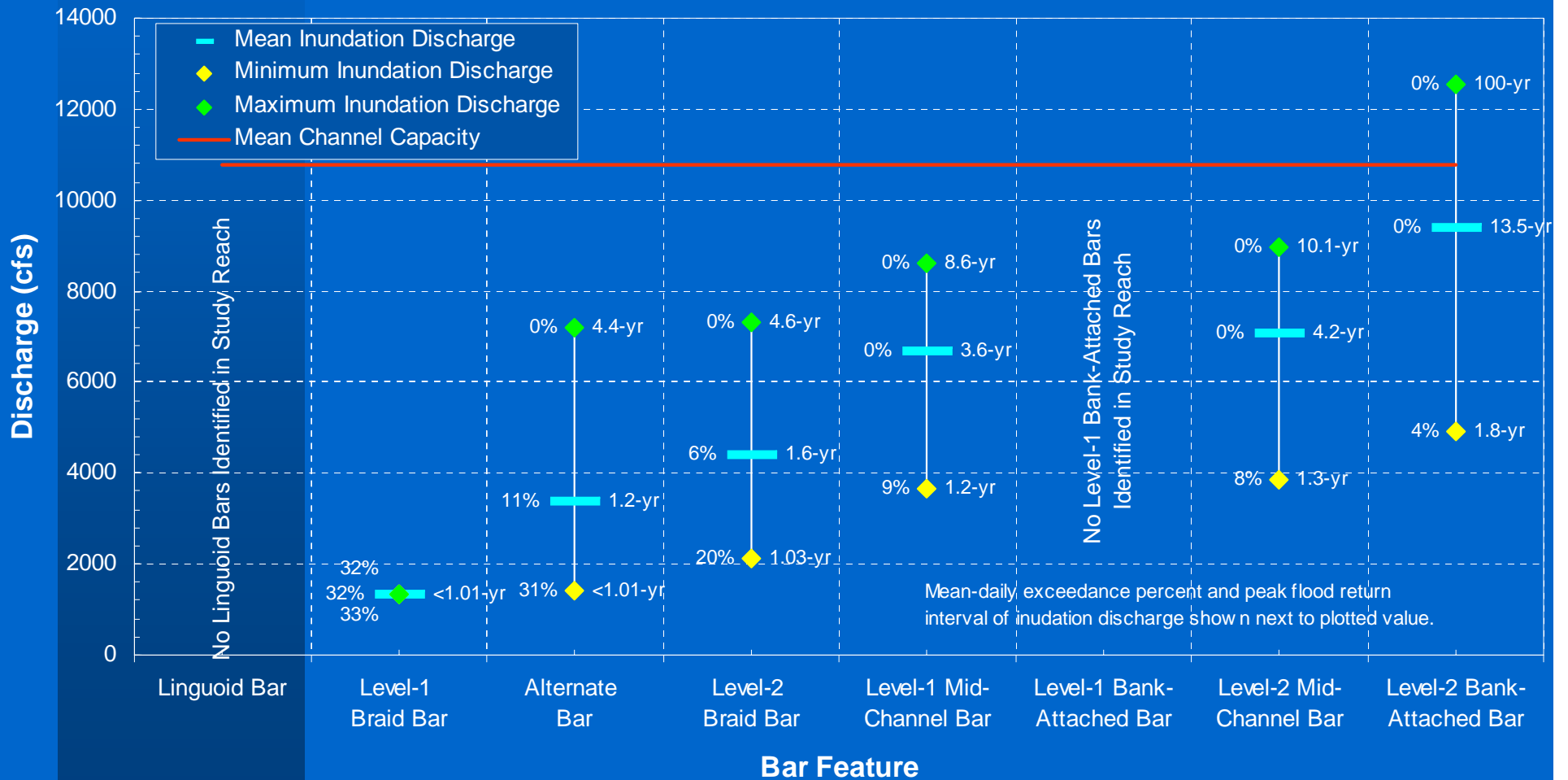
- Degradation causes hydrologic abandonment of bars
- If restoration is being considered is the bed currently stable?
- If degradation continues, restoration will be compromised



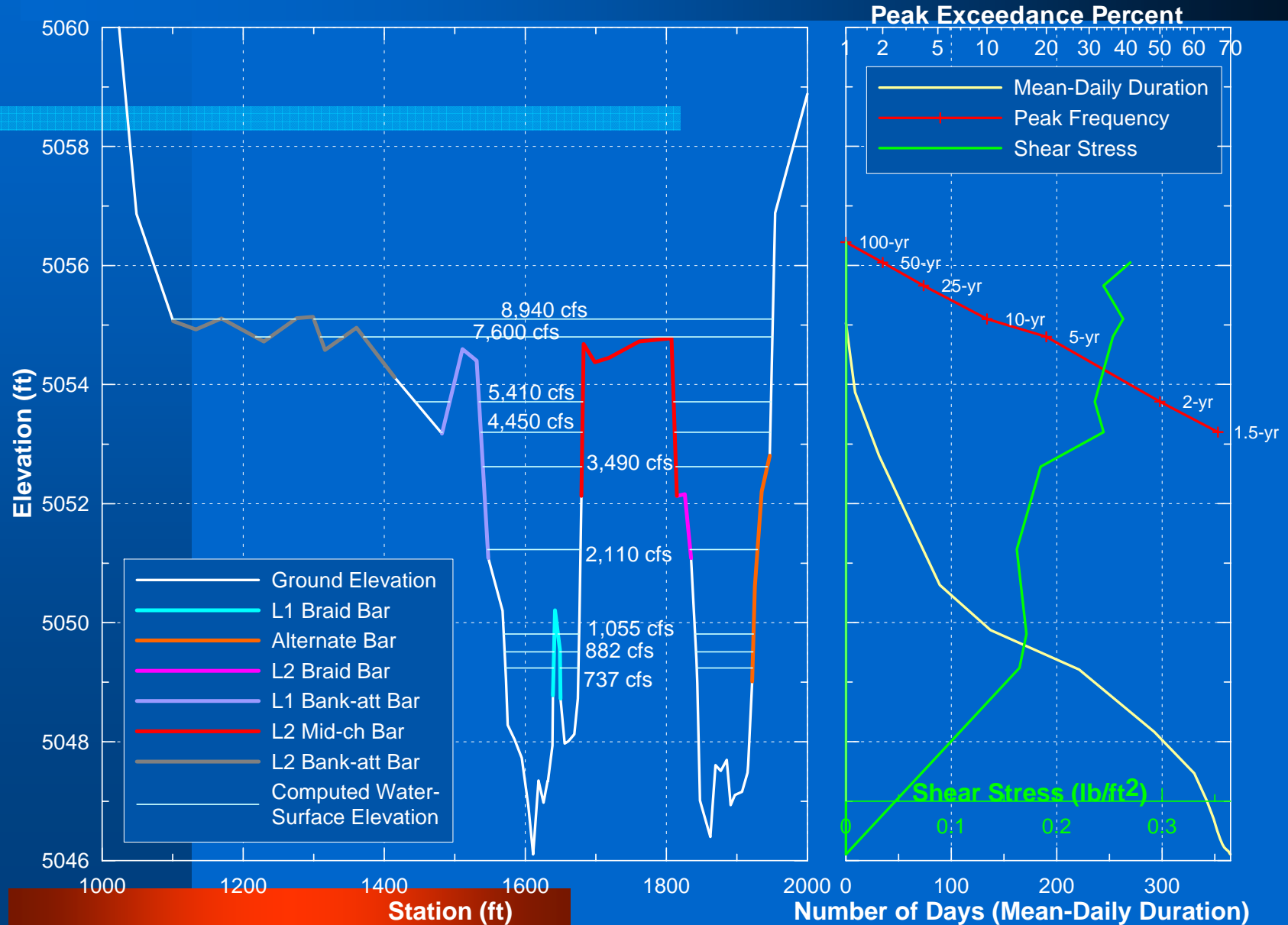
Abandoned L-2
mid-channel bar

Bernalillo Site

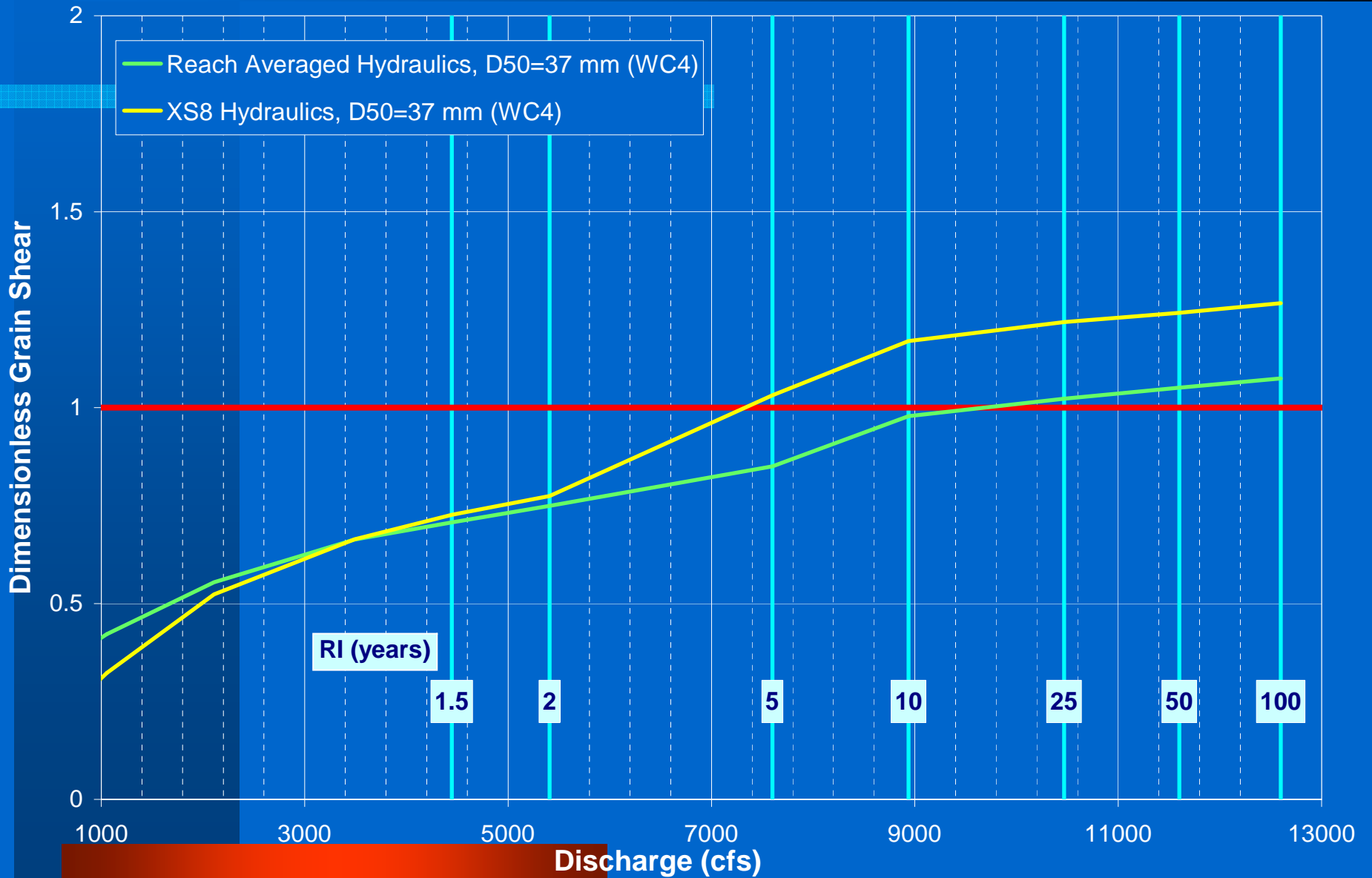
Bar Inundation Analysis



Bernalillo Site – Cross Section 10



Bernalillo Site



CONCLUSIONS

- Bar indices reflect changes in flow, sediment supply and channel morphology
- Bar classification is a communication tool, and provides first-cut hydraulic assessments

CONCLUSIONS

- Active braid bars require average shear stresses < 0.2 psf
- Inundation of bars leads to vertical growth and reduced frequency and duration of inundation
- Degradation will adversely affect restoration efforts, so vertical stability must be assessed

APPLICATION TO RESTORATION





Bridge Blvd.



RIO GRANDE SILVERY MINNOW



TARGETED LIFE STAGES:

- EGGS
- LARVAE
- JUVENILES

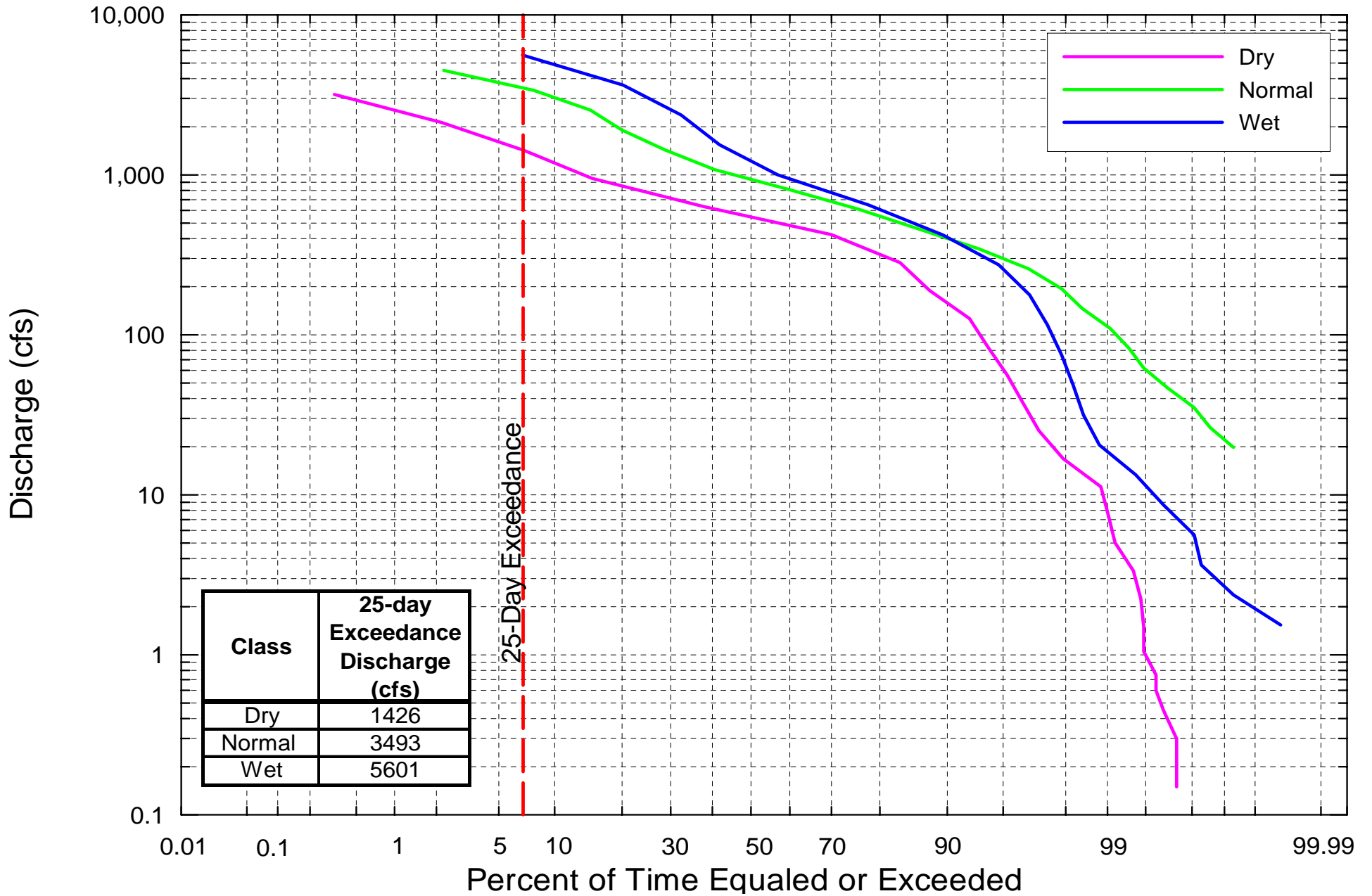
PHYSICAL NEEDS

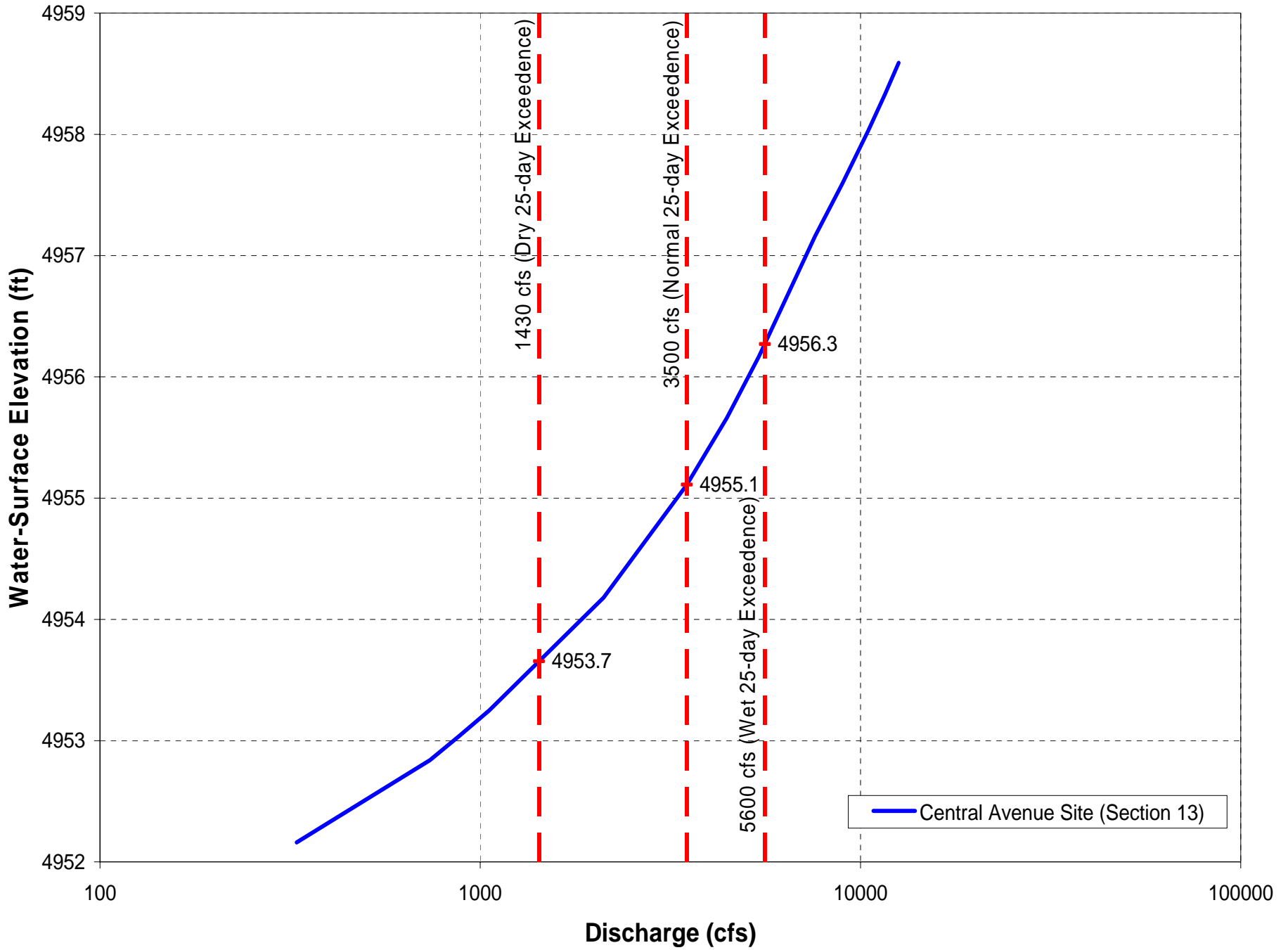
- LOW VELOCITY
- SHALLOW DEPTH

BIOLOGICAL TARGET
25 DAYS INUNDATION
(~ 7 % EXCEEDENCE)

POST-COCHITI (1974 -2005)
Flow Duration Curve:
~ 4000 CFS

Rio Grande at Albuquerque, NM (Central Ave.) USGS Gage no. 08330000 Flow Duration Curves



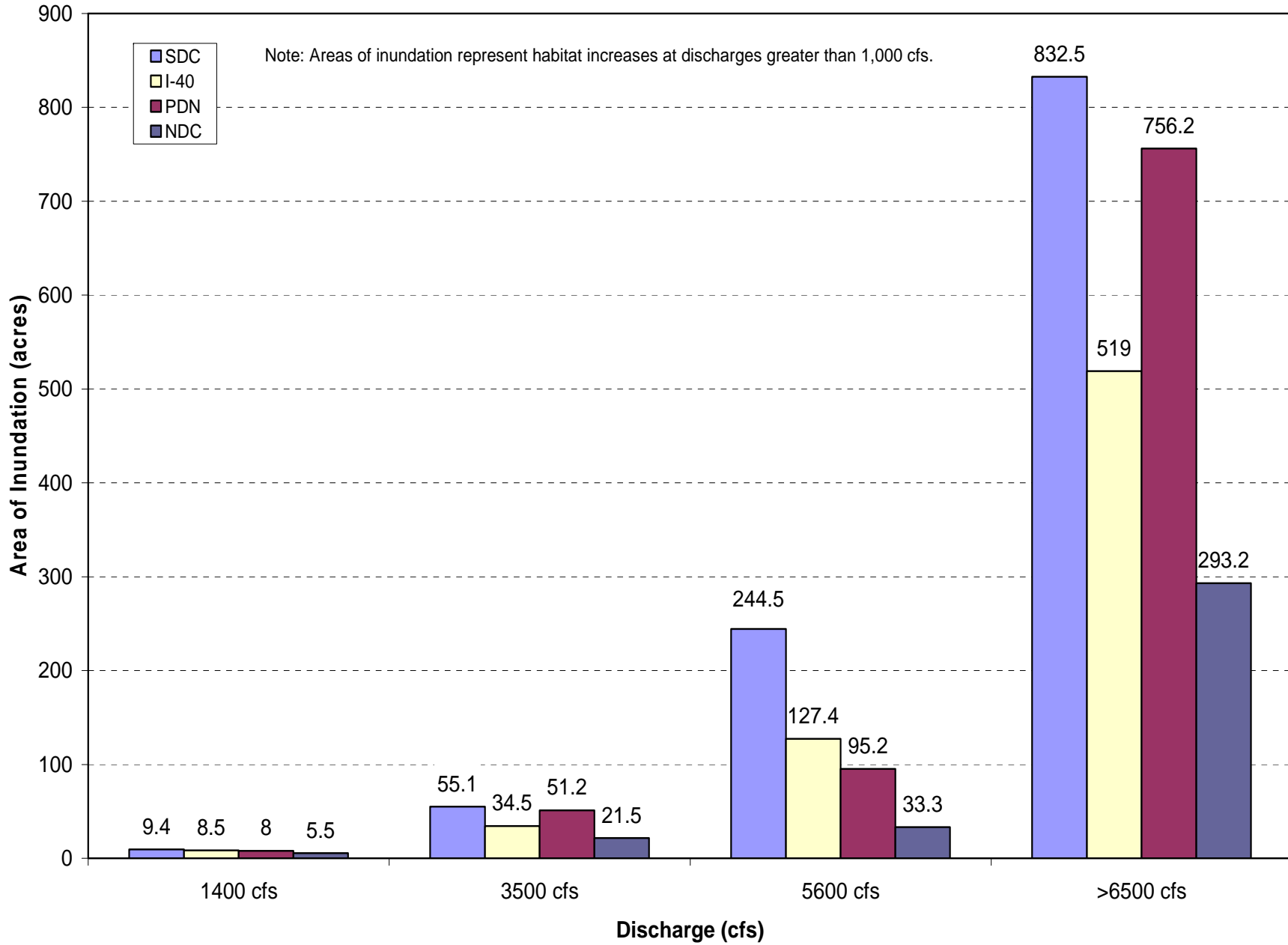




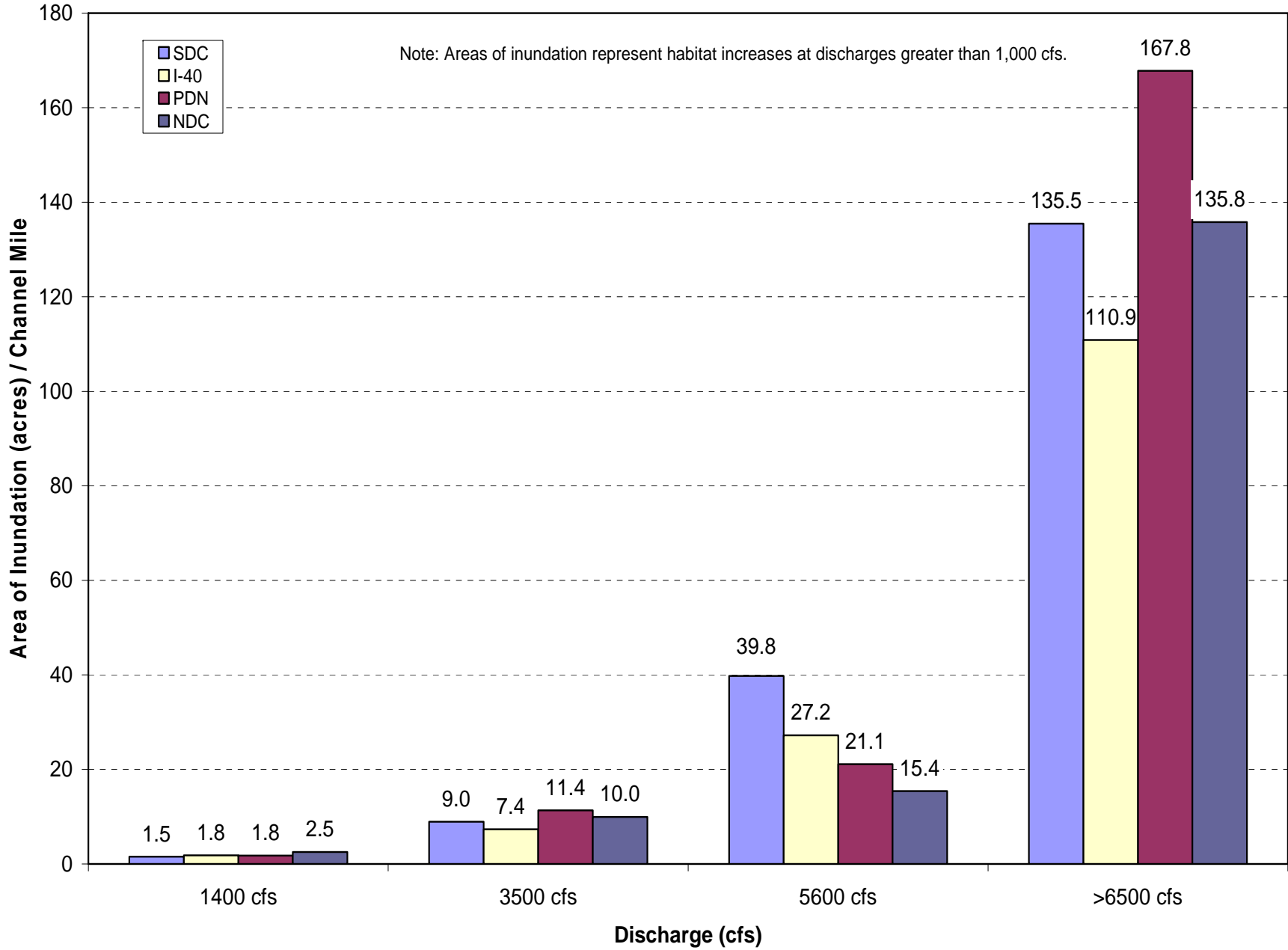
Bridge Blvd.



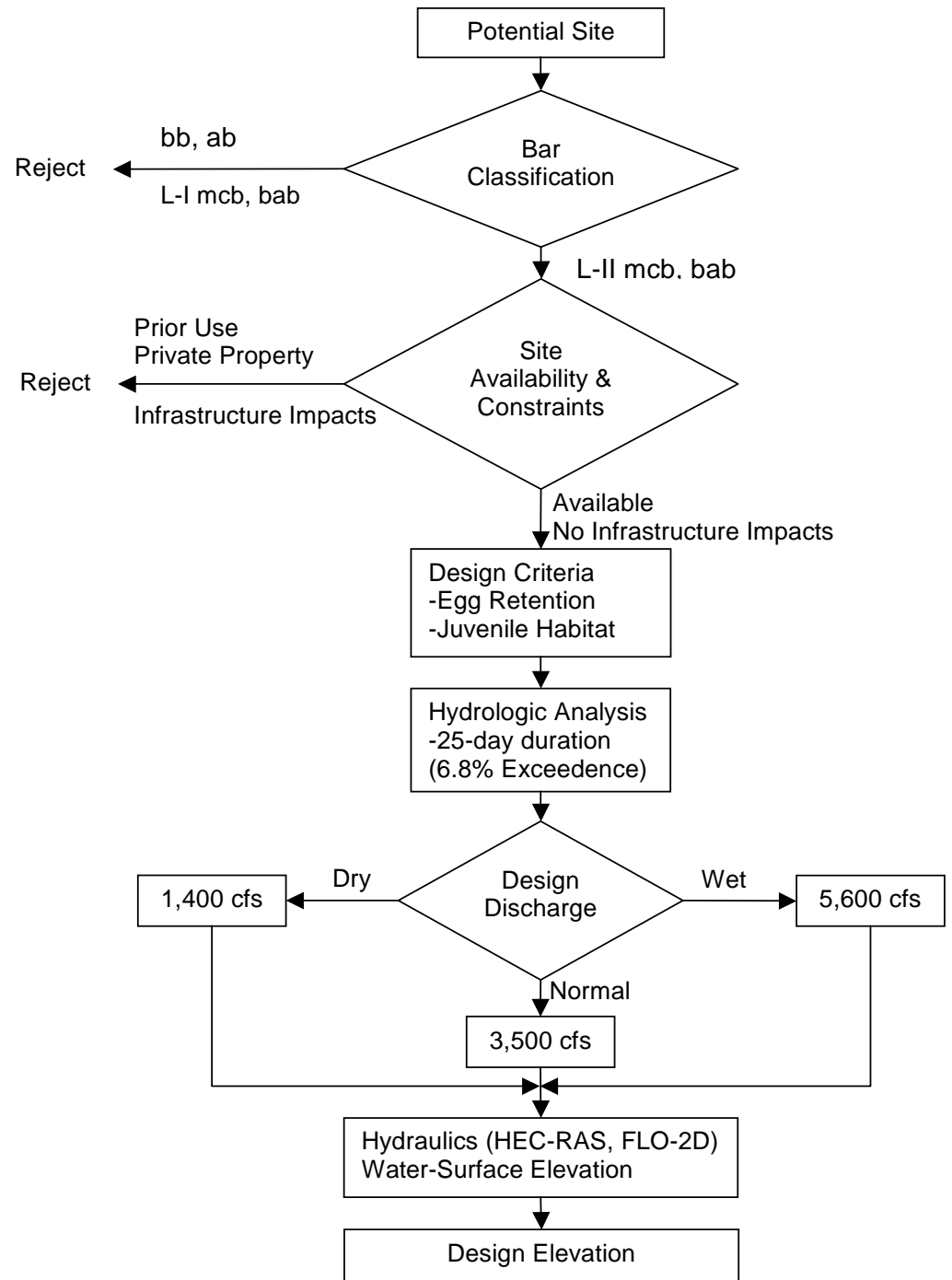
Rio Grande Phase II

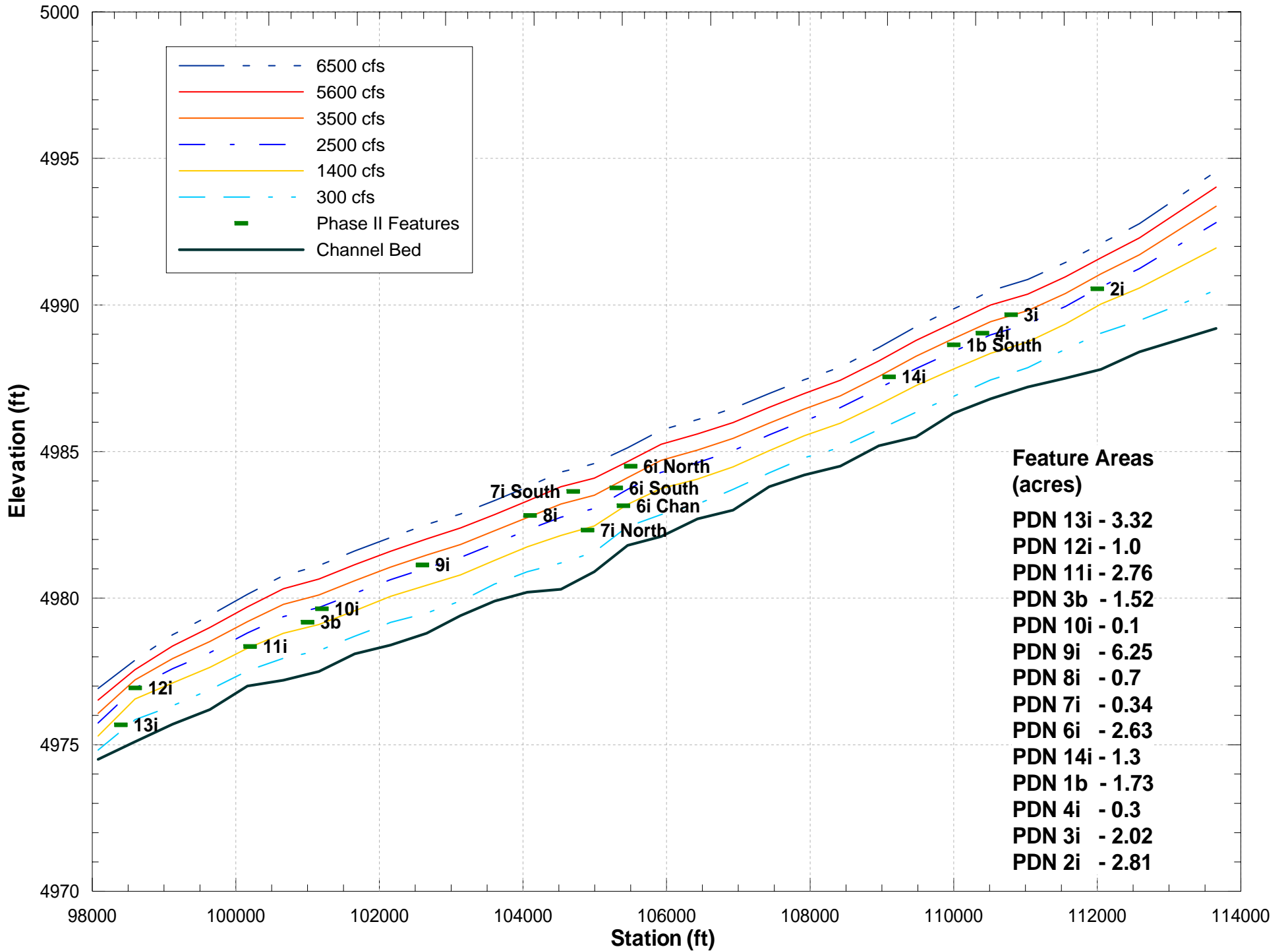


Rio Grande Phase II



SITE SELECTION SCREENING TOOL





SDC

Stage differences (for reference)

SDC SITE	Station (ft)	Average Elevation (ft)	Existing Overtopping Discharge (cfs)	Existing Area (ac)	1400 to 2500 cfs	2500 to 3500 cfs	3500 to 5600 cfs
9i	17100	4903.13	2,920	1.98	0.69	0.54	0.68
8i	21200	4906.98	4,687	0.33	0.54	0.42	0.54
6i	23100	4908.58	4,686	2.03	0.61	0.45	0.59
5i Main	23600	4909.13	4,637	0.93	0.59	0.44	0.58
4i Main	24100	4909.81	4,981	1.73	0.57	0.43	0.56
3i	24800	4910.4	4,467	0.84	0.56	0.43	0.56
5b	26000	4911.49	4,428	1.70	0.64	0.47	0.60
4b South	26200	4912.06	5,670	0.33	0.67	0.50	0.63
4b North	26400	4912.87	6,795	0.67	0.67	0.50	0.64
1i	28800	4914.09	4,655	0.70	0.55	0.45	0.61
3b	32800	4917.64	3,872	3.27	0.70	0.53	0.67
1b	38200	4921.79	3,187	0.32	0.75	0.56	0.70
TOTAL				14.81			

SDC SITE	Total Percent Area	Excavation Volume (yd³)
9i	0	0
8i	100	612
6i	100	5,194
5i Main	100	1,408
4i Main	100	4,466
3i	100	1,508
5b	85.8	3,073
4b South	100	634
4b North	100	1,939
1i	100	1,489
3b	18.7	3,181
1b	100	1,686
Total		25,189

SDC SITE	Safety Factor (ft)	AREA 1					New Inundation Q (cfs)	AREA 2					New Inundation Q (cfs)
		Target Discharge 1	Design Depth (ft)	X - Grade	Percent of Area	Cut (ft)		Target Discharge 2	Design Depth (ft)	X - Grade	Percent of Area	Cut (ft)	
9i	0	3500	0.5	YES	0	0.20	2920	2500	0.25	YES	0	0.49	2920
8i	0	3500	0.5	YES	49.9	0.93	2327	1400	0.25	NO	50.1	1.64	1001
6i	0	3500	0.5	NO	24.2	0.97	2404	1400	0.25	NO	75.8	1.78	1043
5i Main	0	3500	0.5	NO	100	0.94	2388	1400	0.25	NO	0	1.73	4637
4i Main	0	3500	0.5	NO	26.9	1.06	2362	1400	0.25	NO	73.1	1.81	1006
3i	0	3500	0.5	NO	30.4	0.87	2359	3500	0.25	NO	27.1	0.62	2911
5b	0	3500	0.5	NO	70.7	0.88	2447	Bed	0	NO	15.1	3.28	Bed
4b South	0	3500	0.5	NO	100	1.19	2493	1400	0.25	NO	0	2.10	5670
4b North	0	3500	0.5	NO	100	1.79	2500	1400	0.25	NO	0	2.71	6795
1i	0	3500	0.5	NO	55.9	0.98	2398	1400	0.25	NO	44.1	1.73	976
3b	0	Bed	0	NO	0	3.23	3872	Bed	0	NO	18.7	3.23	Bed
1b	0	Bed	0	NO	100	3.32	Bed	1400	0.25	NO	0	1.39	3187

UPDATE SUMMARY TABLE

Summary				
Design Discharge (cfs)	Existing Area (acres)		Post-Mod Area (acres)	
	(acres)	(%)	(acres)	(%)
< 1400	0	0.00%	1.18	7.99%
1400	0.00	0.00%	3.86	26.04%
2500	2.29	15.47%	1.98	13.34%
3500	11.52	77.78%	7.79	52.63%
5600	1.00	6.75%	0.00	0.00%

WarningProblem
 Warning : Excavation Volume is negative
 Warning : Feature is being cut to an elevation below the bed
 Warning : Target Discharge is set to Bed, design depth should be zero.

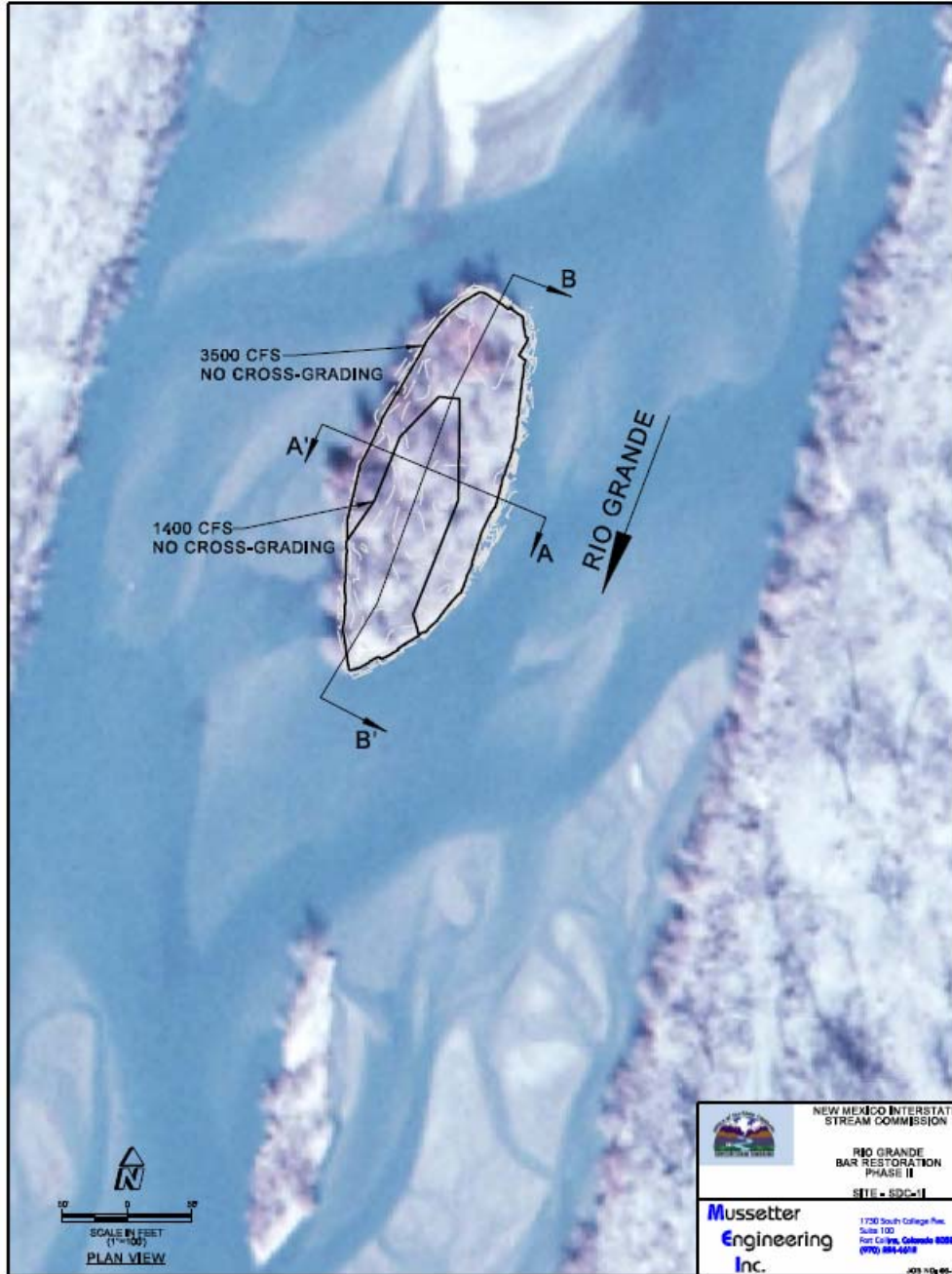
SUMMARY

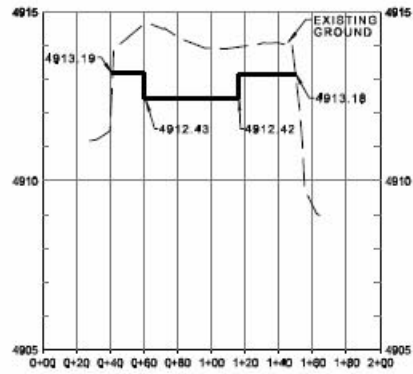
SDC	Total Excavation Volume (yd ³)				25,189
Design Discharge (cfs)	Existing Area		Post-Mod Area		
	(acres)	(%)	(acres)	(%)	
< 1400	0.00	0.0%	1.18	8.0%	
1400	0.00	0.0%	3.86	26.0%	
2500	2.29	15.5%	1.98	13.3%	
3500	11.52	77.8%	7.79	52.6%	
5600	1.00	6.8%	0.00	0.0%	

PDN	Total Excavation Volume (yd ³)				16,475
Design Discharge (cfs)	Existing Area		Post-Mod Area		
	(acres)	(%)	(acres)	(%)	
< 1400	3.32	13.8%	3.65	15.1%	
1400	4.25	17.6%	9.74	40.4%	
2500	12.32	51.1%	5.69	23.6%	
3500	4.20	17.4%	5.01	20.8%	
5600	0.00	0.0%	0.00	0.0%	

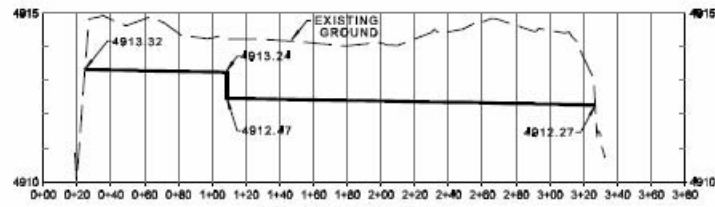
I-40	Total Excavation Volume (yd ³)				62,500
Design Discharge (cfs)	Existing Area		Post-Mod Area		
	(acres)	(%)	(acres)	(%)	
< 1400	1.04	4.1%	1.99	7.7%	
1400	0.58	2.2%	5.99	23.3%	
2500	0.00	0.0%	2.98	11.6%	
3500	15.57	60.6%	11.19	43.5%	
5600	8.52	33.1%	3.55	13.8%	

	Yards
Grand Total	104,164





CROSS SECTION A-A'
 HORIZ: 1"=100'
 VERT: 1"=5'



CROSS SECTION B-B'
 HORIZ: 1"=100'
 VERT: 1"=5'



NEW MEXICO INTERSTATE
 STREAM COMMISSION

RIO GRANDE
 BAR RESTORATION
 PHASE II

SITE - SDC-1I

Mussetter
Engineering
Inc.

1730 South College Ave.
 Suite 100
 Fort Collins, Colorado 80595
 (970) 284-1012

JOB NO: 09-11

TAKE HOME MESSAGES

- **Restoration requires a clear understanding of river dynamics and biological objectives.**
- **Must be able to translate biological objectives into physical parameters to provide a basis of design.**
- **Bar classification provides a first-cut tool for relating fluvial process to habitat requirements and initial site selection.**