Sediment Loadings and Channel Erosion: Lake Tahoe Basin

A. Simon, E. Langendoen, R. Bingner, R. Wells, A. Heins, N. Jokay and I. Jaramillo

Lake Tahoe Basin

Framework Implementation Study

USDA ARS

Issues

- Concerns over the clarity of Lake Tahoe from fine-grained/colloidal materials
- Previous anecdotal evidence from late 1970s and early 1980s channel materials were an important source
- Studies from a range of physiographic regions show that streambank materials are the dominant source of sediment in eroding channel systems
- Channel sediments serve as a vehicle for adsorbed nutrients
- Determining sediment sources is vital for developing appropriate management strategies

Main Objectives

- Determine historical sediment loads
- Evaluate channel contributions in selected watersheds
- Determine bulk and fine-grained loads
- Simulate sediment loads for 3 watersheds (50 years)
- Determine differences between loadings from disturbed and undisturbed streams
- Evaluate what combinations of upland and channel conditions result in greatest sediment hazards

Past and Future Loadings

DETERMINED USING:

1. **Historical Flow and Sediment-Transport Data (38 sites)**
2. **Direct Comparison of Surveyed Cross Sections (5 streams)**
3. **AnnAGNPS for Upland & Tributary Contributions (3 watersheds)**
4. **CONCEPTS for Main Channel Contributions (3 watersheds)**

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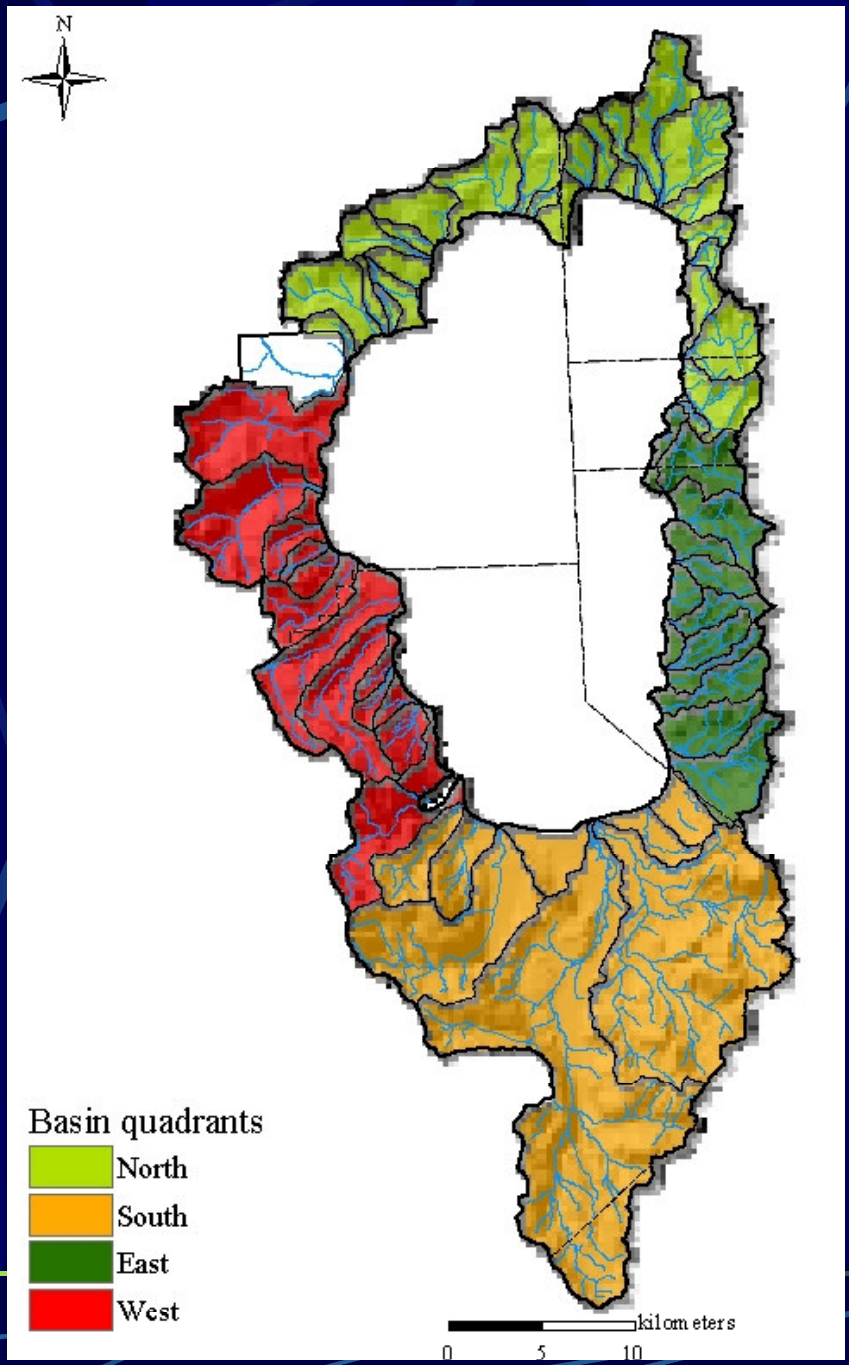
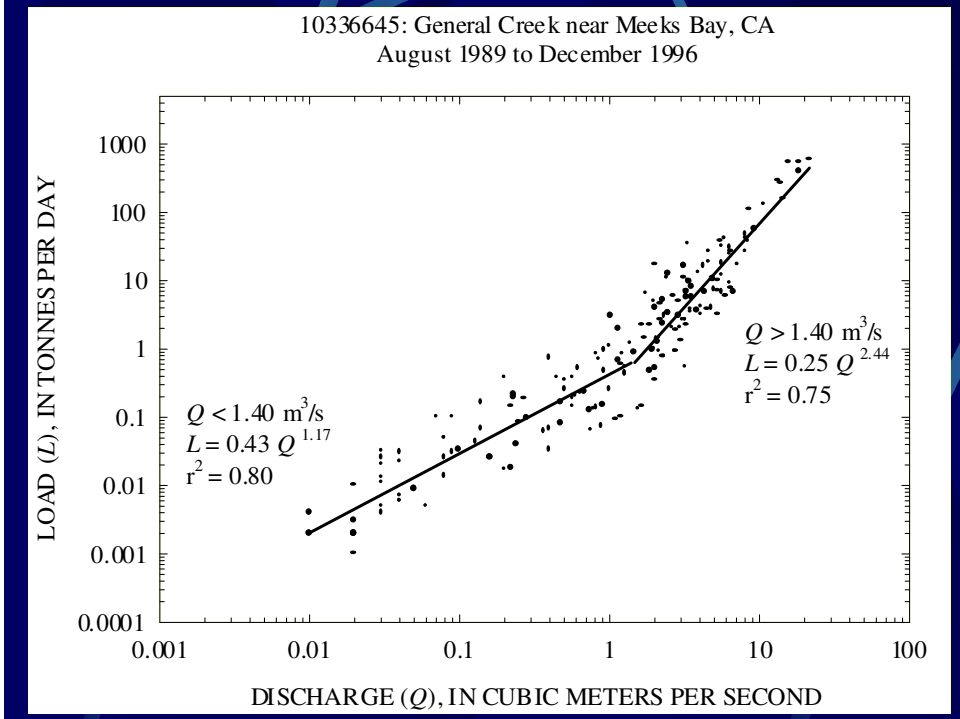
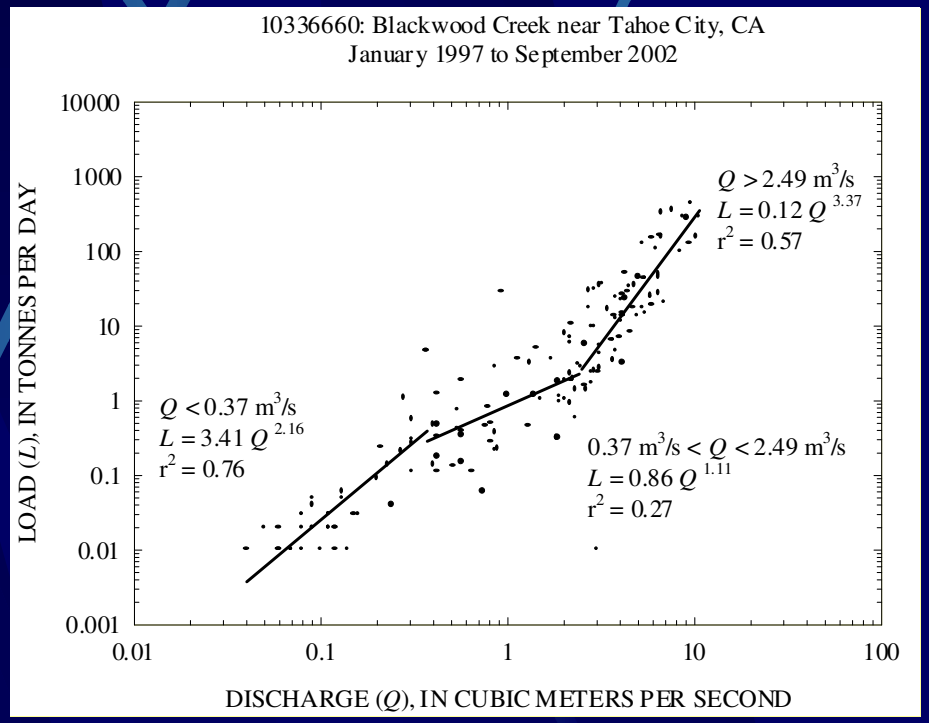
Designation of Basin Quadrants



Examples of Two- and Three-Stage Ratings





Annual Suspended-Sediment Loads (tonnes, T)

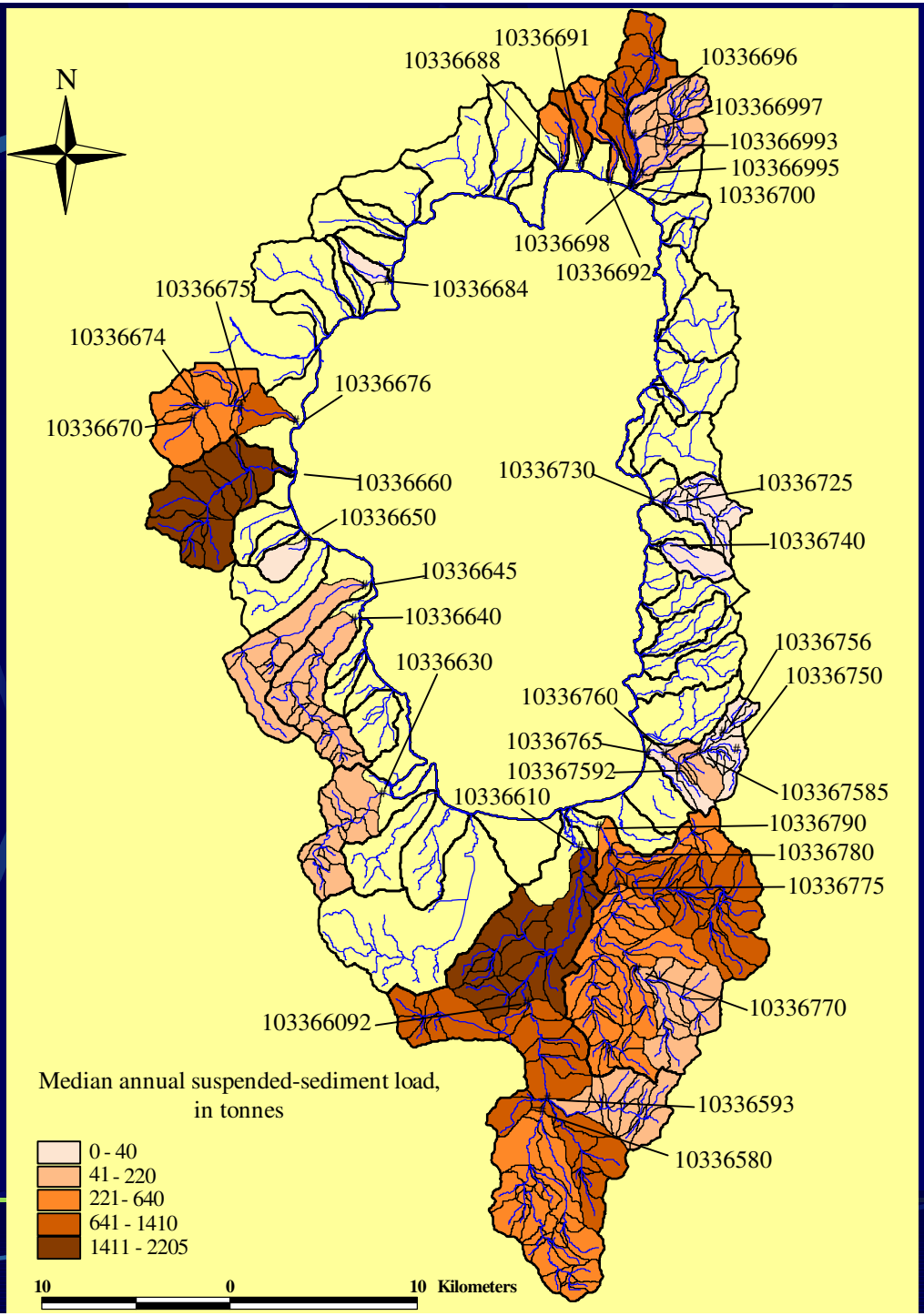
Green = index station

Stream	Station number	Annual load		Quadrant	Complete years of data	Drainage area (km^2)
		Average (tonnes)	Median (tonnes)			
Upper Truckee	10336610	2850	2200	S	24	142
Blackwood	10336660	3060	1930	W	40	29.0
Upper Truckee	103366092	1410	1410	S	10	88.8
Second[2]	10336691	1500	1410	N	4	4.7
Trout	10336780	1790	1190	S	40	95.1
Third	10336698	1680	880	N	26	15.7
Ward	10336676	1730	855	W	28	25.1
Ward	10336670	641	638	W	3	5.2
Wood[2]	10336692	467	490	N	4	5.3
Ward	10336675	551	449	W	9	23.2
First[2]	10336688	402	413	N	4	2.8
Ward	10336674	427	356	W	9	12.9
Trout	10336790	360	355	S	5	105
Upper Truckee	10336580	363	334	S	10	36.5
Trout	10336775	376	331	S	10	61.4
Incline	10336700	612	217	N	17	18.1
Grass[1]	10336593	181	181	S	3	16.6
General	10336645	283	176	W	20	19.3
Incline	103366995	174	163	N	11	11.6
Trout	10336770	158	109	S	10	19.1
Incline	103366993	80.1	90.5	N	10	7.2
Meeks[1]	10336640	79.8	79.8	W	3	22.2
Eagle[1]	10336630	69.9	69.9	W	3	20.4
Edgewood	10336760	34.7	44.8	E	8	14.2
Edgewood	103367585	24.5	21.3	E	11	8.1
Edgewood	10336765	9.5	9.5	E	2	16.2
Glenbrook	10336730	11.3	8.9	E	16	10.5
Quail Lake[1]	10336650	6.4	6.4	W	3	4.2
Dollar[1]	10336684	4.6	4.6	N	3	4.7
Eagle Rock	103367592	5.6	4.6	E	10	1.5
Logan House	10336740	5.6	3.0	E	17	5.4
Edgewood Trib.	10336756	0.5	0.5	E	2	0.6

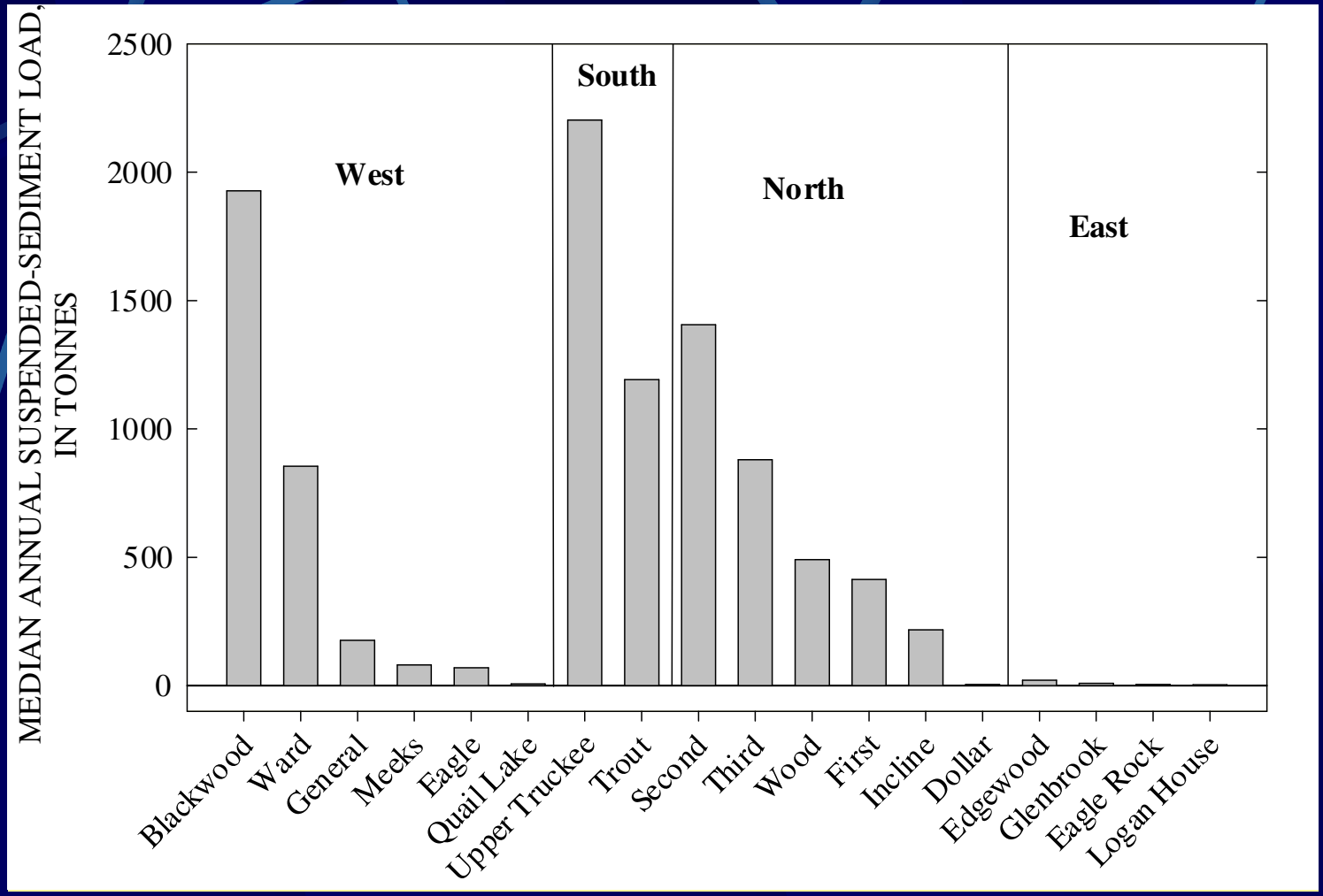
[1] = Mean values from Kroll (1976)

[2] = Data from Glancy (1988)

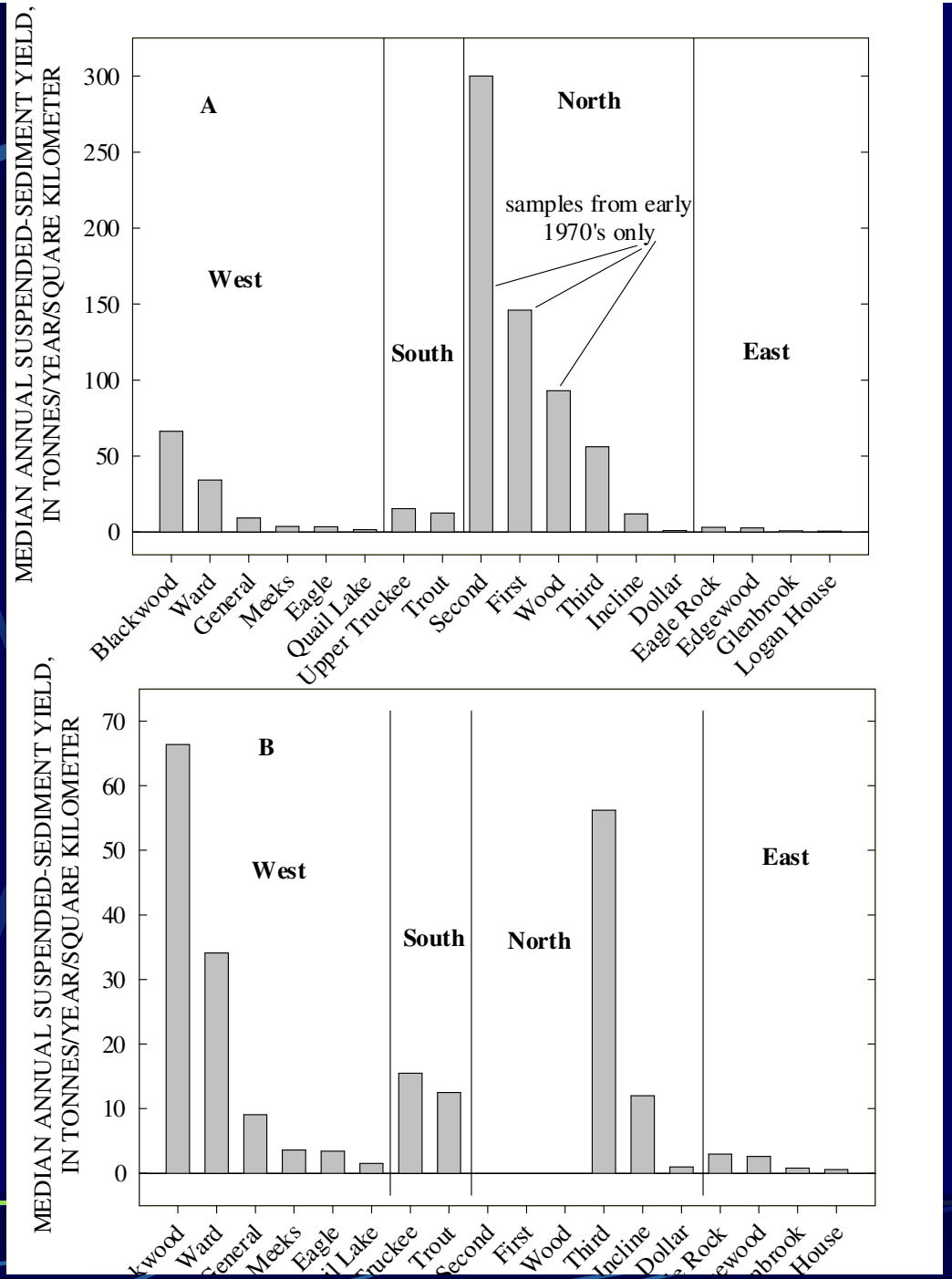
Annual Suspended-Sediment Loads



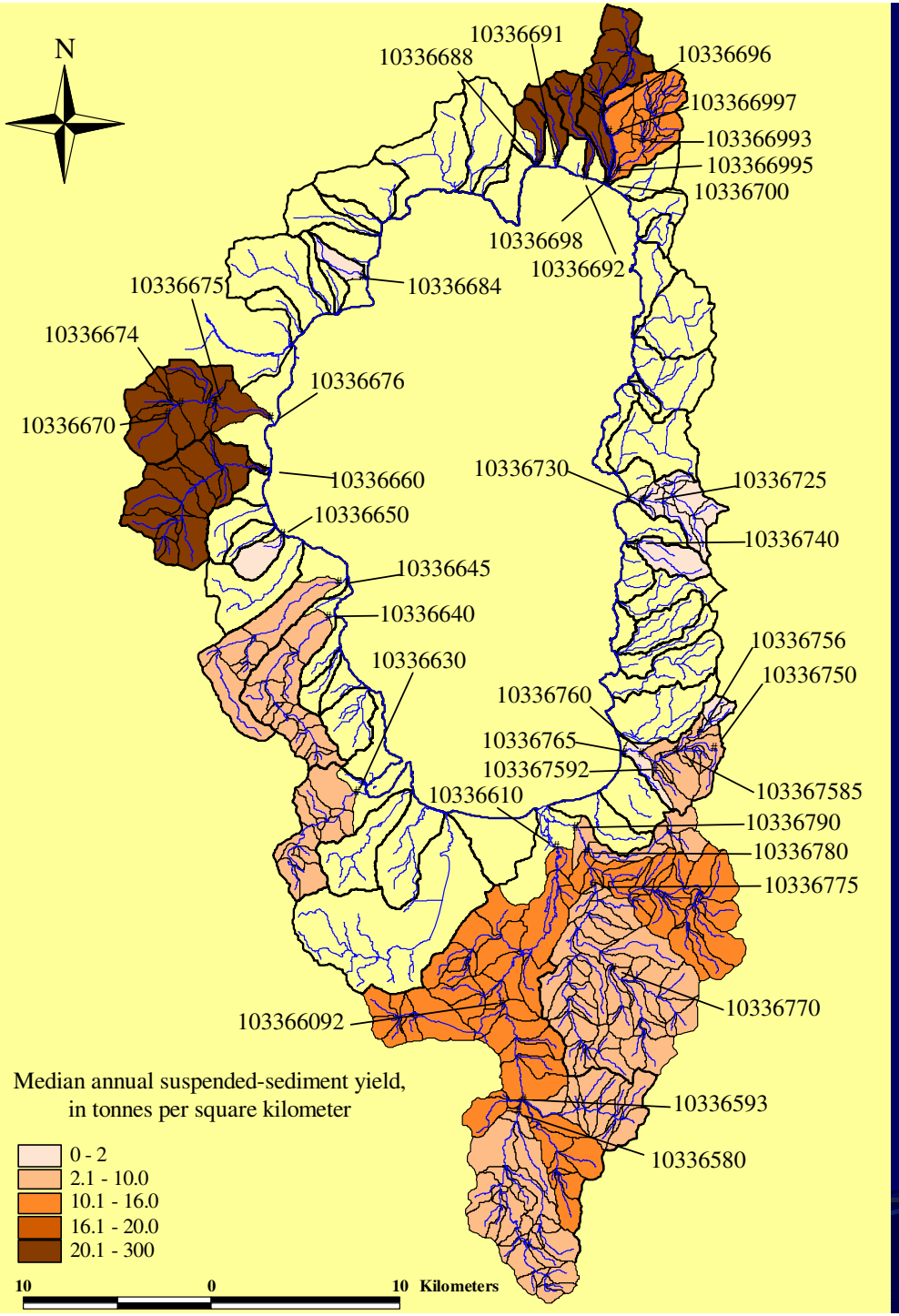
Spatial Distribution of Loads by Quadrant (T/y)



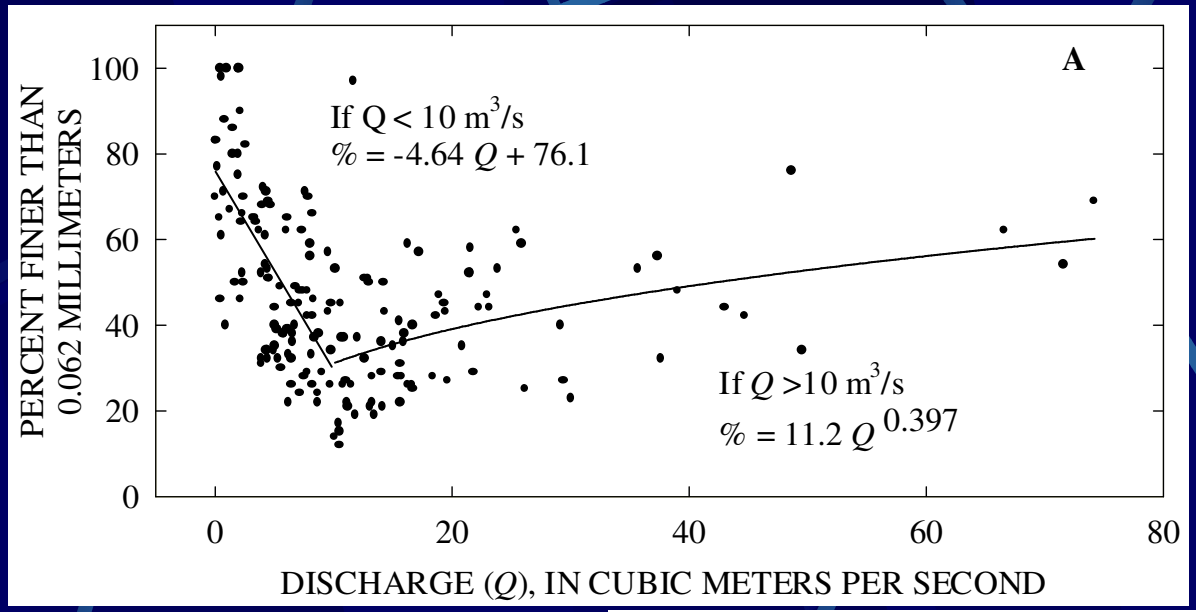
Spatial Distirubution of Suspended-Sediment Yields by Quadrant (T/y/km^2)



Suspended-Sediment Yields (T/km^2)

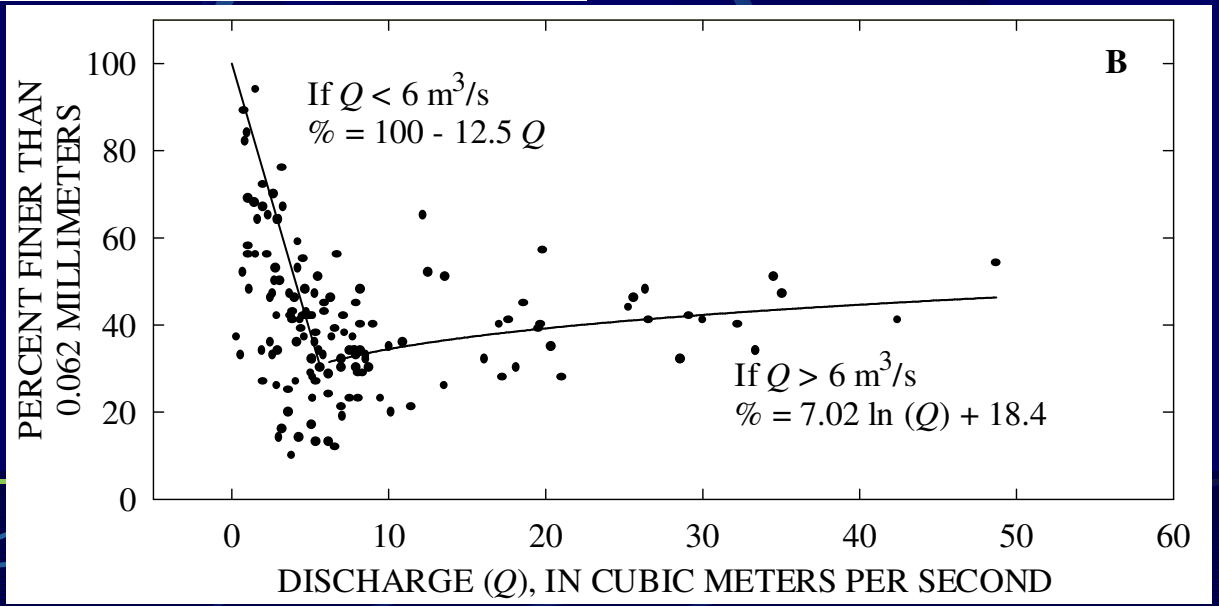


Fine-Sediment Relations with Flow



Upper Truckee River

Blackwood Creek

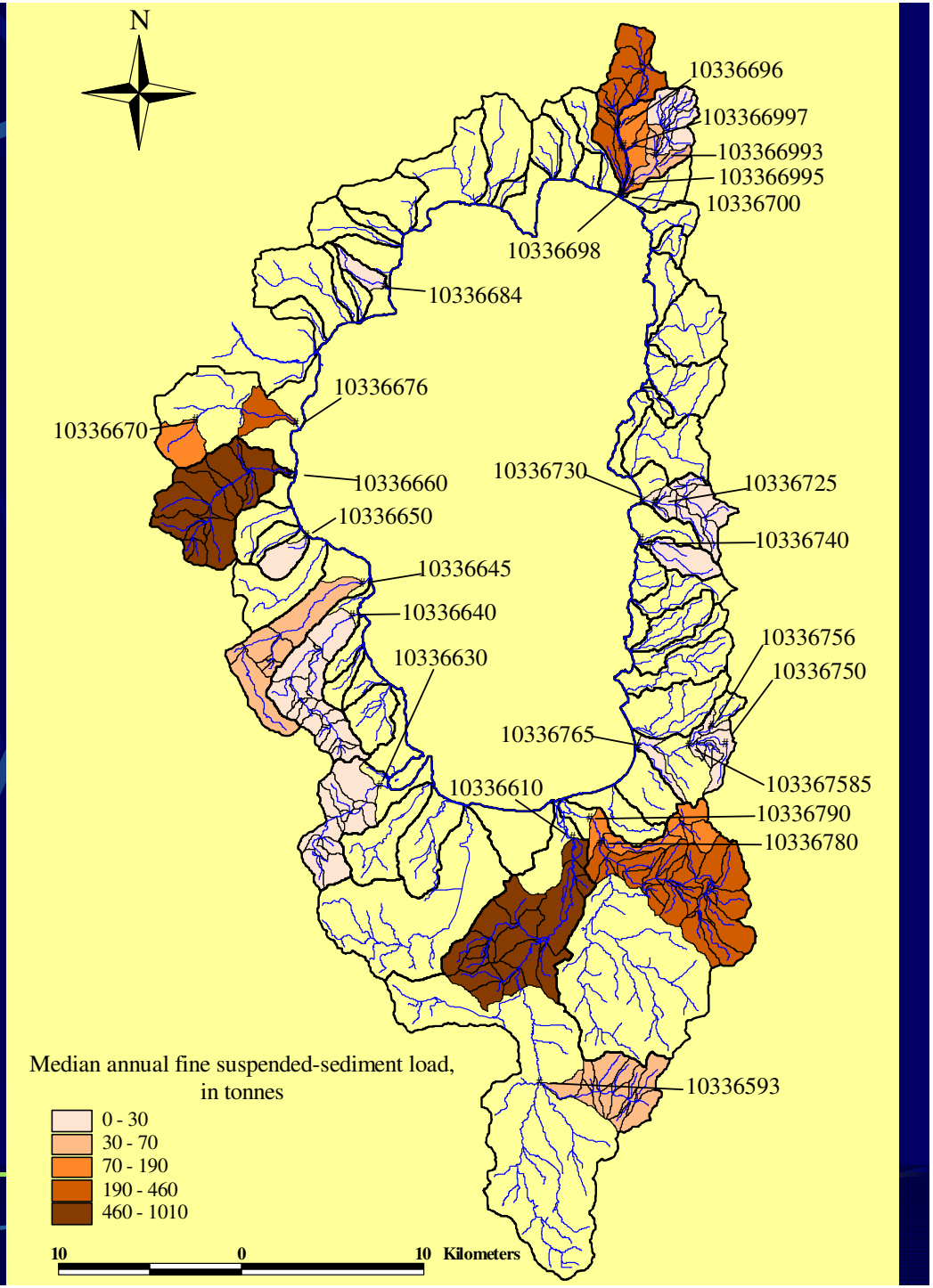


Fine-Sediment Loads

Green = index station

Stream	Station number	Annual Fine Load		Median relative contribution (percent)	Years of data	Drainage Area (km^2)
		Average (tonnes)	Median (tonnes)			
UTR	10336610	1261	1010	44	24	142
Blackwood	10336660	1347	846	45	40	29.0
Trout	10336780	624	462	38	40	95.1
Ward	10336676	658	412	47	28	25.1
Third	10336698	462	318	31	26	15.7
Ward	10336670	194	193	30	3	5.2
Trout	10336790	134	141	40	5	105
Incline	10336700	320	129	67	17	18.1
Incline	103366995	74.4	66.7	47	11	11.6
General	10336645	69.2	53.3	29	20	19.3
Grass	10336593	40.4	40.4	31	2	16.6
Incline	103366993	24.4	27.7	36	10	7.2
Eagle[1]	10336630		21.8		3	20.4
Meeks[1]	10336640		19.1		3	22.2
Edgewood	103367585	12.9	11.4	59	11	8.1
Edgewood	10336765	8.5	8.5	89	2	16.2
Glenbrook	10336730	8.8	7.0	80	16	10.5
Quail Lake[1]	10336650		3.2		3	4.2
Dollar [1]	10336684		2.6		3	4.7
Logan House	10336740	3.5	2.3	75	17	5.4

Fine-Grained Loads



Temporal Trends of Sediment Loads

Decreasing

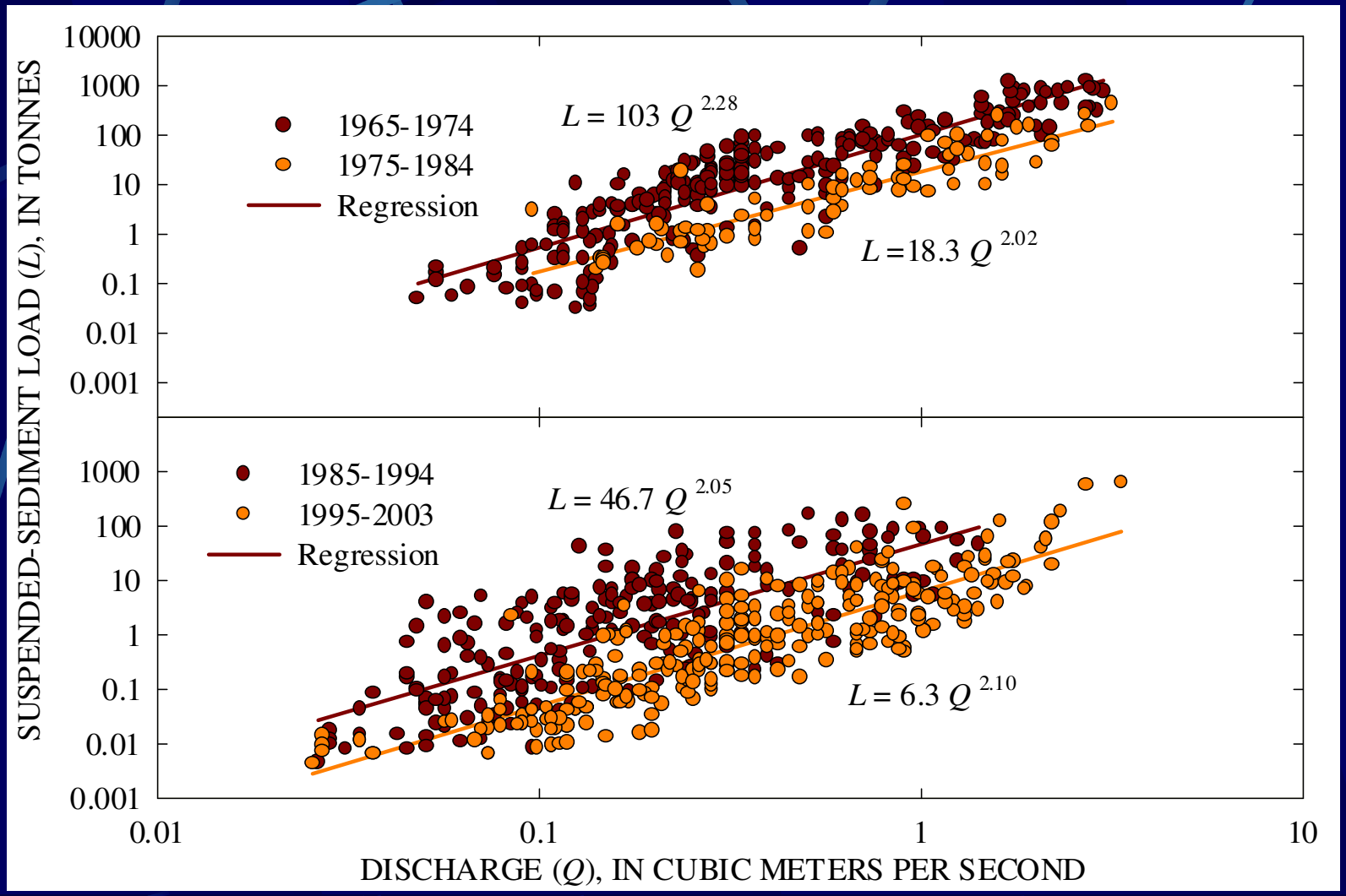
1. UTR
2. Incline
3. Third
4. Glenbrook

P = 0.0001

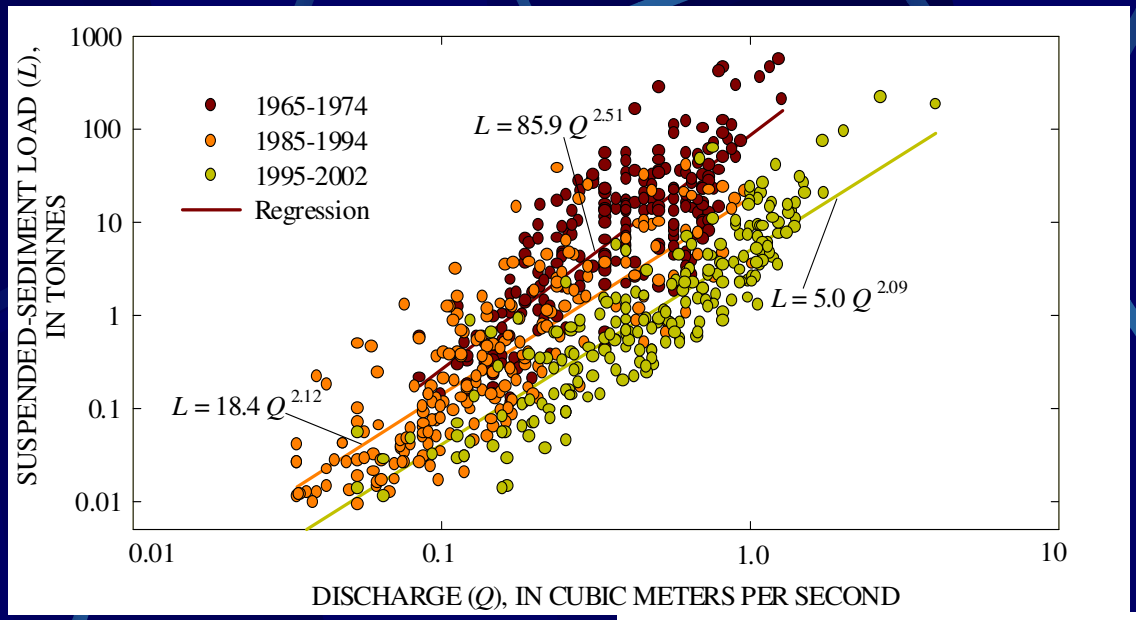
F = 90

Stream	Station	Equation	r^2	F - value	P - value	n	Significance and trend
Blackwood	10336660	y=18.5-1.74e-4x	.0003	4.75	0.03	14975	definite (-)
General	10336645	y=4.33+7.43e-5x	.0003	2.39	0.12	7756	none
Ward	10336674	y=6.76-7.83e-4x	.006	20.5	0.0001	3652	definite (-)
Ward	10336675	y=6.45-3.47e-4x	.001	4.55	0.03	3653	definite (-)
Ward	10336676	y=14.0-3.84e-4x	.0009	9.41	0.0022	10592	definite (-)
Trout	10336770	y=5.54-2.42e-4x	.001	5.71	0.02	4150	definite (-)
Trout	10336775	y=619-8.87e-5x	.0002	0.94	0.33	4140	none
Trout	10336780	y=25.0+1.51e-4x	.0007	11.0	0.0009	14975	definite (+)
Trout	10336790	y=15.1-3.35e-3x	0.15	465	0.0001	2557	definite (-)
UTR	10336580	y=2.86-7.05e-5x	.004	1.77	0.18	4160	none
UTR	10336610	y=19.4-8.00e-4x	0.03	299	0.0001	9526	definite (-)
UTR	103366092	y=4.20-2.21e-4x	.001	5.55	0.02	4140	definite (-)
Incline	10336700	y=51.7-3.44e-3x	0.01	90.5	0.0001	6839	definite (-)
Incline	103366993	y=8.04-2.93e-4x	.002	6.96	0.01	4171	definite (-)
Incline	103366995	y=18.0-1.08e-3x	.009	37.3	0.0001	4295	definite (-)
Third	10336698	y=128-7.75e-3x	0.04	376	0.0001	10469	definite (-)
Eagle Rock	103367592	y=5.23+7.96e-4x	0.11	469	0.0001	3970	definite (+)
Edgewood	10336760	y=5.34-3.61e-5x	.00002	0.49	0.49	3287	none
Edgewood	103367585	y=10.2-2.54e-4x	.001	5.96	0.01	4383	definite (-)
Glenbrook	10336730	y=8.07-5.27e-4x	0.11	769	.0001	6529	definite (-)
Logan House	10336740	y=4.28+1.75e-6x	5.70E-07	0.004	0.95	6575	none

Reduction in Loads: Third Creek

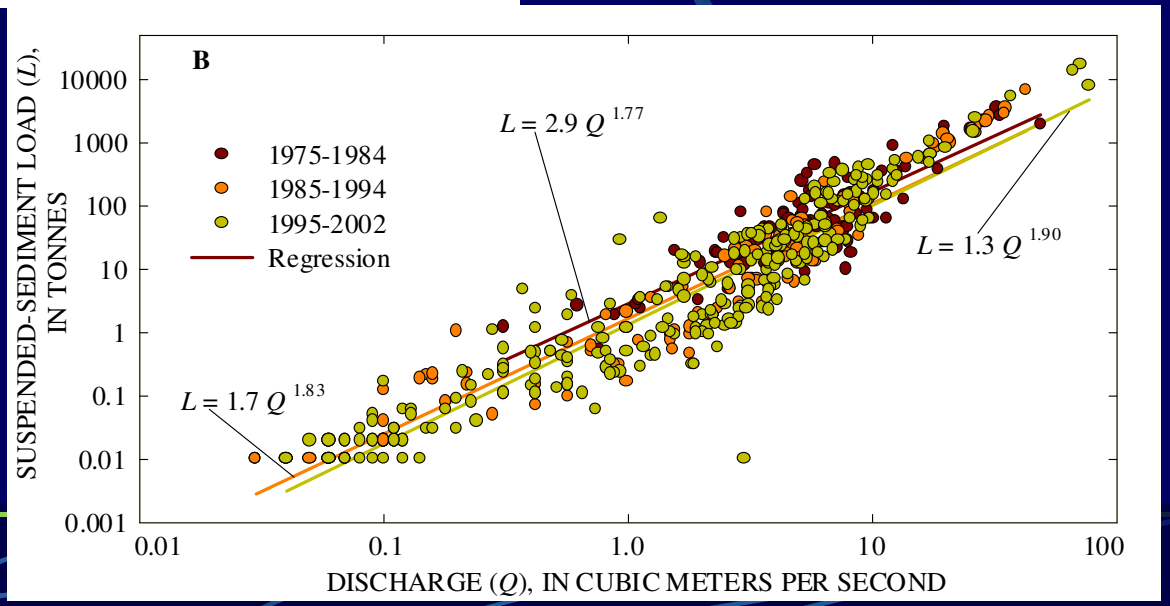


Rating Curve Shifts



Incline

Blackwood



Estimates of Total Suspended-Sediment Loadings to Lake Tahoe

- Estimates based on extrapolation of average-annual and median-annual data from index stations that cover 54% of total watershed area

Average annual: 28,600 T/y

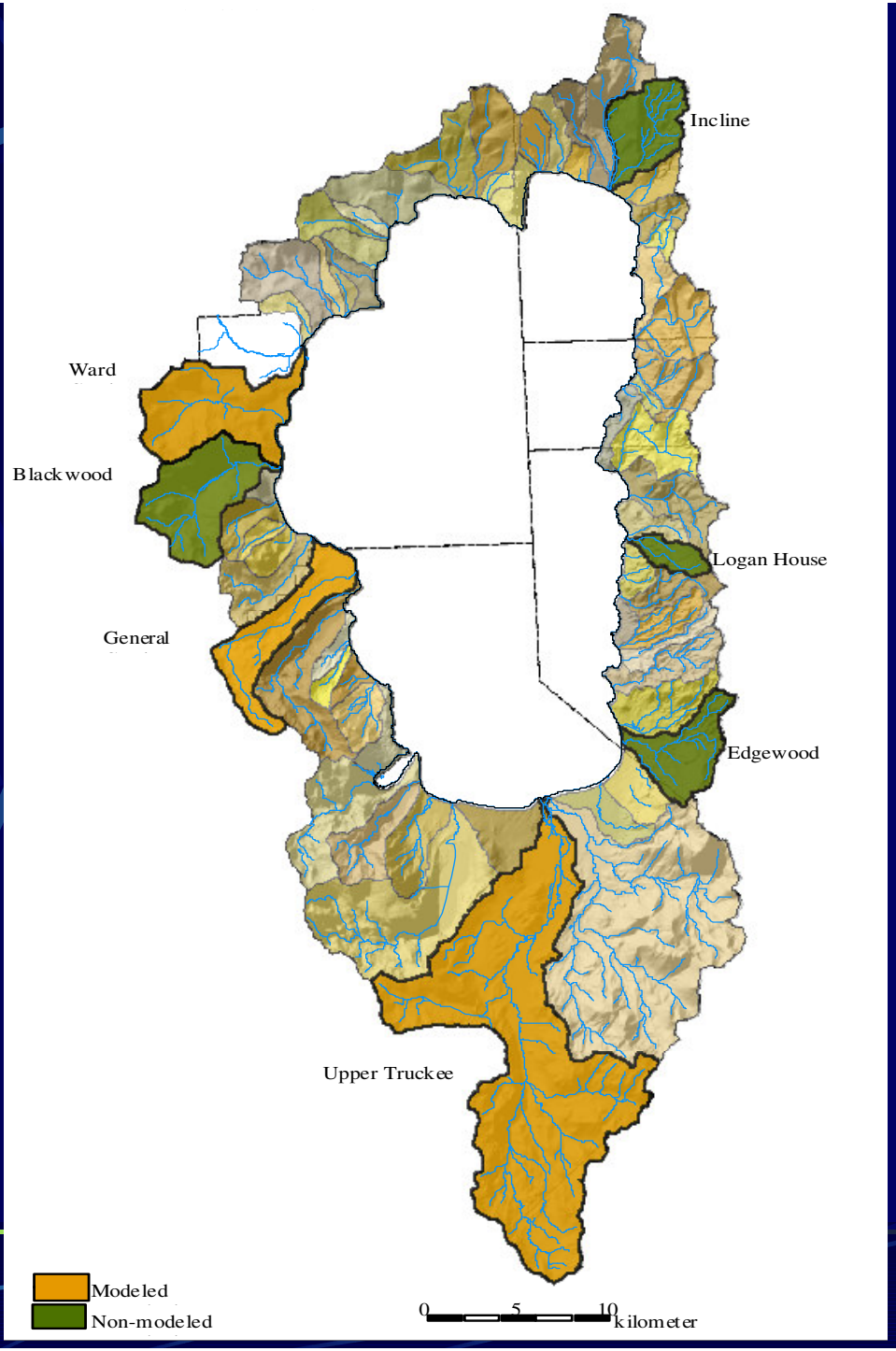
Median annual: 18,300 T/y

Median-annual fines: 6,300 T/y

- Estimate based on extrapolation of average, median-annual values within each quadrant

25,500 T/y

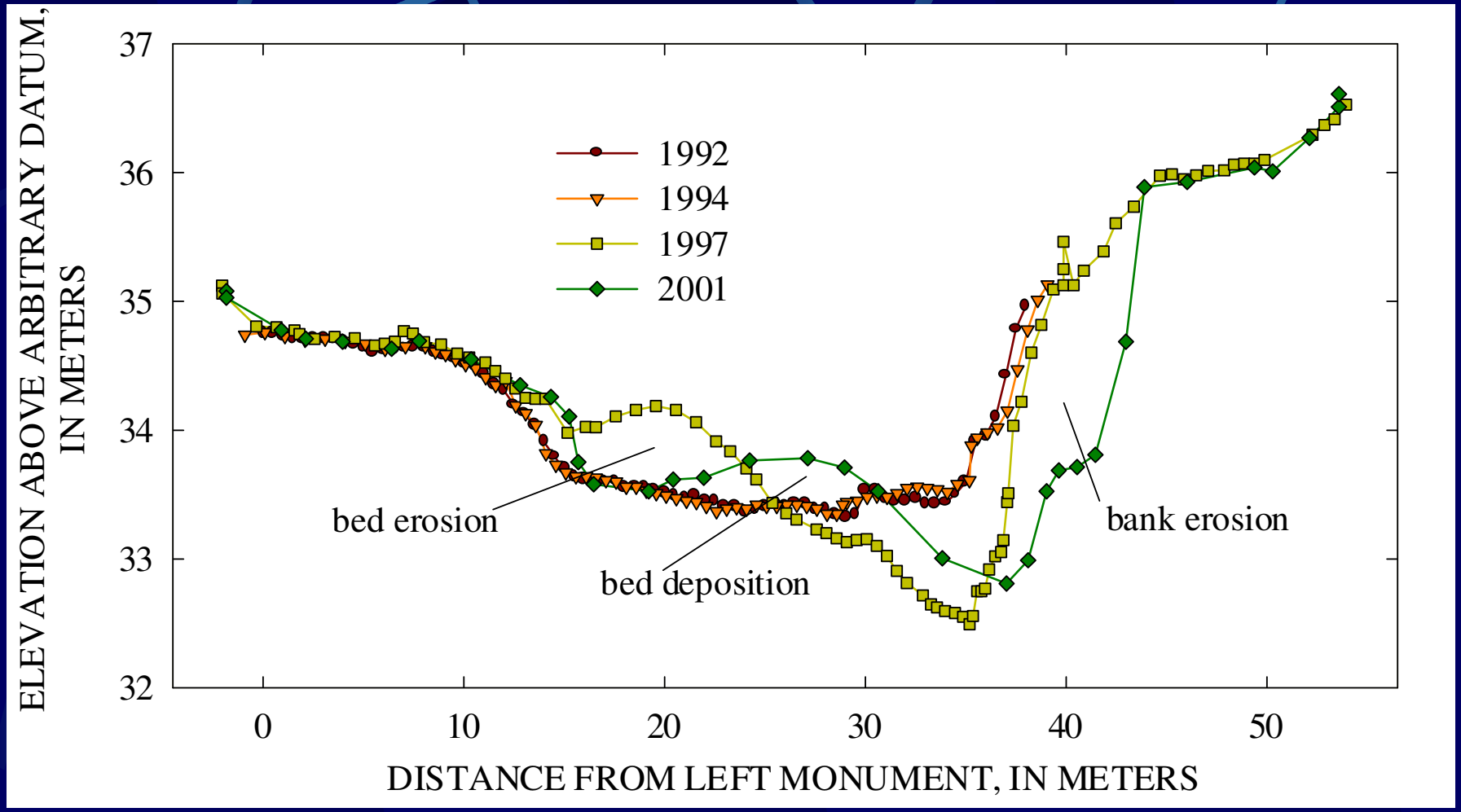
Surveyed and Modeled Watersheds



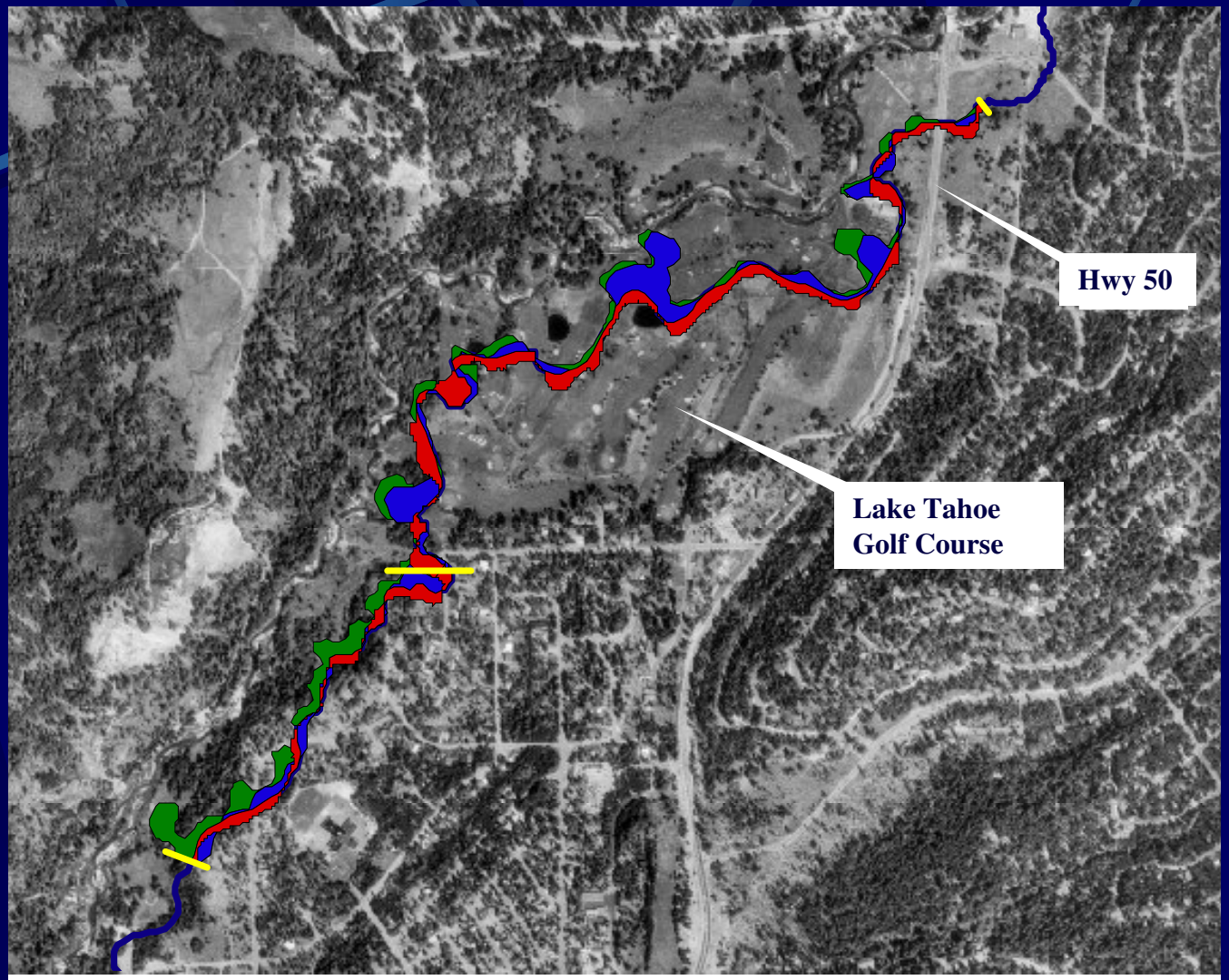
Direct Cross-Section Matches

Stream	Date of first survey used	Number of sections matched	Total matched length (km)	Source of historical data
Blackwood	1983	17	8.3	USGS[1]
Edgewood	1983	23	5.6	USGS[1]
General	1983	12	8.5	USGS[1]
Logan House	1984	10	3.3	USGS[1]
Upper Truckee	1992	24	2.9	Calif. Parks[2]

Cross-Section Match: Upper Truckee



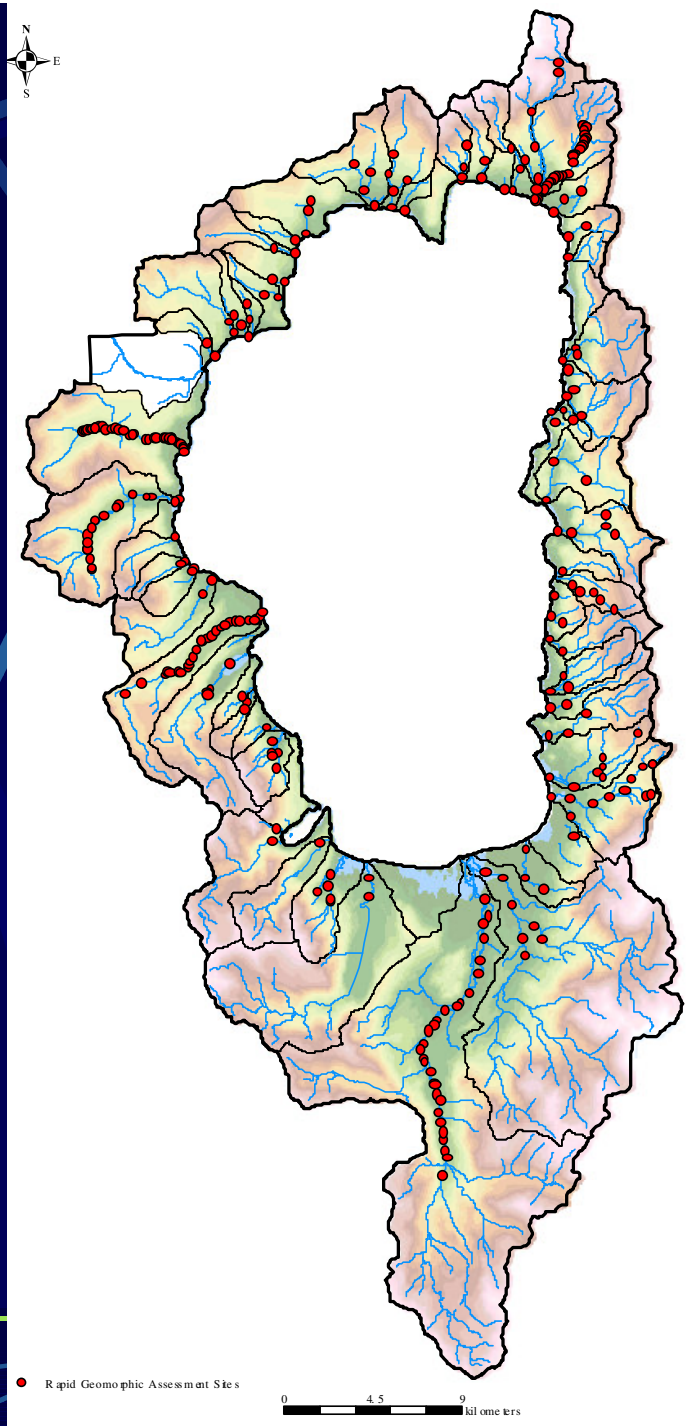
Channel Activity: Upper Truckee River



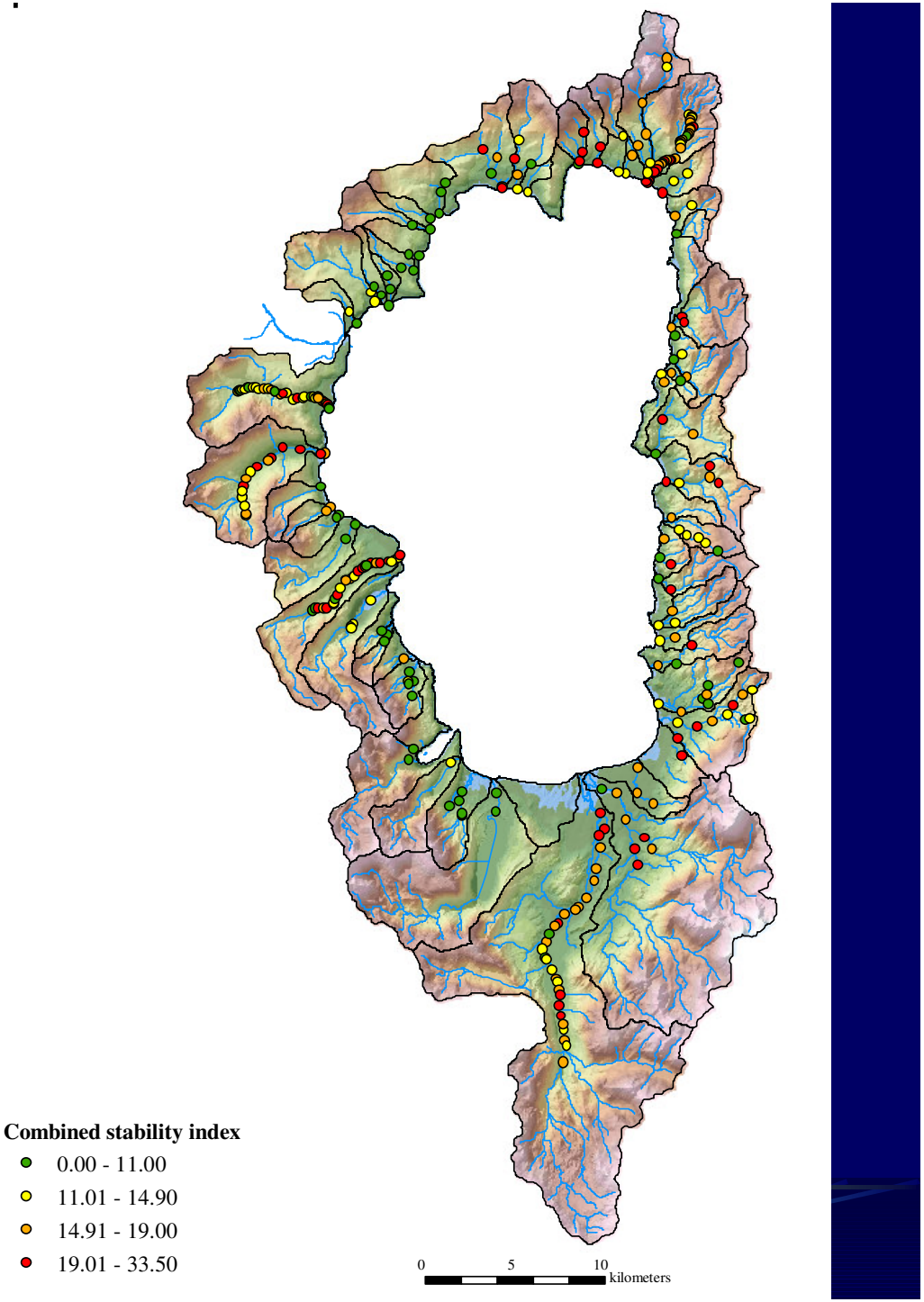
Channel Contributions

Stream	Total (m^3/y)	Bank (m^3/y)	Bed (m^3/y)	Silt-clay in banks (%)	Bank erosion rate ($m^3/y/km$)	Bank erosion of fines (m^3/y)	Bank erosion of fines ($m^3/y/km$)
Blackwood	-413	1800	-2220	6	217	101	12.2
Edgewood	-78	-51	-28	2	-	-	-
General	-237	125	-362	10	14.6	13.0	1.5
Logan House	-21	-8	-13	-	-	-	-
Upper Truckee	2340	1860	476	14	645	261	90.3

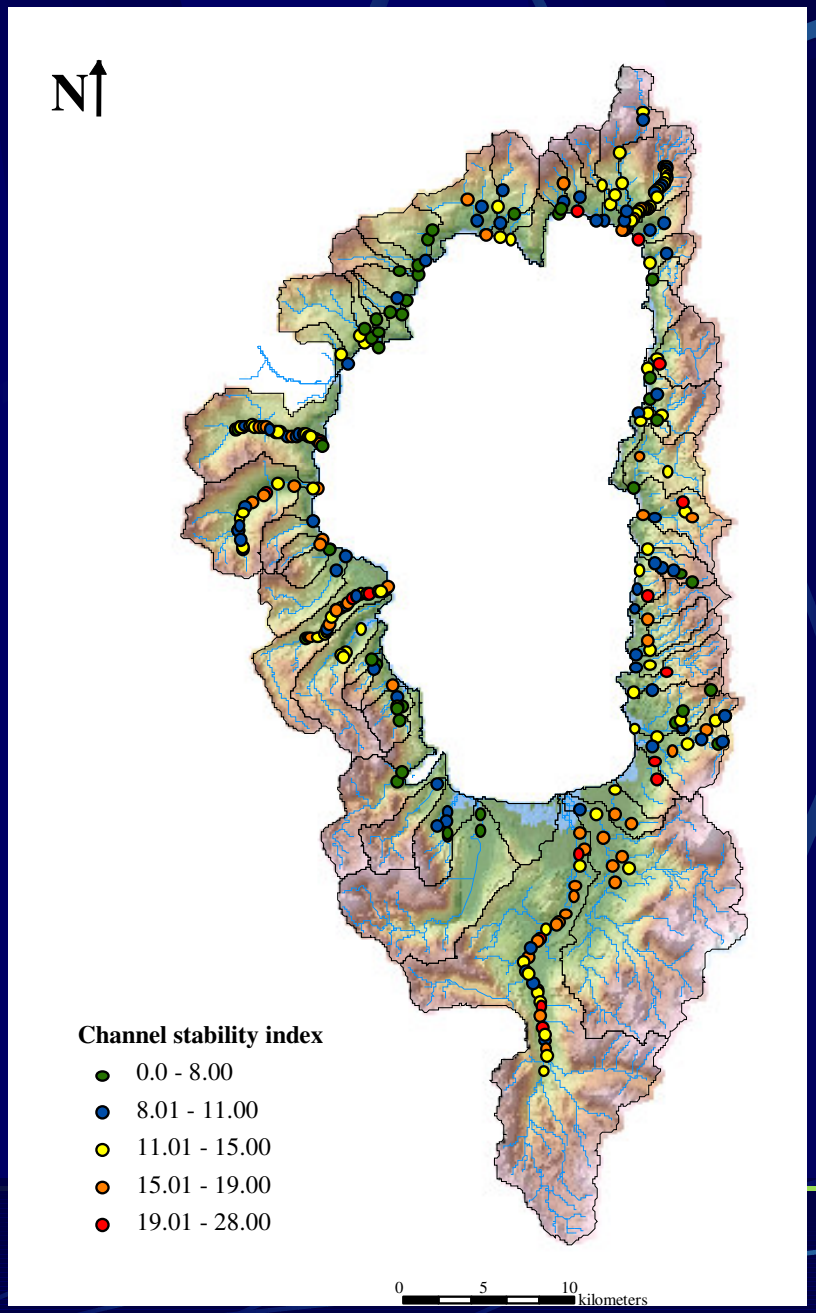
Locations of Rapid Geomorphic Assessments (RGAs)

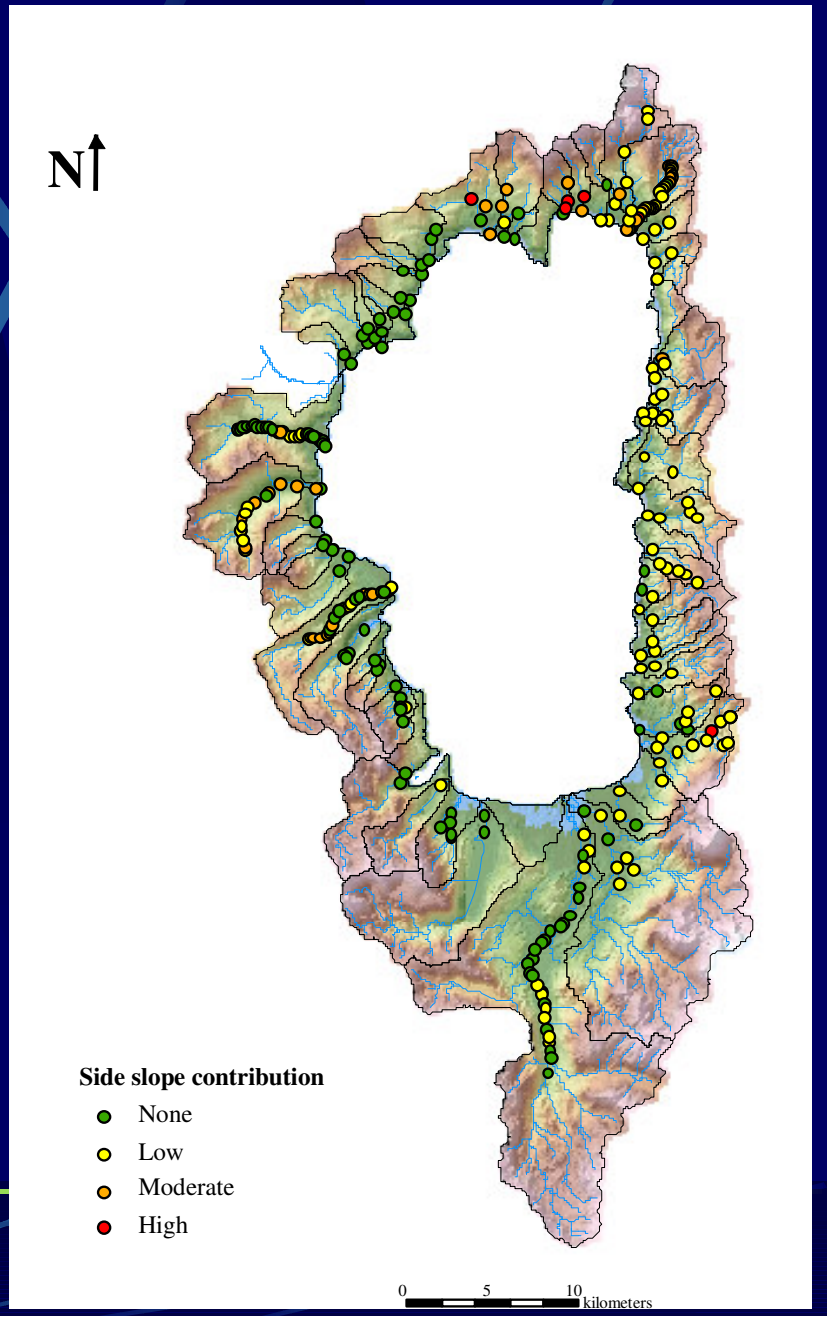


Combined-Stability Index for 304 Sites

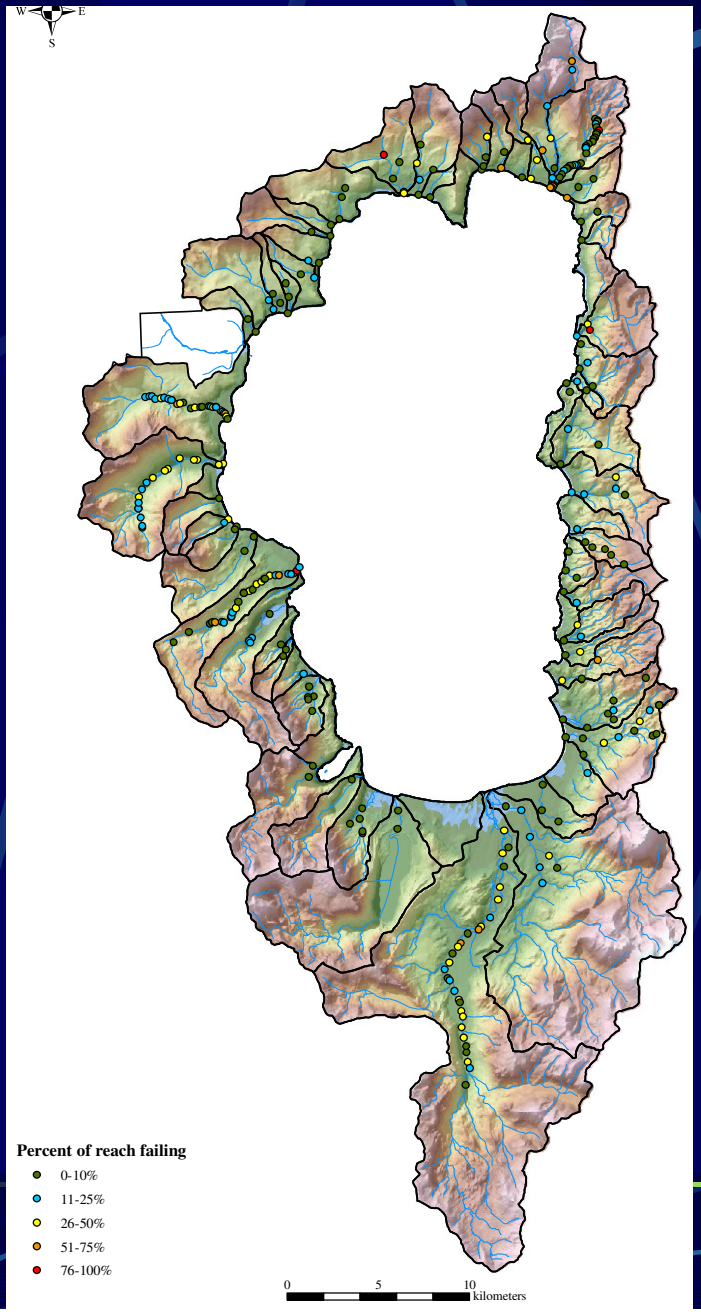


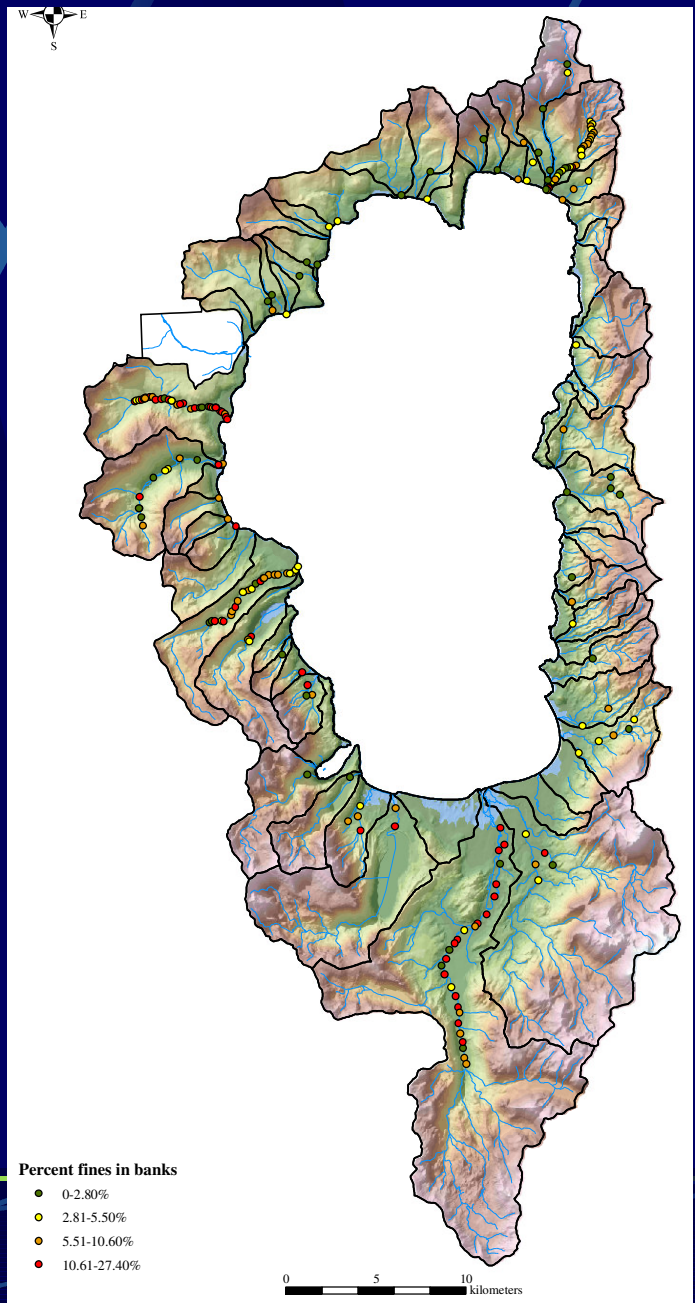
Relative Contributions from Channels and Side Slopes



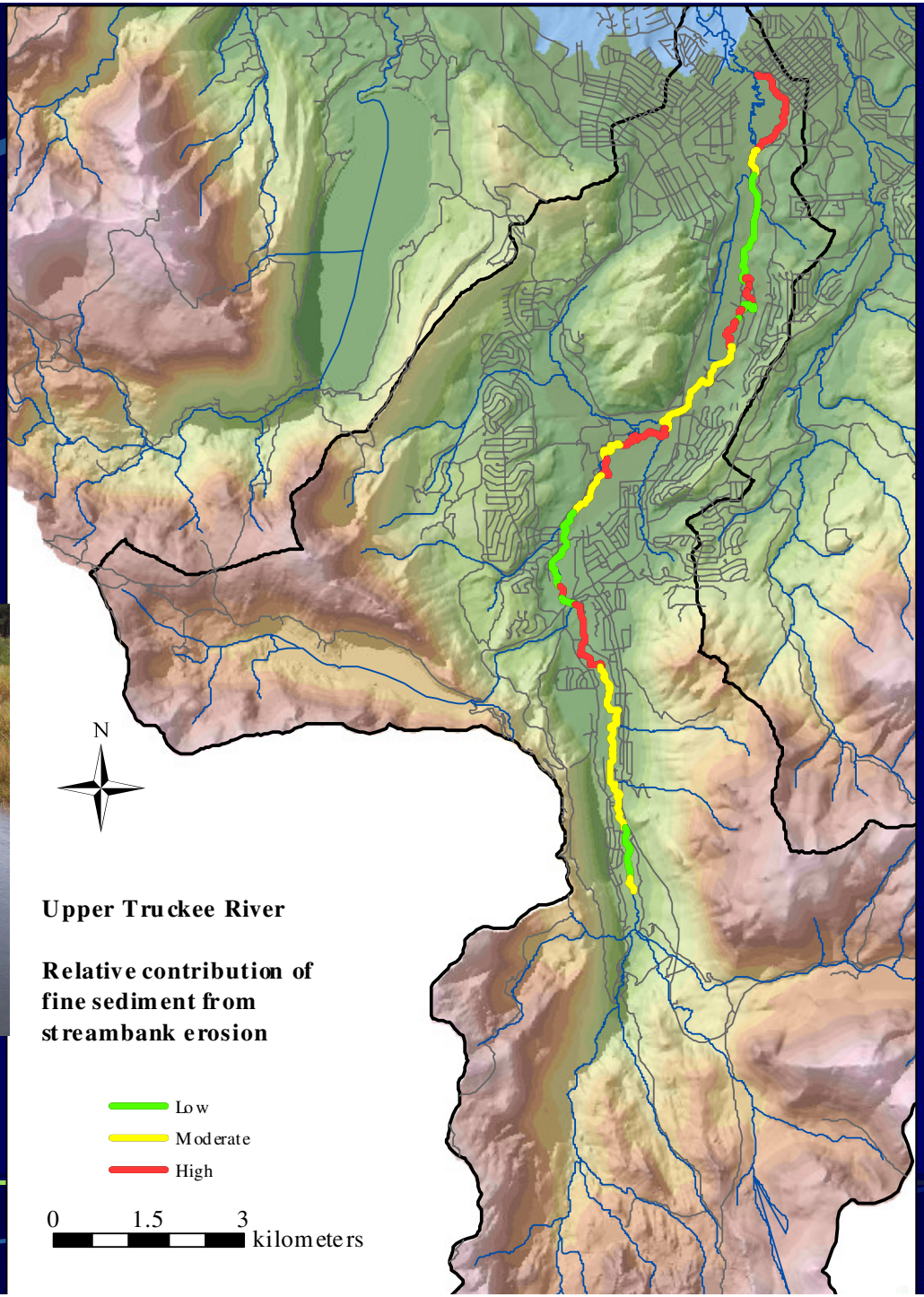


Fine-Grained Contributions from Streambanks





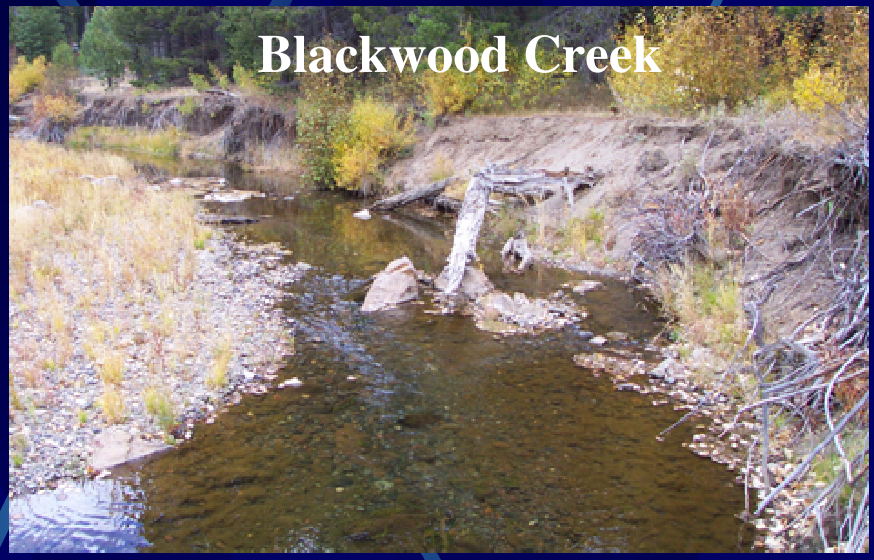
Example Results of Detailed Stream Evaluations



Streambank Erosion

Ward Creek

Blackwood Creek



Incline Creek

Streambank Erosion

Upper Truckee River

General Creek

Upland and Channel Simulations of Upper Truckee River, Ward Creek, and General Creek

AnnAGNPS and CONCEPTS are Part of Approved EPA Tool Box

AGNPS OVERVIEW

- DEVELOPMENT OF WATERSHED BOUNDARIES FOR STREAMS, STREAM NETWORK, AND SUBDRAINAGE AREAS
- WATERSHED LANDUSE DESCRIPTION
- DEVELOPMENT OF AnnAGNPS WEATHER DATABASE
- PRODUCTION OF LOADINGS FOR USE WITH CONCEPTS
- IDENTIFY UPLAND SOURCES WITHIN THE WATERSHEDS

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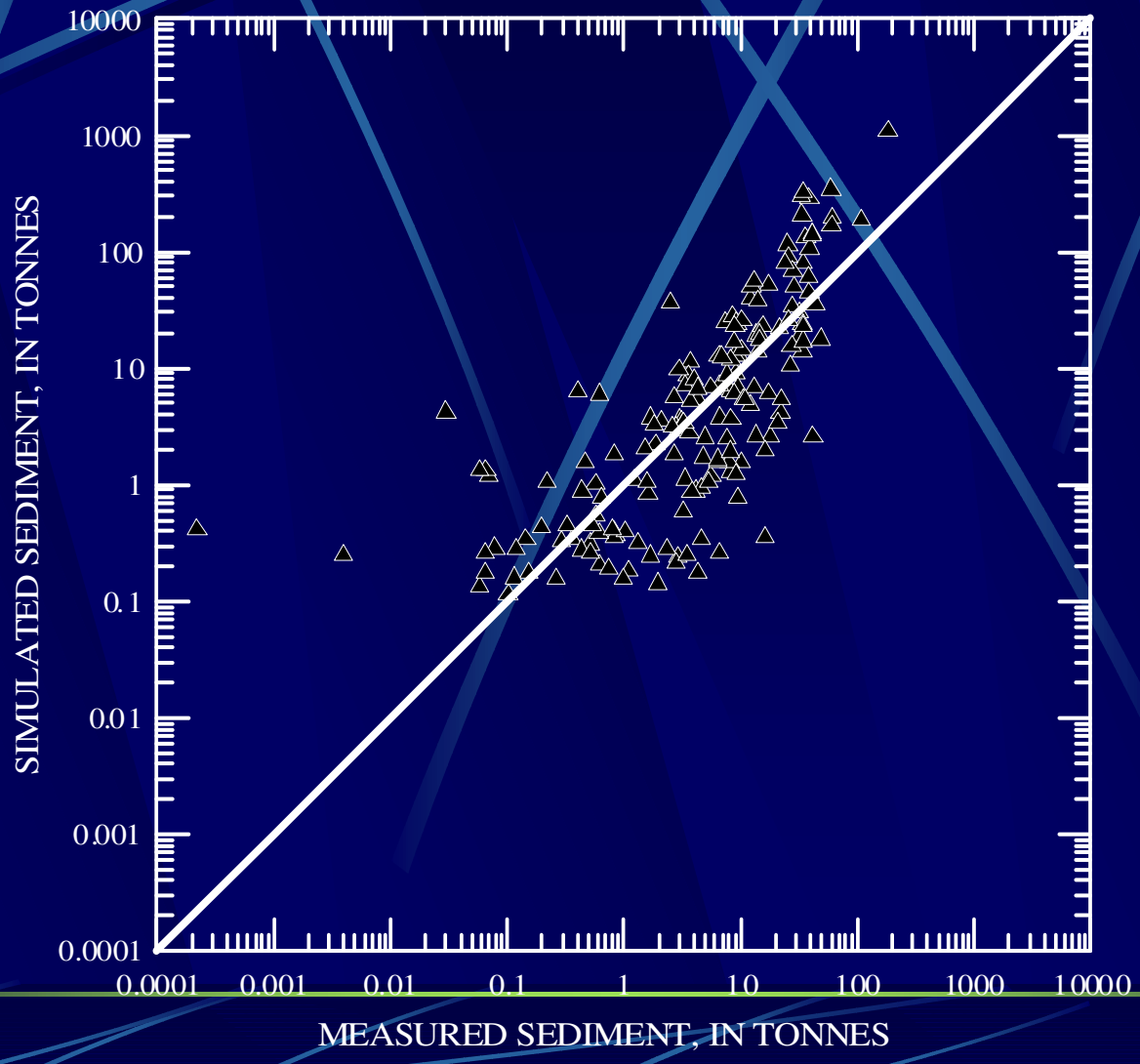
Measured and Simulated Fine Sediment: General Creek



CONCEPTS Conservational Channel Evolution and Pollutant Transport System

Input:

- Channel geometry
- Composition of bed and bank materials
- Erosion resistance and shear strength of bed and bank materials
- Rates of flow and sediments entering the channel

Output:

- Changes in channel geometry
- Time series of hydraulic variables and sediment loads and concentrations

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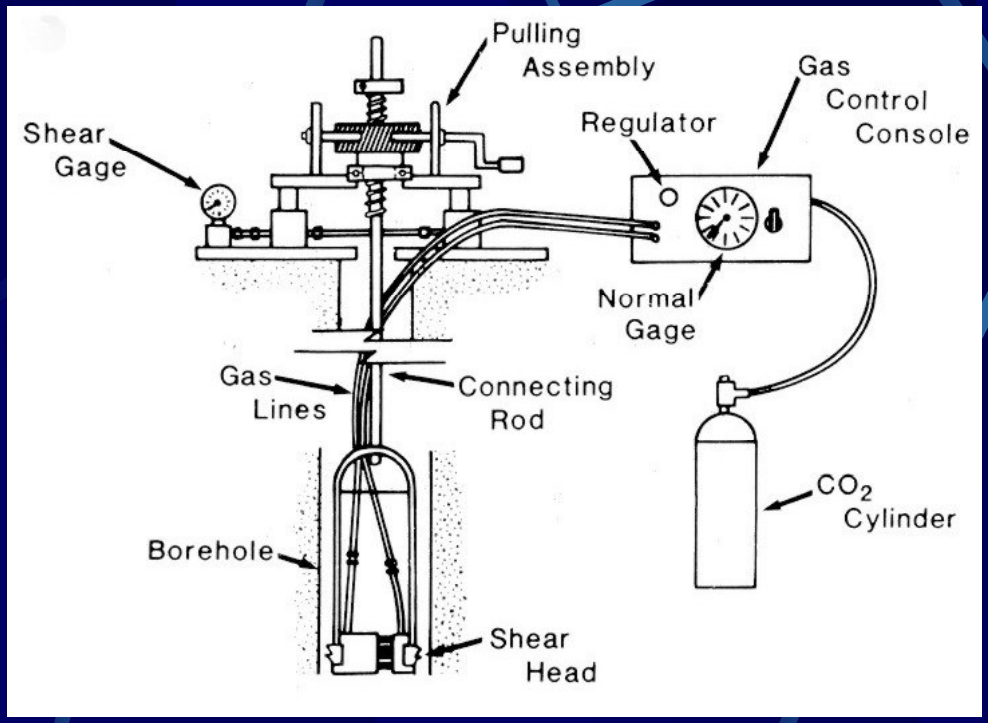
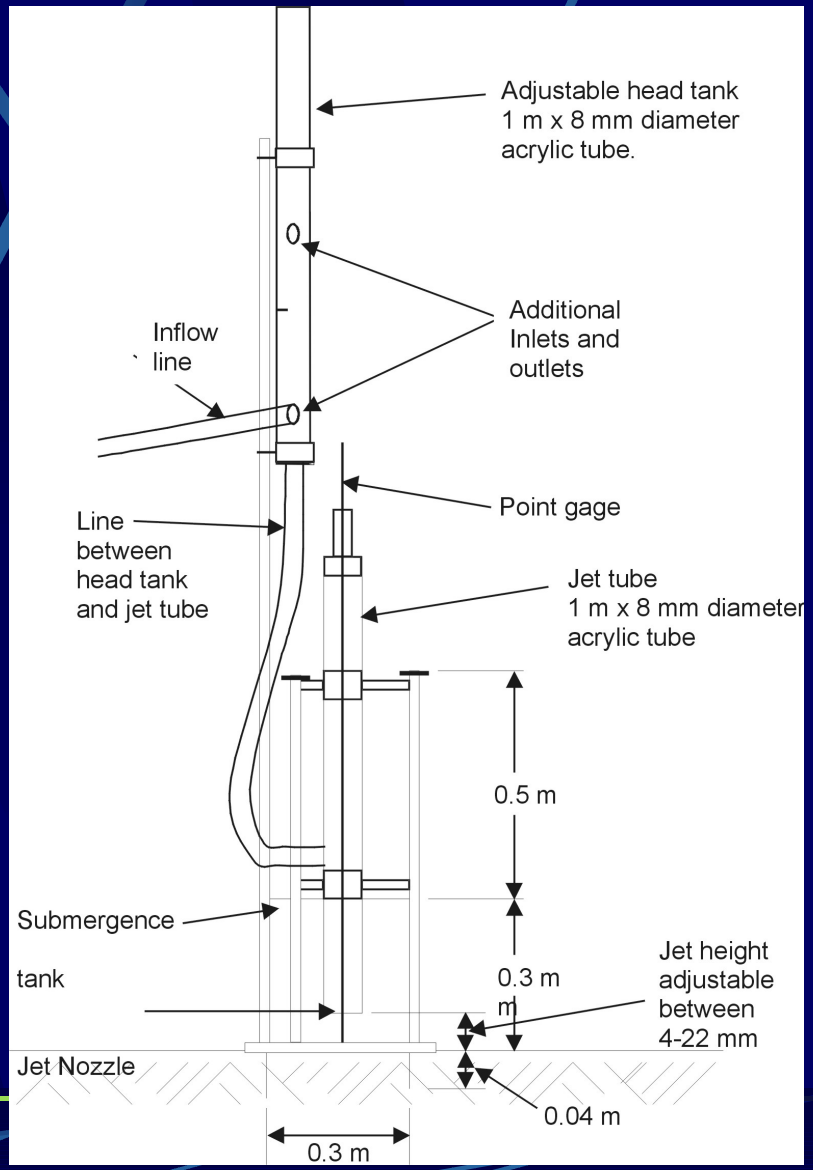
Hydraulic and Geotechnical Testing

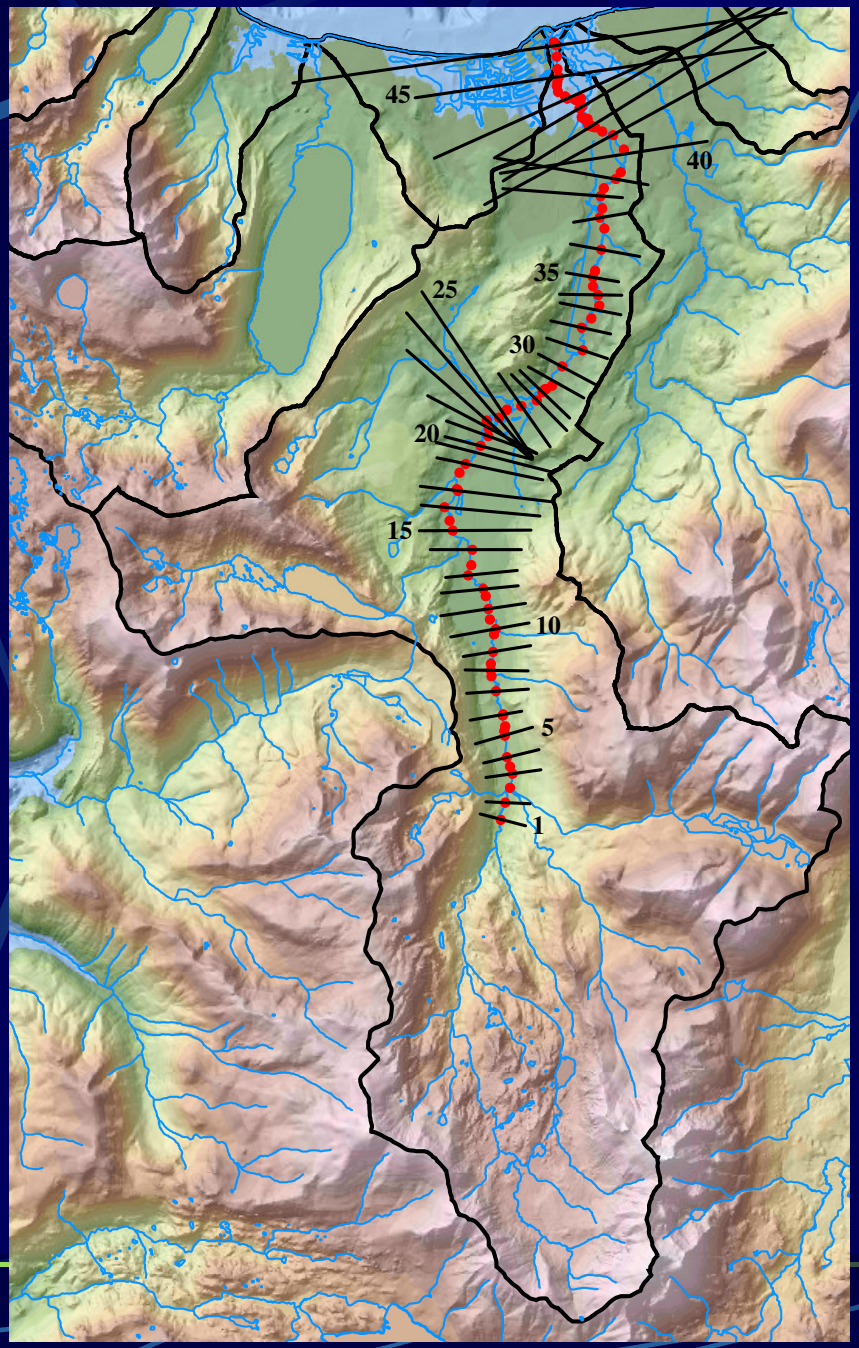


Borehole shear tester



Submerged jet-test device

Data Collection Locations for Modeling: Upper Truckee



Sediment Sources: Validation Periods (results at outlet to lake)

General Creek

Sediment size	Uplands (%)	Streambanks (%)	Total (T/y)
Fines	78	22	48
Sands	40	60	193
Total suspended	47	53	241

Upper Truckee River

Sediment size	Uplands (%)	Streambanks (%)	Total (T/y)
Fines	49	51	782
Sands	10	90	2110
Total suspended	21	79	2892

Ward Creek

Sediment size	Uplands (%)	Streambanks (%)	Total (T/y)
Fines	79	21	210
Sands	14	86	485
Total suspended	34	66	695

Simulated and Measured Annual Loads (T/y)

	Stream	Simulated	Measured	Difference
Total Suspended	General Creek	241	176	+37 %
	Upper Truckee River	2890	2200	+31 %
	Ward Creek	695	855	-19 %
Fines	General Creek	48	53	-9 %
	Upper Truckee River	782	1010	-23%
	Ward Creek	210	412	-49 %

Streambank Contributions (in $m^3/y/km$)

Stream	Total simulated	Total measured	Fines simulated	Fines measured
Blackwood	-	217	-	12.2
General	10.6	14.6	0.90	1.5
Upper Truckee[1]	54.5	645	9.5	90.3
Ward	45.6	-	4.4	-

[1] Represents eroded volume over 2.9 km reach near Lake Tahoe Golf Course

Upland and Channel Contributions (%)

	Source	General Creek	Ward Creek	Upper Truckee River
Total Suspended	Uplands	47	34	21
	Channel	53	66	79
Suspended Fines	Uplands	72	79	49
	Channel	28	21	51

Summay of Research Results

- Streambank erosion is an important contributor of suspended-sediment from disturbed streams,

- The Upper Truckee River is the greatest contributor of suspended-sediment and fine-grained sediment in the Lake Tahoe Basin,

- Sediment delivery from the Upper Truckee River could be significantly reduced by controlling streambank erosion in the reaches adjacent to the golf course and downstream from the airport,

- Blackwood Creek is a major contributor of both total and fine-grained sediment, particularly for the size of its drainage area; loads from disturbed western streams remain high.

- Loads from western streams are not increasing with time as reported by others,

- Median, long term suspended-sediment yields (per unit runoff) from northern streams are high, about the same as the wetter western streams but yields have shown significant decreases from the major development period in the 1960s and 1970s.

Results… continued

- Third Creek still produces a great deal of sediment for its size as a result of both upland and channel contributions.

- Disturbed watersheds contribute considerably more suspended sediment than their stable counterparts in each basin quadrant.

- Eastern streams produce the lowest sediment loads and those studied are net sinks for sediment.

- The major runoff event of January 1997 impacted western streams and the Upper Truckee River most severely, but did not seem to rejuvenate these fluvial systems. Effects were minor in the northern streams,

- The most significant effect of the January 1997 was to flush stored sediment from alluvial valleys resulting in generally lower transport rates in the years following the event,

- Numerical simulations of General and Ward Creeks and the Upper Truckee River show that suspended-sediment loads will continue to decrease from these streams over the next 50 years.