2.0 FIELD-DATA COLLECTION AND ANALYSIS OF SEDIMENT-TRANSPORT DATA

2.1 Introduction

Collection of field data was required to support several aspects of the research. Given that the research scope covered the entire basin, it was essential that as much information was collected first hand as possible to evaluate channel, upland, and sediment-transport conditions. Some of the data-collection activities such as ground reconnaissance and rapid geomorphic assessments (RGAs), as well as the GIS-based upland-erosion potential INDEX will be described in later sections as appropriate. This section concentrates on field work that was used to support numerical modeling, re-surveying of monumented historical, channel cross sections and computational techniques used in the analysis of suspended-sediment transport loadings.

2.2 Cross-Section Surveys

Ground surveys of channels were required for two main purposes:

(1) To provide input geometries of stream channels for the CONCEPTS channel-evolution model; and
(2) To compare previously surveyed locations with current (2002) conditions.

A total of 245 cross sections were surveyed in the Lake Tahoe Basin during a three-month data-collection campaign in the fall of 2002. Vertical-control surveys were conducted on General Creek (37 cross sections), Incline Creek (48 cross sections), Logan House Creek (21 cross sections), the Upper Truckee River (38 cross sections), and Ward Creek (44 cross sections). A vertical-control survey is a survey in which elevations are carried through a series of benchmarks (the majority of the benchmarks were not established, documented benchmarks). Detailed channel- geometry surveys were conducted at regularly spaced intervals along the channel, from a predetermined upper boundary (usually a major confluence) to the outlet at the lake, to provide input information for CONCEPTS or comparison with historic cross sections.

Historic cross-section information was available for Blackwood Creek (31 cross sections), Edgewood Creek (26 cross sections), General Creek (12 cross sections), Logan House Creek (11 cross sections), Ward Creek (8 cross sections), and the Upper Truckee River (33 cross sections). Because many of these cross sections had been last surveyed in 1987 it was not possible to re-locate all of the historical section monuments. Cross-section data for Blackwood Creek, Edgewood Creek, General Creek, and Logan House Creek were provided by K. Nolan (USGS, written communication, 2003). A. Stubblefield (U. California at Davis, written commun., 2002) provided location information and newly monumented cross-section information for Blackwood Creek and Ward Creek, and the Upper Truckee River cross-section information was provided by C. Walck (California State Parks, written commun., 2003).

2.3 Geotechnical Data for Analysis of Streambank Stability

The adjustment of channel width by mass-wasting and related processes represents an important mechanism of channel response and a potential major contributor to sediment loads in the Lake Tahoe Basin. In the loess area of the Midwest United States, for example, bank material contributes as much as 80% of the total sediment eroded from incised channels (Simon and Rinaldi, 2000). In the Lake Tahoe watershed, sediment entrained from bank failures are blamed as a major contributor to the sediment and lake-clarity problems affecting the lake.

Conceptual models of bank retreat and the delivery of bank sediments to the flow emphasize the importance of interactions between hydraulic forces acting at the bed and bank toe, and gravitational forces acting on *in situ* bank materials (Carson and Kirkby, 1972; Thorne, 1982; Simon *et al*., 1991). Failure occurs when erosion of the bank toe and the channel bed adjacent to the bank have increased the height and angle of the bank to the point that gravitational forces exceed the shear strength of the bank material. After failure, failed bank materials may be delivered directly to the flow and deposited as bed material, or dispersed as wash load, or deposited along the toe of the bank as intact blocks, or as smaller, dispersed aggregates (Simon *et al*., 1991). Analysis of streambank stability within CONCEPTS is based on measured field data using *in situ* devices such as the borehole shear test (Figure 2-1) and the submerged jet-test device (Figure 2-2).

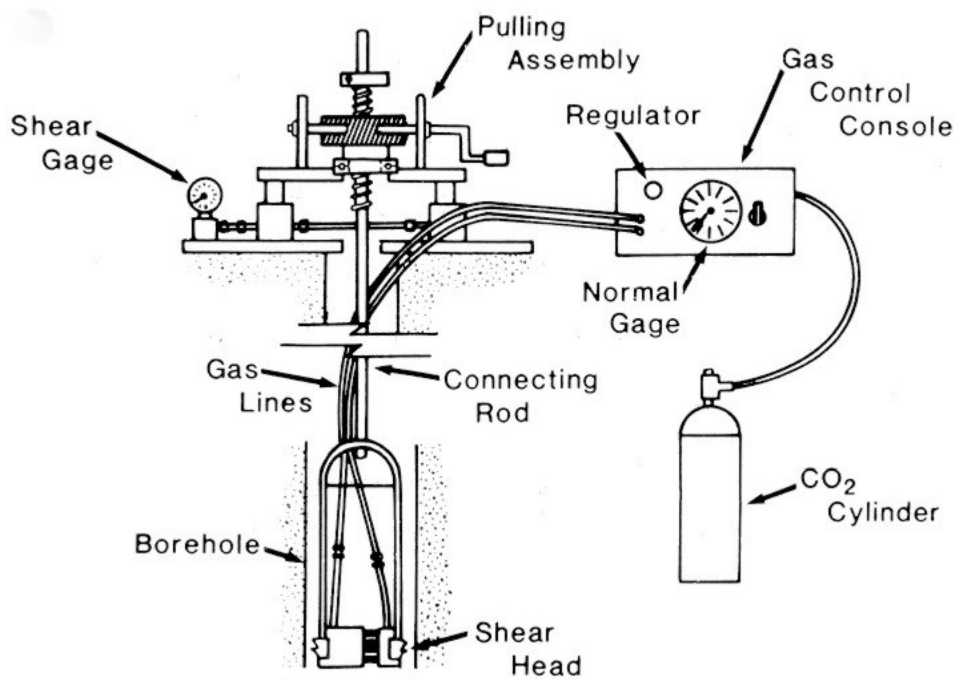

Figure 2-1. Schematic representation of borehole shear tester (BST) used to determine cohesive and frictional strengths of *in situ* streambank materials. Modified from Thorne *et al*., 1981.

2.3.1 Borehole Shear Testing and Bulk Unit Weights

To properly determine the resistance of cohesive materials to erosion by mass movement, data must be acquired on those characteristics that control shear strength; that is cohesion, angle of internal friction, pore-water pressure, and bulk unit weight. Cohesion and friction angle data can be obtained from standard laboratory testing (triaxial shear or unconfined compression tests), or by *in-situ* testing with a borehole shear-test (BST) device (Lohnes and Handy 1968; Thorne *et al.* 1981; Little *et al*. 1982; Lutenegger and Hallberg 1981). The BST provides, direct, drained shear-strength tests on the walls of a borehole (Figure 2-1). BST results for the General, Incline, Ward and Upper Truckee watersheds are shown in Tables 2-1 to 2-3. Advantages of the instrument include:

1. The test is performed *in situ* and testing is, therefore, performed on undisturbed material;
2. Cohesion and friction angle are evaluated separately with the cohesion value representing apparent cohesion (c_a). Effective cohesion (c') is then obtained by adjusting c_a according to measured pore-water pressure and ϕ^b.
3. A number of separate trials are run at the same sample depth to produce single values of cohesion and friction angle based on a standard Mohr-Coulomb failure envelope.
4. Data and results obtained from the instrument are plotted and calculated on site, allowing for repetition if results are unreasonable; and
5. Tests can be carried out at various depths in the bank to locate weak strata (Thorne *et al.* 1981).

Table 2-1. BST values obtained for General Creek.

Site name	River kilometer	Bank	Depth (m)	Material	c_a (kPa)	c' (kPa)	ϕ' (degrees)	Pore-water pressure (kPa)
56-36	0.30	Right	0.45	Sand/Silt	1.80	1.10	33.1	3.75
56-30	0.89	Right	0.45	Sand/Silt	6.50	2.90	21.9	20.7
56-23	2.20	Right	0.40	Sand/Silt	0.920	0.00	22.3	70.1
56-19	3.25	Right	0.45	Sand/Silt	2.40	0.00	14.8	68.1
56-17	3.60	Right	0.50	Sand/Silt	0.00	0.00	15.0	66.4
56-12	4.73	Right	0.45	Sand/Silt	6.28	1.30	21.7	57.2
56-06	5.90	Right	0.43	Sand/Silt	1.04	0.00	35.1	51.5
56-05	6.06	Right	0.32	Sand	8.09	1.00	33.0	50.5
56-03	6.50	Right	0.44	Sand/Silt	1.50	0.00	32.5	71.5

Table 2-2. BST values obtained for Incline Creek.

Site name	River kilometer	Bank	Depth (m)	Material	c_a (kPa)	c' (kPa)	ϕ' (degrees)	Pore-water pressure (kPa)
18-33	0.72	Left	0.45	Silt	0.00	0.00	35.8	54.0
18-32	0.85	Left	0.38	Silt	5.79	0.100	34.9	65.1
18-31	1.08	Right	0.45	Silt/Sand	14.5	6.00	26.6	48.3
18-10	4.53	Left	0.30	Silt/Sand	6.11	0.700	12.5	61.5
18-5	5.22	Left	0.40	Silt/Sand	0.00	0.00	21.1	2.30
18-2	5.61	Left	0.40	Silt/Sand	3.51	1.60	34.3	10.9

Table 2-3. BST values obtained for Ward Creek.

Site name	River kilometer	Bank	Depth (m)	Material	c_a (kPa)	c' (kPa)	ϕ' (degrees)	Pore-water pressure (kPa)
63-43	0.25	Right	0.70	Sand/Silt	0.00	0.00	32.2	68.6
63-39	0.78	Right	0.70	Sand/Silt	2.27	0.00	18.4	-
63-37	1.11	Left	0.35	Sand/Silt	0.00	0.00	31.5	50.7
63-33	1.42	Left	0.35	Sand/Silt	1.99	0.00	35.8	55.2
63-29	2.08	Left	0.40	Sand/Silt	0.00	0.00	33.1	68.6
63-21	3.64	Left	0.70	Sand/Silt	0.00	0.00	33.3	46.0
63-19	4.06	Left	0.40	Sand/Silt	0.65	0.00	35.0	65.8
63-14	5.12	Right	1.50	Silt	1.04	0.00	33.4	55.6
63-12	5.53	Right	0.80	Sand/Silt	3.09	0.500	33.6	59.1

2.4 Submerged Hydraulic Jet Testing: Erodibility of Fine-Grained Materials

The submerged jet-test device is used to estimate erosion rates due to hydraulic forces in fine-grained *in situ* materials (Hanson 1990; 1991; Hanson and Simon, 2001) (Figure 2-2). The device shoots a jet of water at a known head (stress) onto the streambed causing it to erode at a given rate. As the bed erodes, the distance between the jet and the bed increases, resulting in a decrease in the applied shear stress. Theoretically, the rate of erosion beneath the jet decreases asymptotically with time to zero. A critical shear stress for the material can then be calculated from the field data as that shear stress where there is no erosion.

The rate of erosion ε (m/s) is assumed to be proportional to the shear stress in excess of a critical shear stress and is expressed as:

$$\varepsilon = k\,(\tau_o - \tau_c)^{a} = k\,(\tau_e)^{a} \tag{1}$$

where k = erodibility coefficient (m^3/N-s); τ_o = average boundary shear stress (Pa); τ_c = critical shear stress; a = exponent assumed to equal 1.0l and τ_e = excess shear stress (Pa). An inverse relation between τ_c and k occurs when soils exhibiting a low τ_c have a high k or when soils having a high τ_c have a low k. The measure of material resistance to hydraulic stresses is a function of both τ_c and k. Based on observations from across the United States, k can be estimated as a function of τ_c (Figure 2-3). This is generalized to:

$$k = 0.1\ \tau_c^{-0.5} \qquad (2)$$

Two jet tests were conducted at each site where cohesive bed or bank-toe material was present. In general, the average value of the two tests were used to represent the cross section and for input into CONCEPTS. Values for the Upper Truckee watershed are shown in Table 2-4.

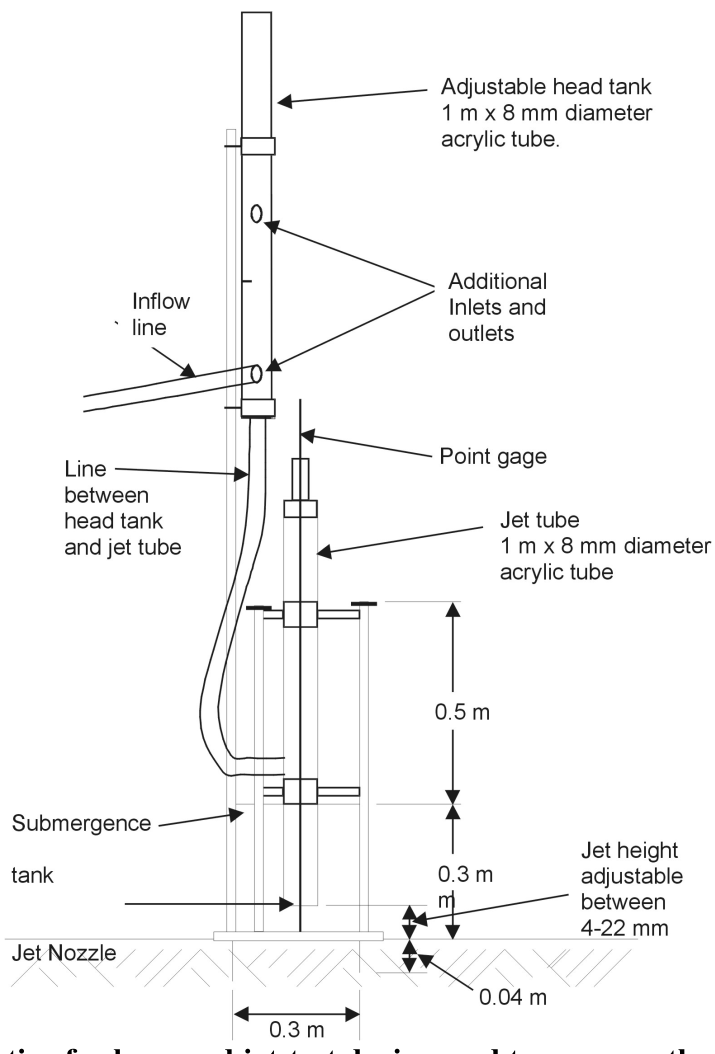

Figure 2-2. Schematic of submerged jet-test device used to measure the erodibility coefficient *k*, and the critical shear stress of fine-grained materials.

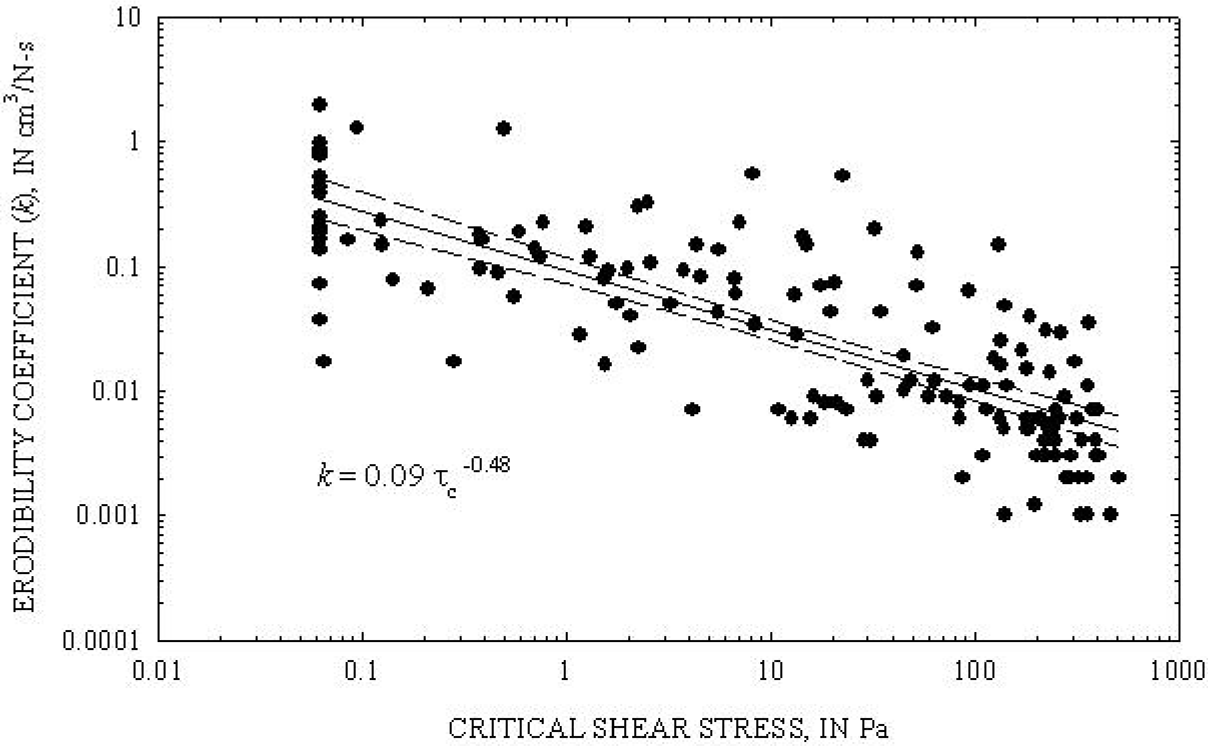

Figure 2-3. General relation between the erodibility coefficient *k*, and critical shear stress τ_c for fine-grained materials based on hundreds of jet tests from across the United States (Hanson and Simon, 2001).

Table 2-4. BST and submerged jet-test values obtained for the Upper Truckee River.

Site name	River kilometer	Bank	Depth (m)	Material	c_a (kPa)	c' (kPa)	ϕ' (degrees)	Pore-water pressure (kPa)	Jet location	τ_c (Pa)	k (cm^3/N-s)
44-110	1.56	Left	0.60	Silt Clay	7.95	2.20	37.6	65.5	-	-	-
44-92	2.94	Left	1.00	Sandy Silt	0.772	0.00	36.8	25.2	LBface	5.24	2.76
44-92	2.94	-	-	-	-	-	-	-	LBtoe	1.92	4.24
44-87	4.51	Right	0.30	Sand	0.160	0.00	31.0	4.30	-	-	-
44-85	5.06	Right	0.90	Silt	1.21	0.00	31.1	72.1	LBtoe	0.390	5.65
44-85	5.06	-	-	-	-	-	-	-	LBface	0.500	13.5
44-78	7.14	Left	0.35	Silt	4.20	0.90	32.5	75.7	-	-	-
44-75	8.46	Right	1.00	Silty Sand	3.30	2.60	27.4	4.20	RBtoe	0.280	29.6
44-75	8.46	-	-	-	-	-	-	-	RBface	0.360	4.87
44-68	10.8	Right	0.20	Silt	5.67	0.70	6.58	57.1	RBtoe	0.611	11.7
44-43	13.1	Right	1.15	Silty Sand	4.20	1.20	21.8	69.0	RBtoe	1.65	7.98
44-43	13.1	-	-	-	-	-	-	-	RBface	0.991	11.7

44-39	13.5	Right	0.30	Sandy Silt	0.230	0.00	30.5	70.4	RBtoe	1.15	12.5
44-39	13.5	-	-	-	-	-	-	-	RBface	1.29	16.8
44-26	14.8	Right	0.40	Sandy Silt	3.84	0.600	31.0	73.5	RBface	0.104	14.9
44-20	17.8	Left	0.40	Sandy Silt	1.77	0.00	18.8	39.5	LBface	1.49	4.28
44-20	17.8	-	-	-	-	-	-	-	LBtoe	0.0160	28.3
44-15	19.9	Left	0.89	Silty Sand	3.17	1.00	31.0	25.2	LBtoe	0.400	27.9
44-12	20.7	Right	1.10	Silty	2.38	0.00	28.7	73.4	LBface	0.78	29.0
44-04	23.0	Right	0.40	Silt	2.84	0.60	31.0	51.1	RBtoe	1.65	4.71

2.4.1 Bank-Toe Erodibility

In watersheds including Ward, General, Logan House, Edgewood, Blackwood, Incline and Upper Truckee, *in situ* bank-toe materials are composed predominantly of sands inter-mixed with cohesive material, gravel and cobbles. As with determining the erodibility of cohesive streambed materials, a submerged jet-test device (modified to operate on inclined surfaces) was used to determine values of τ_c and k. Values for sites in the Upper Truckee are shown in Table 2-4. Erosion of bank-toe materials is then calculated using an excess shear stress approach. For coarse-grained materials, bulk samples were obtained for particle-size analysis. Critical shear stress of these types of materials can then be calculated using conventional techniques as a function of particle size and weight.

2.5 <u>Texture of Bank and Bed Materials</u>

Fine-grained sediment is one of the main concerns in the Lake Tahoe area because of the nature of fine sediment to remain in suspension for longer periods of time and degrade lake clarity. Although alluvial materials are dominated by materials of sand size and coarser, fine-grained sediments can be found in varying quantities in streambanks. This sediment is released from the banks when the banks fail. To determine where bank failures were occurring, rapid geomorphic assessments were conducted across the watershed and bulk samples of bank material were collected at each of these sites. The purpose of this was for users of this report to be able to correlate the occurrence of bank failures with the relative proportion of fine sediments delivered by those bank failures not only for the seven intensely studied streams, but in the remainder of the watersheds as well.

The spatial distribution of fine-grained streambank materials, expressed as percent finer than 0.062 mm is illustrated in Figure 2-4. Values ranged from 0 to about 27 %, with the lower reaches of the Upper Truckee River having the greatest volume of fine-grained materials in its banks and an average fine-grained content of 14%. Ward Creek had the highest average concentration of fines, 17%. The average composition of fine-grained bank material for each of the intensely studied watersheds is shown in Table 2-5. Fine-grained materials were not found in measurable quantities on channel beds.

Table 2-5. Average percentage of fine-grained material contained in the banks of each modeled watershed.

Stream	Number of samples	Silt plus clay (%)
Upper Truckee	62	14
Ward	44	17
General	46	10
Edgewood	4	2
Blackwood	13	6
Incline	63	5