4.0 CHANNEL EROSION AND BASIN GEOMORPHOLOGY

4.1 Introduction

Erosion of materials from channel boundaries has been named as a leading contributor to water clarity problems in Lake Tahoe. Increased algal production in the lake has been linked to an increase in the delivery of nutrients from tributary streams (Goldman and Byron, 1986; Goldman, 1988) adsorbed onto fine-grained sediments (Leonard *et al*., 1979). Aside from anecdotal evidence and studies of short duration (Hill and Nolan, 1991 for example) little quantitative information is available on the magnitude of sediment contributions, particularly fine-grained materials, from channel boundaries. The Hill *et al*. (1990) and Nolan and Hill (1991) study on Blackwood, General, Logan House, and Edgewood Creeks stands as an exception, as does some of the recent work by Stubblefield (2002) on Ward and Blackwood Creeks. The current study owes a debt of gratitude to both Mike Nolan (U.S. Geological Survey; USGS) and Andrew Stubblefield (U. California at Davis) for their assistance in re-occupying monumented cross sections in the study watersheds, and to Cynthia Walck (California State Parks) for making past surveys on the Upper Truckee River available to the authors.

The magnitude and extent of channel erosion was determined using three methods:

(1) Direct comparison of monumented, historical cross-section surveys with surveys conducted in 2002 on Blackwood, Edgewood, General, and Logan House Creeks, and the Upper Truckee River (Figure 4-1);

(2) Identification of unstable reaches contributing fine-grained sediment via bank erosion during reconnaissance surveys (stream walks) of geomorphic conditions along Blackwood, Edgewood, Logan House, Incline, General, and Ward Creeks, and the Upper Truckee River (Figure 4-1); and

(3) Rapid geomorphic assessments (RGAs) at 304 locations across the Lake Tahoe Basin.

4.2 Direct Comparison of Measured Cross Sections

One of the simplest but most powerful ways of calculating rates and volumes of channel erosion is by direct comparison of time-series cross-sections. To obtain a relatively good degree of accuracy it is critical to be able to locate the historical cross-section location in both the horizontal and vertical dimensions.

4.2.1 Availability of Data

Cross sections on Blackwood, General, Logan House, and Edgewood Creeks were monumented with metal fence posts and labeled with brass plates (Hill *et al*. 1990) by the U.S. Geological Survey in 1983 and 1984. Original survey notes were obtained from the USGS and new surveys were conducted at as many of these sites as could be located during the fall of 2002. Time-series cross sections of the Upper Truckee River were originally surveyed in 1992 and had been recently re-surveyed (2001 or 2002), thus providing a ten-year record of channel changes (C. Walck, 2003, written commun.). A summary of the historical cross-section data is provided in Table 4-1.

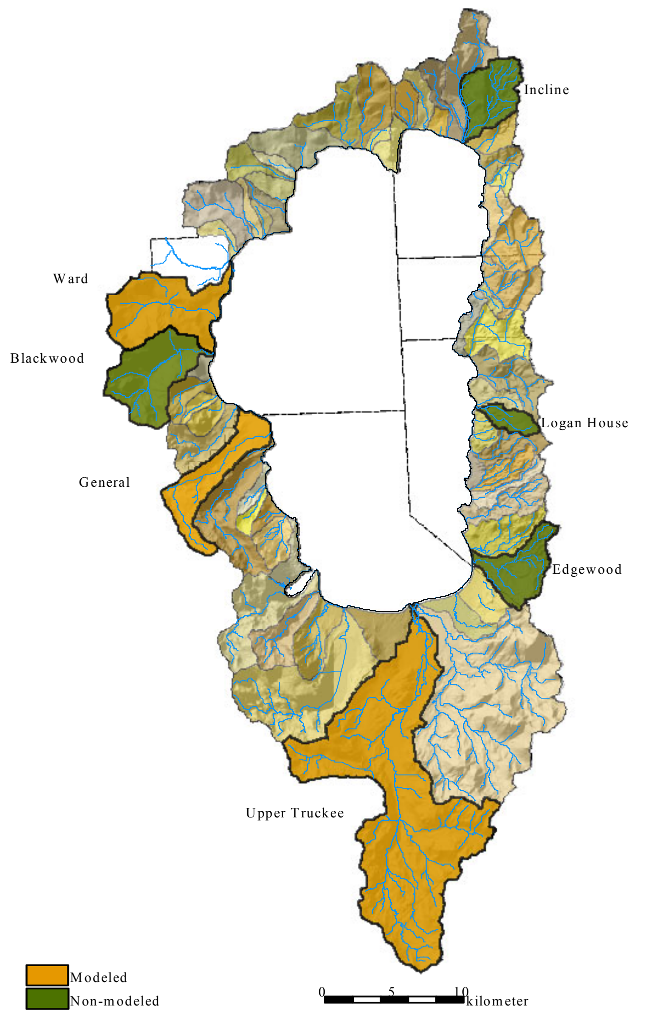


Figure 4-1. Denoted watersheds were the subject of detailed surveying and geomorphic assessments.

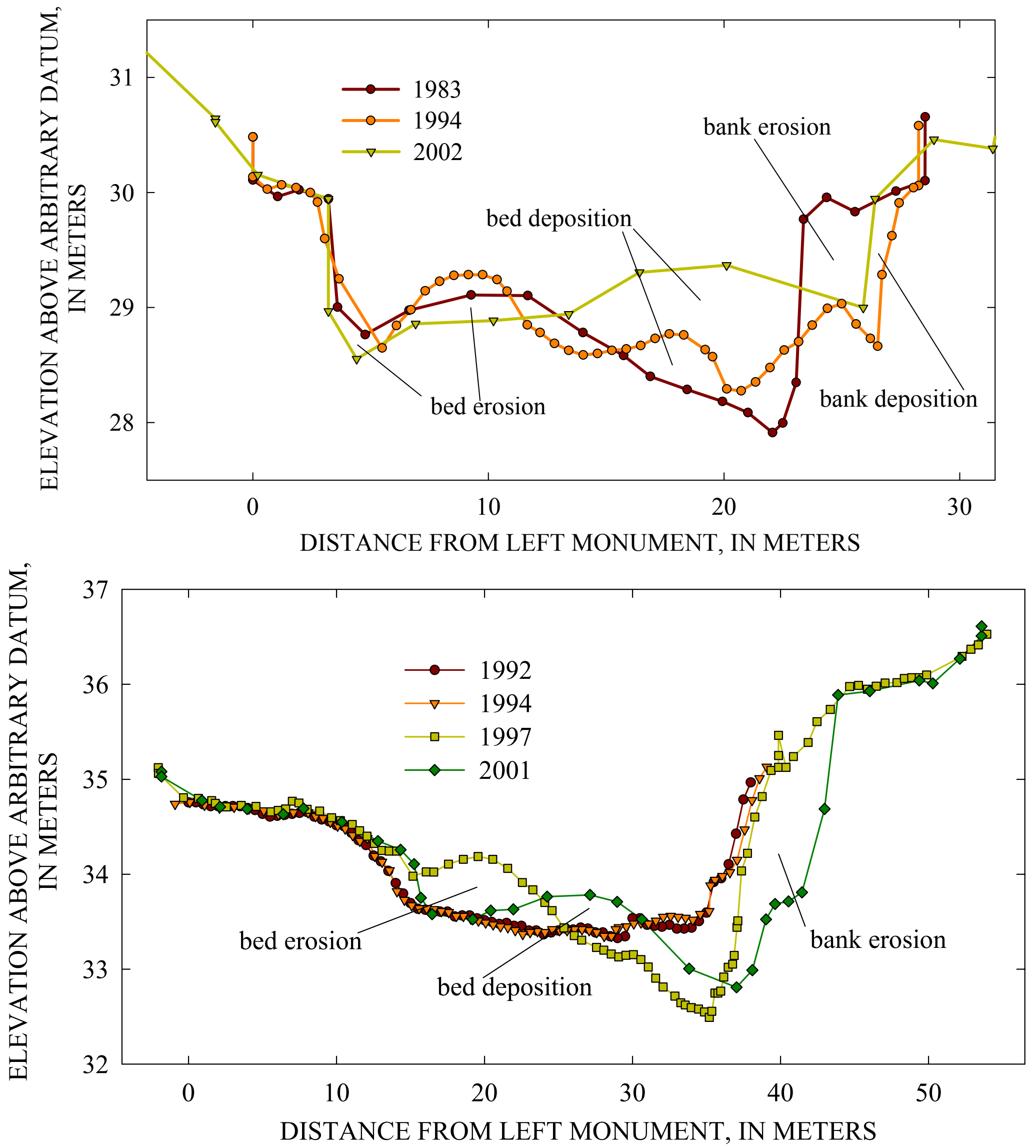
Table 4-1. Summary of historical cross-section data available for this study.

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]

[1] Data from K.M. Nolan (2003 written commun.)
[2] Data from C.M. Walck (2003 written commun.)

4.2.2 Calculation of Volumes Eroded or Deposited

The change in cross-sectional area for a given time period was determined by overlaying time-series cross sections and calculating the area between the plotted lines. The location of the bank toe was determined for the original and 2002 surveyed sections and used to discriminate between erosion or deposition from the bed and banks. Examples are shown in Figure 4-2. Values between adjacent cross sections were averaged and then multiplied by the reach length to obtain a volume in m^3. Results are expressed as a rate (in m^3/y) and as a yield (in $m^3/y/km$ of channel length). The average percentage of fines determined from samples of bank material (Appendix B) was multiplied by the volume of material eroded from the channel banks to determine rates and yields of fine-grained materials delivered by streambank erosion. Because fines were not found in measurable quantities on streambeds, bed erosion was neglected as a contributor of fine sediments.



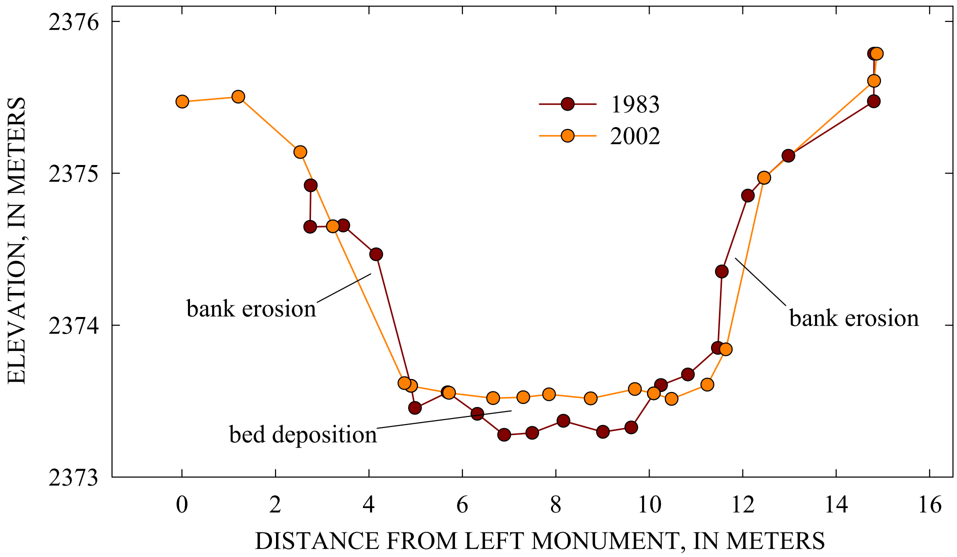


Figure 4-2. Examples of overlain surveys from Blackwood Creek, Upper Truckee River and General Creek.

4.3 Reconnaisance Level Geomorphic Evaluations of Channel Erosion Areas

4.3.1 Evaluation of Continuous Stream Lengths (Stream Walks)

To augment sediment load data and re-surveying of historical cross sections, the seven intensely studied streams were evaluated throughout their study lengths. From September through November 2002 seven stream channels (Figure 4-1) were assessed to provide direct field evidence of stream stability trends throughout each of the intensely studied watersheds. Streams included the Upper Truckee River, General Creek, Blackwood Creek, Ward Creek, Incline Creek, Logan House Creek, and Edgewood Creek.

Evaluations were carried out through stream walks of each main-stem channel. Typically the lower 80% of the main channel length was covered during each walk. At approximate 100 m intervals, notes and photographs were taken to document eroding reaches and assess their potential for supplying fine sediment. The levels of erosion are divided into four classes: none to negligible, low, moderate, and high. The classes were determined through an objective evaluation based on bank height, length of bank instability, vegetation root density, and relative amount of fine-grained materials. The eroding reaches for each stream were then tabulated and mapped to show bank erosion “hotspots” and overall geomorphic trends along the channel. These data were combined geomorphic data derived from rapid geomorphic assessments (RGAs) of point locations that were conducted not only along the seven intensely studied streams, but throughout the entire Lake Tahoe Basin as well. Since the purpose of these eval;uations was to identify potential sources of eroding streambank materials, non-contributing streambanks were not specifically notated.

4.3.2 Rapid Geomorphic Assessments (RGAs)

To determine the relative stability and stage of channel evolution for all of the sites with available sediment data in the Lake Tahoe Basin, rapid geomorphic assessments (RGAs) were conducted. RGA techniques utilize diagnostic criteria of channel form to infer dominant channel processes and the magnitude of channel instabilities (Figure 4-5). They have been used successfully in a variety of physiographic environments to rapidly determine system-wide geomorphic conditions of large fluvial networks. Because they provide information on dominant channel processes rather than only channel form, they can be used to identify disturbances and critical areas of erosion and deposition. This is the justification for classifying streams by "stage of channel evolution" (Figure 4-5) which uses diagnostic characteristics of channel form to infer dominant channel processes that systematically vary over time and space. Of specific interest to practitioners in the Lake Tahoe Basin are stages IV and V which represent channel instabilities marked by mass failures of streambanks.

In some classification schemes the "reference" condition simply means "representative" of a given category of classified channel forms or morphologies (Rosgen, 1985) and as such, may not be analogous with a "stable", "undisturbed", or "background" rate of sediment production and transport. With stages of channel evolution tied to discrete channel processes and not strictly to specific channel shapes, they have been successfully used to describe systematic channel-stability processes over time and space in diverse environments subject to various disturbances such as stream response to: channelization in the Southeast US Coastal Plain (Simon, 1994); volcanic eruptions in the Cascade Mountains (Simon, 1992); and dams in Tuscany, Italy (Rinaldi and Simon, 1998). Because the stages of channel evolution represent shifts in dominant channel processes, they are systematically related to suspended-sediment and bed-material discharge (Simon, 1989b; Kuhnle and Simon, 2000), rates of channel widening (Simon and Hupp, 1992), and the density and distribution of woody-riparian vegetation (Hupp, 1992).

Conditions along a reach of an alluvial channel reflect upland processes as well as channel-adjustment processes upstream and downstream. Stream channels act as conduits for energy, flow, and materials emanating from upland and upstream channel sources. As such, they reflect a balance or imbalance in the delivery of flow and sediment. Considering the large area of the Lake Tahoe Basin, it was not feasible to perform detailed, time-consuming surveys at every site. However, RGA's provide an efficient alternative for determining stability conditions and dominant processes delivering sediment along channel networks.

The RGA procedure for sites in the Lake Tahoe basin consisted of three steps, which collectively took about one hour to complete over a reach of about 6 – 20 channel widths in length:

(1) Take photographs looking upstream, downstream and across the reach;
(2) Take samples of bed and bank material. This could be a bulk sample, a particle count if the bed is dominated by gravel and coarser fractions, or a combination of the two;
(3) Make observations of channel conditions and diagnostic criteria listed on the combined stability ranking scheme.

RGAs were conducted at 304 sites across the Lake Tahoe watershed in the three-month period between September and November 2002 (Figure 4-3). RGA data collected at these locations are included in Appendix F. Particle-size data for these sites are in Appendix B.

4.4 Combined Stability Index

A simple field form containing twelve criteria was used to record observations of field conditions in an objective manner (Figure 4-4). The field form was modified somewhat from those that have been used elsewhere to include the important characteristics of potential side-slope erosion in the sub-alpine watersheds. Thus, the original channel-stability index includes the first nine questions on the field for, with potential sediment contributions from adjacent side slopes included with questions 10 – 12. Each criterion is ranked, and all values are then summed to obtain an index of channel and near-channel stability. A higher ranking indicates greater instability. The rankings, however, are not weighted and for example, a ranking of twenty does not mean that the site is twice as unstable as a site with a value of ten. Experience has shown that values of twenty or greater are indicative of significant instability; values of ten or below are indicative of relative stability.

To differentiate between potential contributions from channels and adjacent slopes, results are shown as a combined index, a channel index, and potential side-slope erosion. These are plotted on individual maps for the seven intensely studied watersheds and on Lake Tahoe Basin maps for sites in the remaining watersheds. The index of side-slope erosion potential is not meant as a measure of general upland contributions from the entire watershed, only those direct contributions from slopes adjacent to channels. In addition, sites where channel processes are dominated by streambank erosion and channel widening (stages IV or V; Figure 4-5) and the percentage of all banks in a reach that are contributing sediment are also mapped.