Chapter 3

Fluvial Geomorphology

This chapter is a cursory look at the fluvial geomorphology of Butte Creek. The areas of greaterst concern are areas where the creek has the ability to meander. These are: the Butte Meadows area, the canyon section above Helltown to Highway 99, and to some degree the valley section. In August and September of 1998, the consultant team of Matt Kondolf, Ph.D. of Berkeley and John Williams Ph.D. will complete a detailed fluvial geomorphology analysis. They will look at the area of the canyon from above Helltown down through the valley above Highway 162. These areas have the greatest potential for both beneficial and destructive meanders and also the greatest potential for restoration of the riparian corridor. To identify specific restoration areas and methodologies it is important to understand these dynamics. Also to afford the greatest protection to homeowners, agriculturalists, and infrastucture (i.e., bridges and levees) these dynamics need to be well understood. This was identified as a data gap early in the scoping process and funding is being provided by CALFED and USFWS to complete this analysis. This effort will guide restoration, protection, and enhancement efforts for years to come.

Introduction

Although a detailed stream morphology study has not been undertaken at the time this report was prepared, for descriptive purposes Butte Creek has been divided into three distinct sections. The first is the upper portion, from the headwaters to the Centerville Head Dam. The next is the middle section, from Centerville Head Dam to Highway 99. The lower section is from Highway 99 to the Sacramento River. Each section has distinct characteristics in geology, slope, and morphology, although in the future these sections can and should be broken down further for more focused management planning.

Flow Regime

Over the course of a year, Butte Creek sees a great range of discharge conditions. In the past, flows on the creek have ranged from an estimated 35,600 cfs, in January of 1997, down to 44 cfs in August of 1931. Upper Butte Creek drains 147 square miles, measured at the USGS stream gauge just below the Honey Run Covered Bridge and has an annual mean daily flow of 409 cfs, which equals a water yield of 2.78 cfs per square mile (USGS, 1998).

The flow stage that has greatest effect on the shape of the stream channel is bankfull discharge, also referred to as bankfull stage. This event occurs when the channel is entirely filled, but the stream has not yet spilled over onto the adjacent flood plain. Flows above the bankfull stage occur with less frequency. Once the creek spills out of its channel, its power to erode and transport its sediments is greatly reduced (Mount, 1995).

Chang (1979) has established a relationship between mean annual flow and bankfull discharge. The mean annual flow of Butte Creek is 409 cfs and, using Chang's relationship, the computed bankfull discharge is 3250 cfs (USGS, 1998). Using the formula developed by Williams (1978), the calculated bankfull discharge is 3097 cfs.

Butte Creek also experiences flows many times higher than that of the bankfull event. The Peak Flows Figure (see Appendix E) illustrates the annual peak flows for Butte Creek for the period 1931 to 1998. The highest flow occurred on January 1, 1997, when the flow at USGS stream gauge #11390000 reached an estimated 35,600 cfs according to provisional USGS data (USGS, 1998). Similar episodic flows include the February 1986 flow of 22,000 cfs, and the December 1964 flow of 21,200 cfs (USGS, 1996). Table 3.1 shows the *chance* that the peak flow for any given year will be above a given flow. The various *recurrence intervals* and their *flows* given in the table below were computed using the USGS data along with the USGS computer software program "PEAKFQ - Version 2.4 1998/04/03." This program performs flood-frequency analysis based on the guidelines delineated in *Bulletin 17B,* published by the Interagency Advisory Committee on Water Data in 1982.

As measured at USGS stream gauge #11390000, the creek has a slope of 0.005, or 2.41’ of fall in 512’, a hydraulic radius of 135’, and a measured velocity of 9-10 fps at a flow of 22,000 cfs (USGS, 1996). The USGS has also established a bed roughness figure, called the Manning roughness coefficient, of 0.048 for the main channel (USGS, 1996). These numbers may change slightly after the creek is resurveyed following high flow events.

Table 3.1
Recurrence Intervals for Butte Creek at USGS stream gauge #11390000

Recurrence Interval (years)	**Peak Flow (Q)** (cfs)
2	6,670
5	11,766
10	15,573
25	20,743
50	24,801
100	28,997
200	33,339
500	39,302

(Source: USGS, 1998)

Channel Morphology

For this section, USGS 7.5' quadrangles (topographic maps) and selected USGS geologic maps were used for interpretation.

As the creek flows from its headwaters to the Sacramento River, it becomes progressively wider, less steep, and travels over softer bed material. The rocks that compose the upper reaches of the canyon section of the creek are the oldest rocks of the creek (described in more detail in the Geology, Basin Morphology, and Hydrologic System chapter). These rocks make up the steep, narrow canyons that typify this section of the creek, and are found from well above the DeSabla Powerhouse to just above Helltown.

The section from Helltown to the Centerville Powerhouse is made up of the Chico Formation. This formation is composed of marine sandstone conglomerate with beds ranging from fine cobblestone to siltstone (Harwood et al., 1981). The creek is slicing through this formation, and the longitudinal profile of the creek begins to flatten. The upper canyon walls are just as steep as upstream, that the creek has moved through the softer Chico Formation and there are "terraces" along the creek providing slopes suitable for homes. The large, pre-historic landslide (described in the Geology, Basin Morphology, and Hydrologic System chapter) located in the Helltown area actually constricts the creek and pushes it up against the north-eastern side of the canyon, creating dramatic sandstone cliffs.

From the Centerville Powerhouse to Highway 99, the creek travels through an area composed of the Chico Formation, the late Pleistocene Modesto formation, and recent dredge tailings. The Modesto Formation is composed of gravel to sand-sized alluvium eroded from the Pliocene Tuscan Formation and the Chico Formation (the formations directly above the Modesto and the creek in this area), and is thought to be of recent deposition (Harwood et al., 1981). The creeks slope is much lower in this alluvial material and the canyon walls are less confining. The last section, from Highway 99 to the Sacramento River, is made up of the Modesto Formation as well, however it does not have areas of tailings.

The slope of Butte Creek changes dramatically from the upper watershed down to the valley. The creek's gradient averages 164 feet per mile from the headwaters areas to DeSabla. From DeSabla to Highway 99, the creek has an average slope of 56.2 feet per mile. The slope of the lower section, from Highway 99 to the Sacramento River, is 3.37 feet per mile, although the slope for the last 18.5 miles averages 1.08 feet per mile.

The slope of a river is often less than the land it runs through. The measure of this difference is called its sinuosity. The sinuosity (ratio of stream length to valley length) of Butte Creek from the DeSabla Power House to Highway 99, is 1.21 as defined by Mount (1995). This difference is caused by the stream wandering back and forth from one side of the canyon to the other, or meandering.

Channel Stability

The meandering of the creek is a subject of great concern for those who live and make their livelihood along its banks. Meander bends tend to migrate toward the outside of the stream channel, becoming more and more pronounced over time. Meandering is constrained by the resistant canyon walls in the upper reaches, and by human-constructed levees in the lower reaches. The middle section has the greatest potential for meander migration due to the naturally softer bed material, as well as the human introduced mining tailings.

From preliminary map analysis, using the 1948 and 1978 editions of the USGS Chico 7.5’ topographic map, actual channel migration exceeds the predicted values by a factor of five. Hooke (1980) developed two formulas to predict meander migration, which gave values of 1.17 and 1.7 feet per year. Nansen and Hicken’s (1983) meander migration model gives a similar value, of 1.6 feet per year. The various equations developed by Larsen (1995) give expected migration rates from 0.9 to 4.75 feet per year, with an average of 2.12 feet per year. Actual average migration rates in the middle section of the river range from 7.77 feet per year to 11.1 feet per year. The difference between the results of the models and the actual behavior of the creek is best explained by examining the factors that cause meander migration.

Meander formation is a complex phenomenon. In fact, hydrologists have not reached an agreement as to the elements that initially create meanders, but they are in agreement about the factors that cause them to migrate once formed. Meanders are caused by bank erosion, which occurs in direct proportion to the closeness of the high velocity core to the bank (Larsen, 1995). This high velocity core is related to the thalweg, or main flow of the stream. The thalweg crosses over from side to side of the channel, for at bends in the river it is thrown against the outside bank. Bank material also affects bank erosion. Banks with high clay content are the least erodible, due to their high cohesion. The banks of the middle stretch of creek are composed of dredger tailings which have very little erosional resistance.

While there have been many studies of the effects of hydraulic mining on streams, they have mainly concentrated on the migration of artificially introduced sediment downstream. The build-up of bed material in a channel, causing a rise in the elevation of the stream bed, is known as aggradation. Other studies of hydraulic mine debris have focused on the exacerbation of flooding due to stream bed aggradation. An examination of the relationship between gold dredging and its associated tailings and stream channel migration and stream bed aggradation is an obvious data gap for Butte Creek. The Fluvial Geomorphology Study, slated for the summer and fall of 1998, should help to uncover some of these relationships by examining Butte Creek from the Centerville Head Dam downstream to Highway 162 (see Issues and Concerns chapter, #9).

With the creation of a working Geographical Information System (GIS) that would incorporate all existing topographic maps as well as aerial photographs, the impact and extent of channel migration could be analyzed in much greater detail. Elements to examine should include rates and locations of migration, percent of river length undergoing migration, comparisons of migrating areas with land use, and the migration rates on tailings and non-tailings areas.

Erosion and Sedimentation

An area of future study is the erosion and sedimentation regime of the watershed. Studying the actual sediment transport rates, including bed load and suspended load, is an important part of this research. Factoring in sediment production, natural and anthropogenic erosion rates, and sediment inputs from the upper watershed are all key components. These factors, when looked at as inputs and outputs, can be formulated into a "sediment budget." Creating a sediment budget is difficult and time consuming. However, this information is needed to understand the creek's dynamic nature and to plan ecosystem restoration efforts (see Issues and Concerns chapter, #5).

Problem Areas

Flooding becomes an issue primarily in human-inhabited reaches such as the residential areas along the middle section of the creek. The middle section of Butte Creek, specifically from about the Steel Bridge to near Durham, is a section with numerous flooding problems. Certain areas within this reach also appear to have the highest amount of meandering, due to the nature of the bed material, the human-introduced mining tailings, and lack of intact and mature riparian vegetation (see Issues and Concerns chapter, #9).

This is also an area with heavy interactions between humans and the creek and its flood plain. The NRCS Emergency Watershed Protection" work completed in November 1997, constructed over 3,800 feet of rip-rap near the Parrott-Phelan Diversion Dam (Okie Dam). This particular project is outlined in a case study below. Three other NRCS projects were constructed upstream on Butte Creek, another two on Little Butte Creek, and numerous other private projects were undertaken as well. NRCS projects alone totaled 7,681 feet (1.4542 miles) within the watershed. Most of these bank stabilization projects consisted of large rock rip-rap and concrete, and are not conducive to productive riparian habitat. Further, they accelerate flows, increase bed scour in some areas, deposition in others, downstream bank erosion, and ultimately may cause future problems for those property owners located downstream. Sources of additional information regarding alternatives to conventional flood control and bank stabilization methods is available in the Annotated Bibliography pertaining to Butte Creek's Water Quality, Hydrology, and Diversions (see Appendix F).

Note: For a case study investigating the January 1997 flood event's effect on Butte Creek's channel in the Parrott-Phelan Diversion Dam vicinity and the subsequent stream alterations performed to return Butte Creek to its previous channel under the NRCS' Emergency Watershed Protection Project-Phase II, please refer to Appendix G.