BANK PROTECTION/EROSION REPAIR DESIGN GUIDE
PART ONE:
TECHNICAL PRIMER ON STREAM FUNCTION AND FORM

Introduction

Before considering bank protection or erosion repair, it is necessary to understand the process by which streams form and adjust to their surroundings. Streams are shaped by a combination of "forming forces" that include:

- *Gravity,* or the slope of the channel banks
- *Friction,* which is a function of vegetation, the soil's type and particle size, and the channel's pattern and profile.
- *Velocity*, the speed of the water flow.
- *Quantity*, the volume of water flowing and sediment moving through the stream.

Over time, streams move and shift in response to changes in these forming forces. That is why streams do not naturally tend to flow in a straight line. Instead, they meander in search of equilibrium with their forming forces, adjusting to changes in water flow and sediment transport. These changes can have both natural and non-natural causes.

Characteristics and History of Streams in Santa Clara County

Some streams in Santa Clara County are still in a natural condition, while others have been straightened or channelized in response to land development activities and flood control needs. Throughout the County, human-made channels were created to contain the flows that once naturally fanned out over the valley floor, carrying with them nutrients and sediment, and creating alluvial fans and fresh water marsh habitat. These human-made channels were created to accommodate the use of land for agriculture or urban development, and to ameliorate flooding conditions.

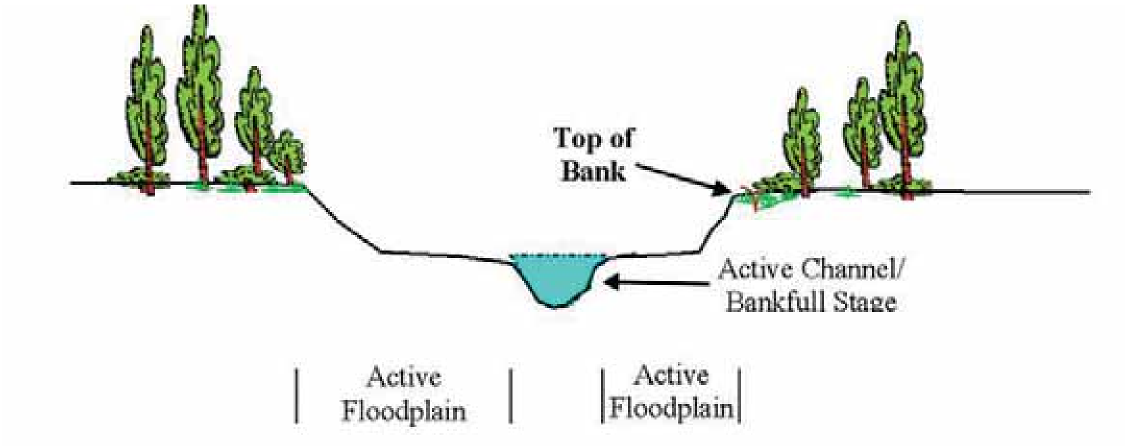
Experience has also shown, however, that significant problems arise when streams in the lower watershed are confined. By lining streams with levees or floodwalls, water that would otherwise slowly spread out over a large area of land in a beneficial way accumulates in the channel until it breaches its levee or floodwall, potentially causing catastrophic flooding. Even if this does not happen, a significant amount of sediment may be deposited in the channel after a storm event, raising the channel bed elevation. This sediment decreases the channel's capacity to handle subsequent storm flow. In other words, the chance of catastrophic flooding increases with every storm if the channel's sediment is not removed often enough.

Significant efforts are underway throughout the County to address these issues, and to maintain and enhance our remaining natural streams. There are also efforts being made to restore and enhance, where possible, channelized urban drainage ways. It is important to remember that even though a stream may be hardened or modified in a particular location, it may remain natural in other areas. Over time, it may be possible and even essential to restore these streams to a more natural state to improve stability and flood protection for nearby property owners. In addition, the protection of water quality is critical in all types of Santa Clara County streams, both natural and unnatural, because they eventually convey water to either Monterey Bay or San Francisco Bay.

Typical Stream Features

In a cross-sectional view, a stable natural stream can be defined by two significant features: the "bankfull" (or "active channel") and the "active floodplain." See Figure 1 below.

Figure 1: Cross-Sectional View of a Natural Stream



The bankfull or "active channel" can be defined by the elevation of the floodplain, which is formed by the most effective channel forming or "dominant" stream discharge. It is the part of the stream where sediment is actively transported and deposited, the part that is capable of containing the most frequent flows.

The active channel is an important feature because it transports the majority of the water and sediment in the stream system, and thus it influences the channel formation over time. As seen in Figure 1, the active channel is usually distinguished from the active floodplain by an abrupt change in the slope of the stream bank, usually from a vertically-sloped plane to the horizontally-sloped plane on top of the floodplain.

Active floodplains are the low-lying areas between Top of Bank (See Figure 1) and adjacent to the active channel that are subject to frequent inundation during moderate and high flows. This area is where sediment is deposited when the active channel's capacity is exceeded during high flows. In urban settings, active floodplains are often hard to identify, due to channel incision and erosion from increased urban runoff. On rural streams, the active floodplain normally fills approximately every year or two. Floodplain filling usually occurs more often in urban areas. Vegetation is typically present in the floodplain area, as it will become established between the alternating seasonal periods of inundation and sediment deposition.
(Section 2 of the Guidelines and Standards also includes more detailed definitions and sketches showing these features in a variety of settings).
Important Note: A stream's active floodplain is not to be confused with the delineation of floodplain used for flood insurance purposes. The floodplain defined for flood insurance purposes is the one percent (100-year) flood, or the area that has a one percent chance of being flooded to a depth of one foot or greater each year. For insurance purposes, this equates to a 26 percent chance of suffering some flood damage during the term of a 30-year mortgage.

Stream Beltwidth and Stream Meander Width

A channel has a certain beltwidth within which it naturally moves. This beltwidth can be determined by studying: sections of the channel which have not been straightened; pre-development photographs; or, adjacent similar channels. Levees should not, for example, be constructed in a way that does not accommodate the beltwidth. Doing otherwise increases erosion potential and maintenance costs. Meander width is the amplitude of the meander within the beltwidth. It is smaller than the beltwidth. At a minimum, the average meander width of a channel should not be compromised in the lower flood plains. In the mid to upper slopes above the valley floor, where the natural channel may be fairly straight, the beltwidth should also be respected.

Factors that Affect Stream Stability

Several factors affect stream stability. They include stream topography, the width-to-depth ratio, and extent of channel incision.

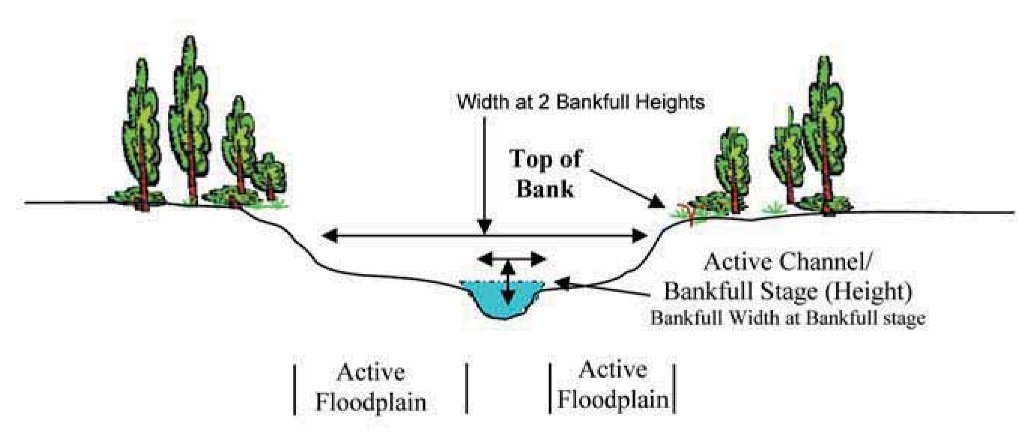
The quantity and movement of both water and sediment in a stream are two of the primary influences on the topography of a stream. These materials tend to balance each other within the confines of the stream channel. For example, erosion on one bank is typically balanced by sediment deposition on the other. While the location and extent of the erosion and resulting deposition may change over time, the width and depth of a stable stream does not change much. Thus, any type of erosion repair project must be designed to maintain width-to-depth ratio in order to ensure long-term stream stability, while also allowing the streambed to erode and fill naturally.

A channel's width-to-depth ratio is calculated by dividing the width of the stream channel (at the bankfull level) by the mean channel depth. Width-to-depth ratio is part of a more complicated concept called entrenchment ratio, which is important because it calculates a channel's stability. Generally speaking, it calculates its stability in terms of its floodplain—the larger the floodplain, the higher the entrenchment ratio. Specifically the entrenchment ratio is equal to the width of the stream channel (at twice the maximum bankfull depth) divided by the width-to-depth ratio of the bankfull channel.

In order to prevent channel incision and maintain a stable stream, the ratio of the width of the channel at 2 bankfull heights (see Figure 2) to the bankfull width should be a minimum of 2 where the channel is constrained. It should be a 3 to 4 ratio at other locations, both upstream and downstream.

This provides sufficient relief, and thus prevents excessive erosion of streambed and bank. It also prevents damage to bankside properties during 1 year–10 year storm events.

Figure 2. Determining the Appropriate Width to Depth Ratio



Effects of Water and Sediment Transport on Bank Stability

Streams adjust themselves to transport, as efficiently as possible, water and sediment from higher elevations to lower elevations. If the amount of sediment available to a creek is significantly increased or decreased, the creek adjusts its channel area or cross section to handle the change in sediment. In a normally-functioning gravel bed stream, for example, it is not uncommon for the stream channel (or portions of the stream channel) to downcut and refill significantly—from a few inches to 10 feet or more in a single storm event. This is one way streams transport their sediment loads, clean themselves, and temporarily increase their flow capacity.

With the expanded development in Santa Clara County, the time it takes for runoff to reach the streams has decreased, which leads to the increase in the amount of water in most streams. Some of the specific factors that have led to this increase in water flows are:

- Substantial increases in impervious surfaces such as pavement and roof tops.
- The routing of storm water runoff directly into streams through piped storm drain systems.
- Removal of large areas of streamside vegetation that would otherwise form buffers for runoff, and promote infiltration into the soil.

The stormwater management programs of local municipalities have efforts underway to address these long-term issues. In the interim, however, it is important that armoring the channel be avoided on individual properties whenever possible, for several reasons. First bank armoring prevents channels from adjusting to high flows, and can increase the probability of flooding. Bank armoring also causes accelerated flow velocities and turbulence along banks, which then induces more erosion on unarmored banks. Finally, because armored banks cannot adjust to changing stream conditions, they are prone to undercutting.

Importance of Vegetation and Riparian Buffers

The roots of well-established vegetation not only protect the surface of stream banks, but also penetrate deeply into the ground, helping to stabilizing it. Lack of vegetation close to a creek bank can contribute to slope instability and failure due to overbank drainage or soil saturation. In addition to providing bank stability, streamside vegetation filters pollutants; shades and cools the stream; increases infiltration; reduces flash runoff; and provides habitat for wildlife. A variety of scientific studies of the minimum and optimum width of a vegetated buffer along a stream indicate that a width of 10 feet is not enough to provide adequate filtration or habitat. A study by U.S. Fish and Wildlife indicates that in order to effectively remove pollutants, a buffer of 50 feet is needed. Other sources recommend a vegetated buffer that is 2 to 5 times the width of the stream channel. While there is ongoing discussion about the most appropriate width for vegetated buffers, it is conclusive that at least some adequate buffer is necessary to protect stream resources. In terms of erosion repair projects, the use of live plants, either alone or in combination with dead or select rock materials, can be sufficient to prevent erosion, control sediment, and provide habitat.

Stream Features That Are Important to Fish Habitat

The movement of water through a streambed creates certain natural characteristics or that benefit fish habitat. Some of these important features are riffles, runs, glides and pools. Riffles are located in shallow areas or bends in a stream where water flows over rocks. Runs are the straight sections between riffles. Glides are the transition areas between the downstream end of pools and a run or riffle. Pools are usually formed on the outside of bends in a stream. Deep pools are particularly import ant in providing critical fish habitat and refuge areas. When the flow in the stream decreases in drought, fish can retreat to these pools to wait for the return of higher flows.

These stream features described above differ from stream to stream depending on a stream's geometry and location. For example, at higher elevations, stream channels are steeper, narrower, and drop at faster rates, and may contain series of step-pool cascades. At a lower elevation, however, a channel tends to be less steep, wider, and more sinuous, making riffles and pools more common. The combination of riffles, runs and pools is extremely important for fish because it provides different feeding, spawning and/or nursery areas. These stream characteristics should be preserved, restored, and enhanced where possible, as appropriate to the stream topography, in any type of erosion repair effort.