CHAPTER 6 - CONCLUSIONS AND RECOMMENDATIONS

A significant body of research supports the finding that an urbanized watershed will cause negative impacts to the stream that drains it. Often these impacts can be measured in the form of process-related changes such as discharge, sediment supply, sediment transport, and alterations to channel geometry. That these process-related changes are directly linked to riparian and aquatic habitat and water quality is well understood. Furthermore, it can be said that land uses such as farming and grazing often initiate watershed and channel processes that cause streams to become unstable or in a state of disequilibrium.

Human landscape evolution typically begins with a relatively benign indigenous occupation; it is followed by conversion to agriculture by either native or exotic populations, and eventually reaches, a state of development including multiple land uses such as residential, commercial, industrial, and open space. With the introduction of development in the form of urbanization comes an increase in impervious surface. As described by this study and several earlier works (Wolman 1967; Leopold 1973; Graf 1976; Booth 1991; and Schueler 1994), the presence of impervious surfaces is an indication that hydrologic and sediment related processes have been altered and local waterways degraded. Humans are just beginning to recognize the real need to change the typical paradigms under which we populate, and consequently modify our landscape, but without aggressive planning and recovery efforts, watershed and stream channel impacts will continue unabated.

San Pedro Creek watershed is a classic example of human landscape evolution and the negative environmental impacts that accompany it. It serves as an appropriate and effective case study for urban impacts not only because of the relevance of the historical and physical context in which it changed, but also because of its ecological significance today. Though significant alterations to the system have occurred, San Pedro Creek continues to support a riparian corridor complete with the only steelhead trout fishery within 30 miles (48 km) of San Francisco. It has inspired several concerned members of the community to form the San Pedro Creek Watershed Coalition with the goal of protecting, preserving, and restoring stream functions and ecology, and promoting public awareness of watershed issues (SPCWC 2002). Studying present contrasts between the Middle and North Fork sub-watersheds also improves our understanding of how a severely engineered drainage network responds to storms and increased downstream impacts. Lastly, the study area displays impacts of hillside development, which will likely continue in the San Francisco Bay Area and coastal California, with the complete development of the flatlands.

Historical analysis of the San Pedro Creek watershed reveals distinct human periods of influence, each with unique physical modifications of the watershed and its drainage network. For centuries, Ohlone people managed vegetation communities with fire, perhaps with some change to runoff and sediment supply. Channel condition during this period was not documented, although the Spanish settlers who displaced the Ohlone described a system very different than seen today. Spanish occupants of the Mission period introduced farming and grazing and were perhaps the first to directly modify the stream channel through diversion and realignment. Runoff and erosion rates from farming and grazing also modified the stream by increasing incision and the supply of fine sediments. Mexicans of the Rancho period who replaced the Spanish continued agricultural practices and associated impacts and introduced even greater numbers of cattle to the watershed through the late nineteenth century. The commercial farming period (late 1800s to the mid 1950s) saw the most significant modifications up to that time, as intensive row crops filled the valley flats and dairy cattle grazed the hillsides. Increased runoff and sediment supply were prompted by the installation of diversion dams, straightening and realignment of the stream channel, and a major drop in base level by ditching the lower valley to drain Lake Matilda and the surrounding, marsh. But no period in the human landscape evolution chain saw as dramatic physical and process-related changes as the period of suburban development. Introduction of impervious surfaces and engineered drainage over a 20-year period buried most of the North Fork tributary main stem, increased drainage density, reduced rainfall infiltration, increased runoff rates and volume, increased flood frequency and channel erosion, and led to pervasive channel armoring to protect property from ongoing bank erosion. These modifications of course caused further degradation to the riparian and aquatic habitat of the creek adding to present day conditions of polluted water and threatened species habitat decline.

Research performed in 1999 and 2000 was designed to measure and compare the response of flows and turbidity during storms in the unurbanized Middle Fork and the urbanized North Fork tributaries, and to quantify changes to channel geometry. Impervious surface area in the North Fork was measured at 19% of total drainage area, and considered highly connected to the drainage network. Drainage density increased from 4.0 miles/mile^2 (2.5 km/km^2) to 14.3 miles/miles^2 (8.9 km/km^2), a 72% increase due to the introduction of road gutters, drainage ditches, and stormdrains. Increases in Middle Fork impervious area and drainage density were considered negligible.

Rainfall measurements in the tributaries and the San Pedro Valley Park indicated that on average the Middle Fork received 31% more rainfall than the North Fork and 17% more than the Park. This appears to be a result of the wind patterns that move storm systems from the southwest to the northeast. Under natural conditions, a watershed with greater precipitation would be expected to have greater storm discharge than a physically similar watershed with less rainfall. This was likely the case with the Middle and North Fork tributaries prior to development. Discharge measured in the field under current conditions shows that early rainy season base flows for the Middle Fork are slightly higher than the North Fork, possibly demonstrating more significant groundwater inputs from the more pervious basin. Conversely, measurements taken during or shortly following rainfall indicate approximately 2 to 7.5 times more discharge in the urban drainage due to direct runoff from impervious surfaces into an engineered stormdrain network.

Stream gage stations with electronic sensors and continuous record data loggers were installed in each tributary and the data used to plot discharge and turbidity levels with hourly rainfall intensity, during three consecutive storms on February 11, 13, and 14, 2000. Discharge was derived from recorded stage based on the relationship of observed stage to measured discharge.

In the Middle Fork, time measured between the peak rainfall intensity and peak discharge ranged from 1.25 to 4.75 hours, depending on the duration and total rainfall measured. The longest storm with more rainfall had the longest lag-to-peak time, while the shortest storm with the least rainfall had the shortest lag-to-peak time. Based on the data, the response period between the beginning of rainfall and the initial rise in discharge in the urbanized North Fork was only minutes or an undetectable period of time. The relationship between peak rainfall and peak discharge was the same. Peak stage was also significantly greater in the North Fork because the Middle Fork has a wider cross-section causing water surface elevation to rise more slowly.

During the February 11 storm, average discharge was higher in the North Fork. This appears to be due to reduced infiltration potential in the impervious areas resulting in greater runoff while more rainfall was infiltrated in the Middle Fork. The Middle Fork lag time is also significantly greater. The two later storms exhibited higher average discharge in the Middle Fork. This inversion is likely a result of increased antecedent wetness conditions from the February 11 rainfall, causing a rise in runoff rate and volume in the Middle Fork drainage.

Turbidity data were collected as a surrogate of sediment response for both drainages. In the Middle Fork, the turbidity curve typically paralleled discharge with the exception of the February 13 storm when turbidity exhibited an inverse relationship to peak discharge. This response appears to be a result of dilution of the water column as flows increase at a faster rate than suspended matter. This same relationship was evident in the North Fork, though at a much more frequent and shorter time interval. The Middle Fork also transported significantly more suspended load than the North Fork during all three measured events.

The data presented help illustrate how the influence of urbanization in the North Fork has caused a change in storm response when compared to the pre-urbanization conditions of the Middle Fork. In the North Fork, water levels and discharge increase rapidly and are highly variable, peak discharge and average discharge are higher than the Middle Fork prior to sufficient antecedent wetness conditions. Following enough rainfall, the graphs indicate that the Middle Fork will convey almost double the amount of discharge of the North Fork for the same period of time. This was a result of higher rainfall and increased effective impervious area following soil saturation.

Observations of increased bank erosion downstream of the North Fork and Middle Fork confluence also show how high energy, low sediment flows of the urbanized drainage cause an increase in channel degradation when compared to bank erosion in the Middle Fork above the confluence. Surveyed channel cross-sections of the tributaries reveal that the North Fork cross-section is approximately double that of the Middle Fork. The larger North Fork cross-section is indicative of channel adjustment to urban storm flows and sediment starved water, and is expected downstream of the culvert.

To halt, or at least reduce stream impacts associated with urbanization, significant changes must be made in the way societies view streams and their connection to the surrounding land. In the American west, the advent of water reclamation projects in the form of intra- and interstate level water supply systems eliminated the need for urban and suburban dwellers to draw their water locally. Over this short period in history, controlled water supply opened the door for increased population and floodplain development, which introduced the need for flood protection. Streams were reduced to modifiable conduits for flood conveyance instead of life-giving water and food sources. Today, in communities like the San Pedro Valley, residents may drive across local creeks without even knowing they are there. Getting people to understand that they live, work, and play in a watershed that forms a stream with ecological and social significance is the first step toward creating public interest in protecting and restoring these important natural resources.

With public interest comes the public funding necessary to improve the planning process and avoid channel impacts like those described in the San Pedro Creek system. Public interest will also result in academic programs that better train our politicians, planners, engineers, environmental regulators, and watershed managers to recognize the watershed as an important geographic and ecological unit. As perception and understanding improve, direct measures can be taken to achieve new stream protection and enhancement goals. Developments will have reduced impervious surfaces, reduced effective impervious area, and increased rainfall infiltration, runoff retention and detention; adequate riparian buffers will be preserved to control runoff, allow flood conveyance and improve water quality; drainage networks will no longer be filled, channelized, or put in culverts to maximize the amount of developable space; and drainage density will be preserved in or close to an undeveloped state. Many people are currently working towards public education and adoption of federal, state, and local government regulations intended to meet goals, but will continue to face a significant challenge until public perception is improved.

San Pedro Creek changed significantly as a result of past land use practices but most degradation has been caused by urbanization. Still, a relatively intact riparian corridor traverses the valley and sensitive species like steelhead continue to rely on the system for their survival. Completely undoing changes of the past is virtually impossible but opportunities for several improvements should be studied for implementation. The lower reaches of San Pedro Creek have already been given a head start towards improvement through the design and construction of the fluvial geomorphic design of the U.S. Army Corps of Engineers flood protection project. Now improvements should migrate upstream, bettering passage for steelhead as they go. Certain recommendations apply to the entire watershed but would best serve San Pedro Creek if first implemented in the North Fork drainage.

Continuous recording discharge and rainfall gage stations should be installed to monitor the flows of San Pedro Creek. At a minimum, a discharge gaging station would be put at the mouth of the creek, but if resources allowed, additional stations in the Middle and North Forks would better quantify the influence of urbanization on the watershed as a whole.

Areas should be identified where existing impervious surfaces can be minimized and disconnected from the drainage network. Parking areas can be reduced in size and their pavement partly or entirely replaced with pervious materials like gravels or paver stones. Where possible, vegetated planting medians should be introduced to large paved surfaces and roadways to capture rainfall and improve infiltration. Rainfall runoff from paved surfaces can be directed to bio-retention areas that support vegetation instead of stormdrains that flow directly and rapidly to the creek. Rooftop gutters can be directed to yards, landscaped areas or into private irrigation cisterns, which will also reduce water consumption. These features not only increase infiltration and reduce runoff; they also improve the appearance and environment of sterile paved areas.

The North Fork tributary should be assessed for “day-lighting” and restoration for a few hundred feet between the downstream end of the North Fork culvert and the connection of the Terra Nova tributary with Terra Nova Boulevard upstream. Existing open space at this location could provide opportunity to recreate riparian habitat and to excavate an adjacent floodplain to help reduce velocities exiting the concrete pipe.

The main stem of San Pedro Creek in the Linda Mar reach should be assessed for extensive bank repair using biotechnical methods. Efforts should be made to replace existing armored bank revetments, and eroding banks with appropriate bank stabilization techniques that use natural materials and native riparian vegetation. The proper bankfull channel cross-sectional geometry should first be determined based on upstream discharge to determine requirements to maximize long-term geomorphic stability.

The North Fork watershed should be surveyed for locations of storm detention facilities. Off-stream ponds or floodplain areas that can slow the movement of flows through the drainage network can reduce peak discharge frequency and extent during storms, reducing erosive flows downstream.

Open space in the watershed should be protected in perpetuity. This is already the case for significant portions of the upper watershed that are established county and federal park space, but privately owned lands may be candidates for future development. Additional increases in impervious surfaces and stormdrain contributions to the creek could further prevent establishment of a new post-development equilibrium and further exacerbate erosion and incision.

Finally, municipal and private parties should continue to collaborate on grant applications for funding sources to support special studies and corrective measures that improve the watershed and health of San Pedro Creek.

Given adequate time, and attention from economic and social resources, the physical, chemical, and biological conditions of San Pedro Creek can be enhanced for humans and wildlife in the San Pedro Valley. But let this study of the current conditions and response of the Middle and North Forks, as well as the channel below their confluence, serve as a reminder of what can happen when urban planning and development disregards the physical processes of a watershed.