Carneros Creek Watershed Management Plan

prepared for
Carneros Creek Stewardship
and Bay-Delta Authority Watershed Program

by
Napa County Resource Conservation District
Carneros Creek Stewardship
with
San Francisco Estuary Institute
Pacific Watershed Associates

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Acknowledgements

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Introduction

The Carneros Creek watershed is a relatively small valley in the southwest portion of the greater Napa Valley. Active faults, seasonal rainfall, mild winters, and warm dry summers influence the local vegetation and landscape and result in an aesthetically beautiful backdrop to a peaceful rural setting. The residents of the watershed value the lifestyle provided by this setting and recognize the inherent pressure on the watershed associated with human population and intensive land management.

In 2001, the Carneros Creek Watershed Stewardship (Carneros Stewardship), an apolitical, non-advocacy group of landowners and managers in the Carneros Creek watershed, formed to promote an open dialogue among interested individuals regarding local natural resource concerns and issues. The group developed the following goals:

- Assess the physical features of the watershed on an on-going basis,
- Provide education about the watershed,
- Protect and restore natural resources, including native fish and wildlife species,
- Protect and enhance the economic and human resources, and
- Create a sustainable, enduring watershed stewardship.

Through group dialogue and community meetings, the Carneros Stewardship decided in late 2001 that they were interested in conducting a watershed assessment and developing a watershed management plan to guide future restoration and land management activities. Through a grant received by the Napa County Resource Conservation District (RCD) from the California Bay-Delta Authority Watershed Program in 2002, a team of technical specialists from the San Francisco Estuary Institute (SFEI), Pacific Watershed Associates (PWA), and Napa County RCD set out to understand and document the physical, biological and human aspects of the Carneros Creek watershed. The following types of data collection and/or review of existing information were carried out over a period of several months: historical ecology, flora and fauna, channel form and function, hillslope form and function, sediment, fish habitat and macroinvertebrates, water quality and water budget.[1]

With improved information about current and historic natural resource conditions in the watershed, the Carneros Stewardship formed a subcommittee to guide the development of a watershed management plan that would reflect the interests of the larger group. The subcommittee worked in close collaboration with technical specialists from SFEI, PWA and Napa County RCD to develop this management plan. The plan integrates the results of the technical reports and provides recommendations for management, monitoring and further research. The management plan is meant to be used as a tool for the local community and is meant to be voluntary in nature. It also builds upon a history of on-going community efforts to protect and restore the natural function of the watershed, some of which will be discussed in the following section.

[1] The watershed assessment technical reports are available on CD from the Napa County Resource Conservation District; executive summaries of the reports are included as Appendix XX in this document.

A Reference Document was developed as a companion to this Management Plan. The Reference Document provides a more thorough discussion of existing watershed conditions and recommended actions and monitoring. To a large degree, the Reference Document synthesizes the information contained in the technical reports and provides the reader with information that is beyond the scope of this Management Plan. Much of the information in the Reference Document may be useful if a specific project is being considered or if a specific topic is of particular interest.

The Carneros Creek Watershed

Carneros Creek is a tributary to the Napa River that flows southeast from the west side of the Napa Valley into the Napa River near Cuttings Wharf and Bull Island, 5 miles south of the town center of Napa (Figure 1). The Carneros Creek watershed is 8.9 square miles, nearly rectangular in shape, and approximately 9 miles in length and 1 mile in width. Elevations in the watershed range from mean sea level at the confluence with the Napa River to approximately 1,660 feet above mean sea level in the headwaters. The watershed contains approximately 25 miles of stream: the mainstem is approximately 11 miles in length and an additional 14 miles of tributary streams drain to the mainstem. The lowest 1,640 feet of Carneros Creek is confined within levees designed to protect property from flooding of the Napa River; the remaining miles are not levied.

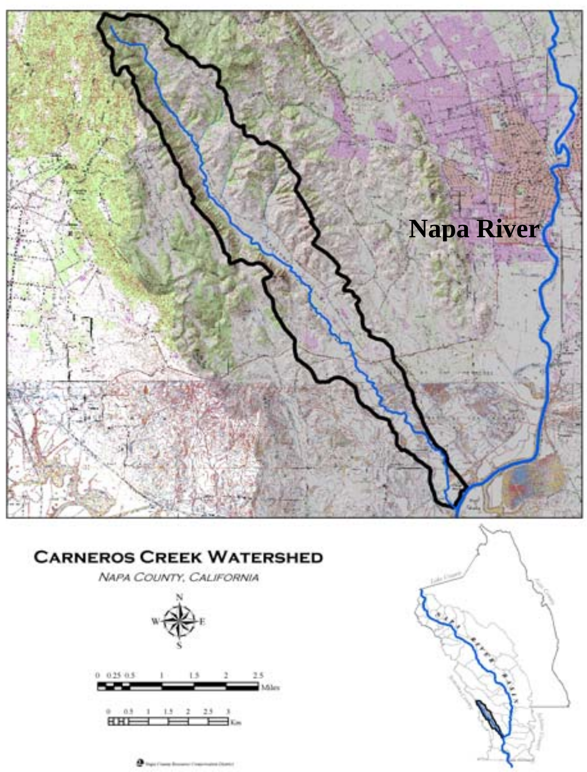


Figure 1: Map of the Carneros Creek Watershed
Source: Napa County Resource Conservation District, 2004

The Carneros Creek watershed is privately owned and is primarily composed of agricultural land (38.2%), forest land (29.9%), shrub and grass land (25.8%), urban/suburban development (4.7%), and water (1.4%). Vegetation in the Carneros Creek watershed is dominated on the eastern side by annual grasses and oak woodlands. The western side of the basin is dominated by mixed conifer and hardwood species. The Carneros Creek watershed has experienced grazing and other agricultural activities since the 1820's. To date, much of the agricultural land within the watershed has been converted to vineyards and residential property and the upper eastern side of the watershed is being commercially grazed.

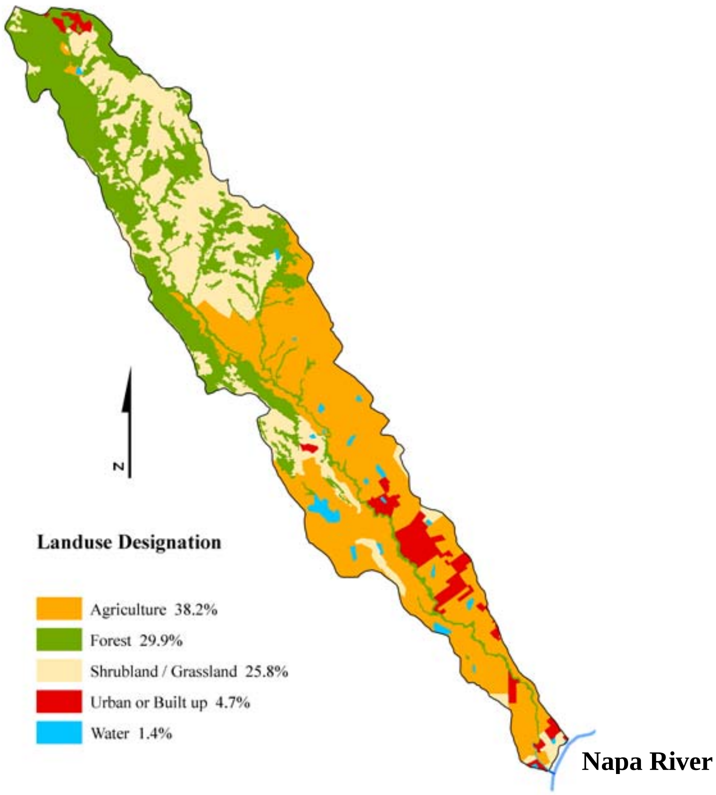


Figure 2: Land use in the Carneros Creek watershed (1993)
Source: Napa County Resource Conservation District, 2004

The watershed supports a native steelhead population and provides habitat in relatively close proximity to the Bay. Steelhead are listed as a threatened species under the Endangered Species Act due to a long term decrease in their populations over the past several decades. Because of their life history, which includes migration from freshwater streams to the ocean and back again, several factors may be contributing to their decline including, but not limited to ocean conditions, predation, low summer flows, increased fine sediment supply, and fish migration barriers.

As previously mentioned, there is an active local community stewardship in the watershed addressing some of the existing resource issues. Over the past several years voluntary efforts have been made to improve fish habitat and collect additional watershed information. Specific efforts include enhancing the riparian corridor, establishing native plant habitat, and collecting information relative to surface and groundwater supplies. With continued community participation and an understanding of historic and existing watershed conditions, the Carneros Creek watershed is an excellent example of how landowners and managers can collectively and individually strive to protect and improve local resources.

History of Watershed Development and Management

An understanding of how human use of the land has changed through time and how those uses have transformed physical processes within the watershed is an important part of developing a watershed management plan for Carneros Creek. Documenting land use change helps us to assess how creek and landscape function and quality have changed in relation to human influences. In addition, an understanding of historic land use and watershed conditions helps ensure that management and restoration recommendations are based on local landscape characteristics, rather than regional assessments. Figure 3 and the following summary of development in the watershed demonstrate the primary management activities that have occurred and their relative intensity over time. Further information regarding the history of the Carneros Creek watershed can be found in the Reference Document that accompanies this management plan and in the Historical Ecology technical report that was completed as part of the watershed assessment.

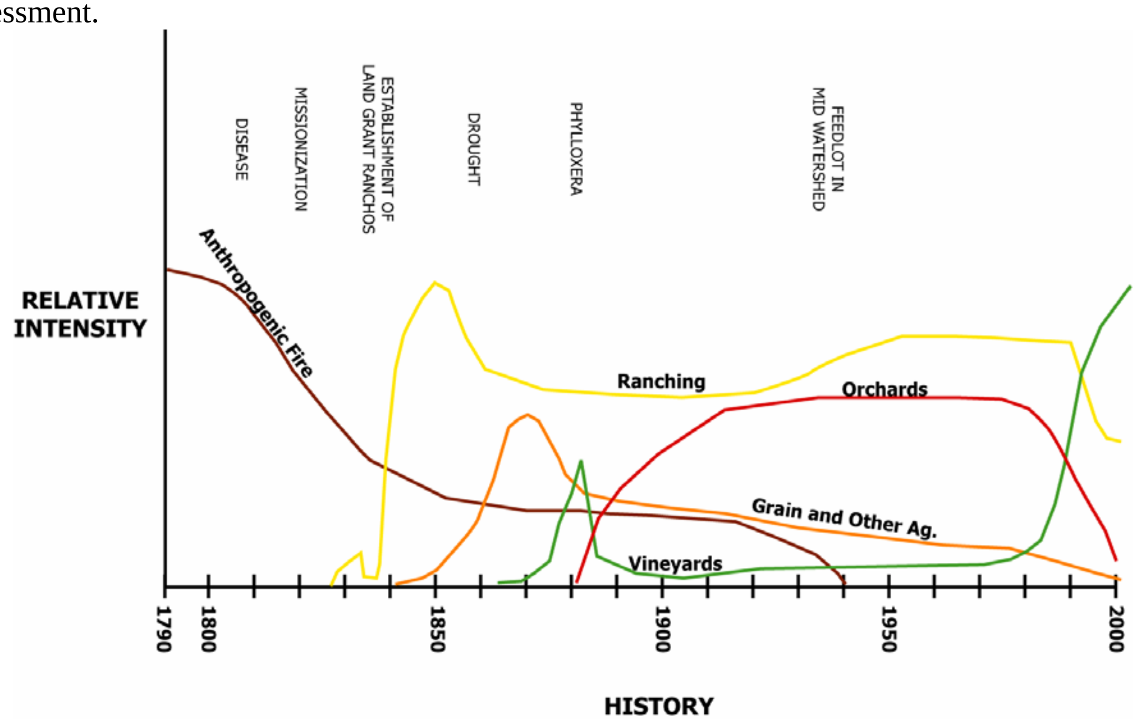


Figure 3: Qualitative summary showing the relative timing and intensity of major land management activities in the Carneros Creek watershed over the past two centuries. Intensities are not necessarily comparable across categories.
Source: San Francisco Estuary Institute, 2002

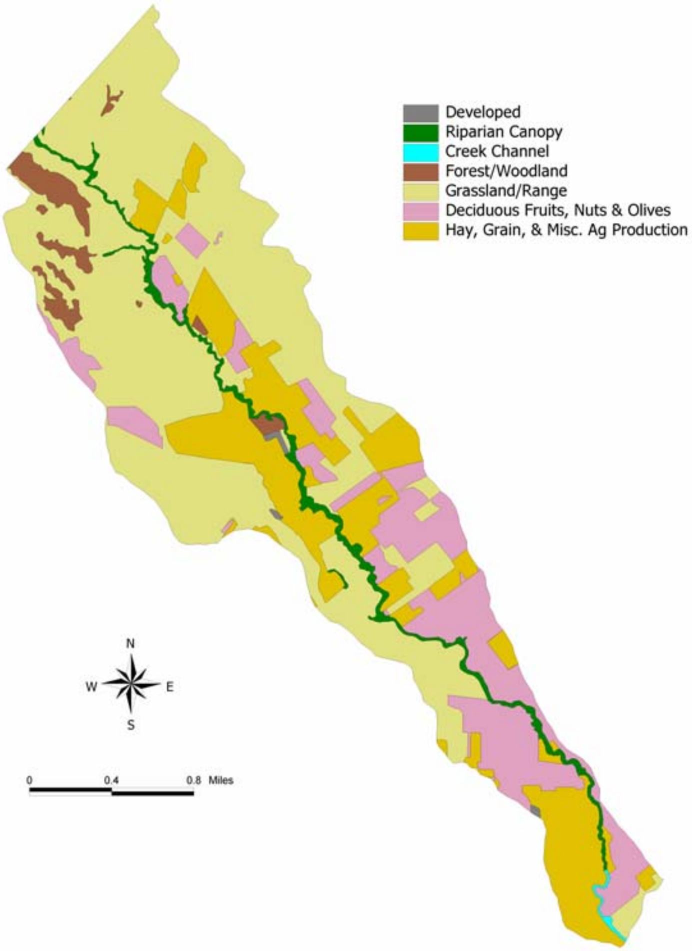
The Carneros Creek watershed has been shaped by a unique and intense land use history spanning more than 200 years. For many centuries prior to European contact, native peoples inhabited the Carneros region and managed the landscape in particular ways to meet their needs. In fact, some of the earliest recorded accounts of Carneros Creek describe the native peoples' use of controlled burns to manage vegetation patterns and improve hunting conditions.

By the time the Sonoma Mission was founded in 1823, signifying permanent establishment of the Euro-American culture in the North Bay, the original Native American villages were largely depopulated as a result of disease and recruitment to Mission Dolores in San Francisco. Operation of the Sonoma Mission during these first few decades of the 19th century marked a significant change in land management where management practices shifted from the traditional subsistence-based techniques used by the Native Americans to practices oriented around open range ranching. These first Euro-American settlers, who rapidly established sheep ranches throughout the valleys of the North Bay, quickly impacted the Carneros Creek watershed.

Operation of the missions ceased in 1834 and the Carneros Creek watershed became part of several land grant ranches and experienced more intensive grazing and some agriculture, primarily production of hay and grain. After the assumption of American control in 1848, agriculture expanded relatively rapidly, primarily consisting of hay, grain and grazing. Grain production and grazing land uses continued to be significant through the 19th and mid-20th centuries, particularly in comparison to other parts of Napa Valley.

As in other parts of the Valley, vineyards were developed in the 1870s and 1880s, only to be lost to the *phylloxera* crisis of the late 19th nineteenth century. The vineyards were replanted with orchard fruits, especially apricots, cherries, and pears. A major shift began in the 1970s, when vineyards returned to the area. Comparison of aerial photographs from the 1940s and the 1990s shows a major conversion in land use in the lower portion of the watershed from a mix of orchards, range, and other agriculture prior to World War II to a landscape primarily dedicated to vineyards (Figure 4). Also notable in Figure 4 is the increase in the numbers of reservoirs and ponds that has occurred over the past few decades as agricultural practices have shifted away from dry farming.

This complex and changing land use history has modified the watershed in many ways. Yet, compared to most other parts of the Bay Area, land use around Carneros Creek has caused fewer fundamental alterations to the stream channel and basic creek processes-- with relatively few road crossings, no railroad crossings, and no major dams or flood control projects. Several inherent geographic and physical characteristics of the watershed have also helped limit population expansion and maintain ecological resources. These factors include relatively limited groundwater, relatively low yielding and unstable soil (which is difficult to farm), a naturally narrow, single-thread channel stream connecting to the bay lands, and Carneros' unique geographic position slightly removed from the major fertile valleys of the North Bay and bordered by the vast Napa-Sonoma marshlands. Effective local preservation efforts have protected these attributes. As a result, the watershed has maintained a relatively high quality of ecological resources through history and displays significant potential for restoration and enhancement of stream, valley, and hillside habitats.



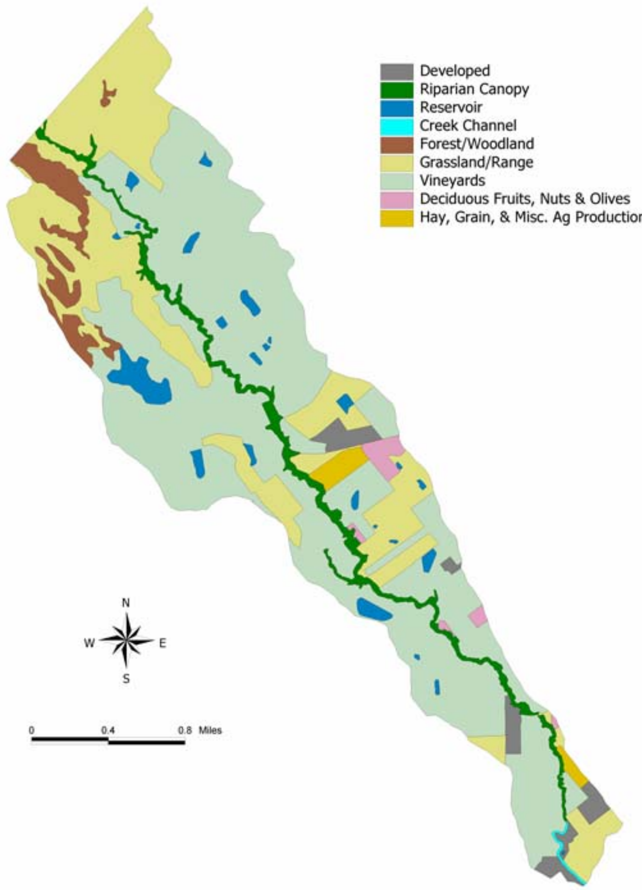


Figure 4: Land use and major vegetation types in the lower Carneros Creek watershed circa 1940 (left) and 1993 (right).
Source: San Francisco Estuary Institute, 2002

It is clear that the Carneros Creek watershed has been managed for human use for over two hundred years, from the controlled burning of vegetation by indigenous tribes to more recent rural residential and vineyard development. Given that the watershed will continue to support human land uses into the future, the question becomes how to better integrate human land uses with the function and needs of the watershed. The following section discusses the results of these land use impacts on the watershed by describing the current condition of significant ecological and landscape characteristics in the Carneros Creek watershed.

Existing Watershed Conditions

In the following discussion and throughout this management plan, the term *lower* reach refers to the portion of Carneros Creek from the Napa River to Old Sonoma Road Bridge, the *middle* reach is the portion from the Old Sonoma Road Bridge to the end of the public portion of Henry Road, and the *upper* reach is the portion from there to the headwaters (Figure 5).

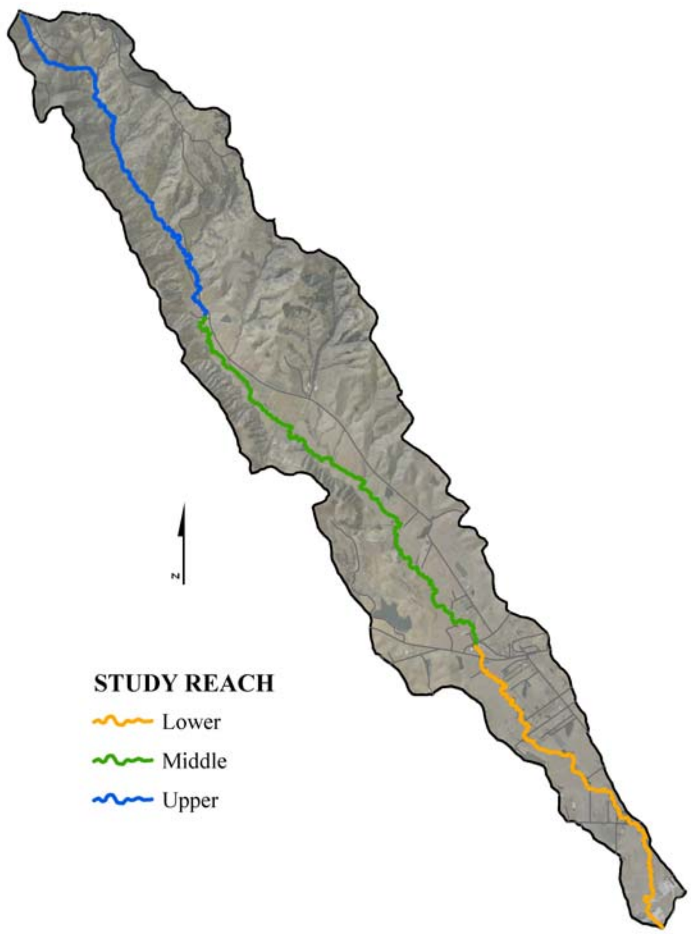


Figure 5: Map of creek reaches within the Carneros Creek watershed.
Source: Napa County Resource Conservation District, 2004

This section is broken down into several resource topics including riparian function, upland ecology, salmonid habitat, soil erosion & excess sediment, flood hazards, and water supply. The relative importance of each resource issue depends upon specific watershed management goals and interests. Further detail regarding the existing condition of the watershed can be found in the Reference Document that accompanies this plan and in the various technical reports that were conducted as a part of the watershed assessment.

Riparian Function

Riparian vegetation along the creek provides an aesthetically pleasing channel corridor and is vitally important to the functioning of the creek. Riparian vegetation provides a myriad of benefits to the stream ecosystem including bank stabilization, erosion control, water temperature regulation, a source of nutrients, a source of large woody debris (fostering pool formation and creek channel complexity), in-stream cover for fish, and a means of filtering runoff (trapping sediment and contaminants) before it enters the channel. In addition, riparian vegetation also provides habitat, food, and a migration corridor for many terrestrial wildlife species.

The riparian corridor along Carneros Creek is fairly continuous and well-developed. It provides shade essential for maintaining adequate water temperatures for cold-water fish (such as steelhead) and provides a mechanism for pool formation through potential recruitment of large woody debris. The total length of the riparian corridor along the lower reach of the creek has increased by approximately 4,000 feet since 1858. Canopy cover is generally high (averaging 91%) and is comprised of 74% evergreen tree species and 26% deciduous tree species. Non-native species such as Himalayan Blackberry also occupy much of the riparian corridor and provide little benefit to the functioning of the creek and its corridor. Figure 6 shows a time-series view of the lower reach of Carneros Creek where it enters the Napa River. Evidence of the downstream riparian extension, past channels, and minor changes in a large meander are visibly comparable between the photos.

Although the riparian corridor is continuous, current observations show that the width of the riparian corridor is narrow, often comprised of a single row of trees, in many sections. Many of the trees are at risk of falling into the creek and younger trees have not been established to replace them. Streambank erosion is threatening the remaining riparian vegetation. In the lower reach, bank erosion has caused many of the mature bay trees to become severely undercut, putting them at risk for falling into the channel in the near future. Loss of these trees would not only create a large gap in canopy cover, but also potential flood hazards, decreased bank stability, and negative effects on water temperature and quality.

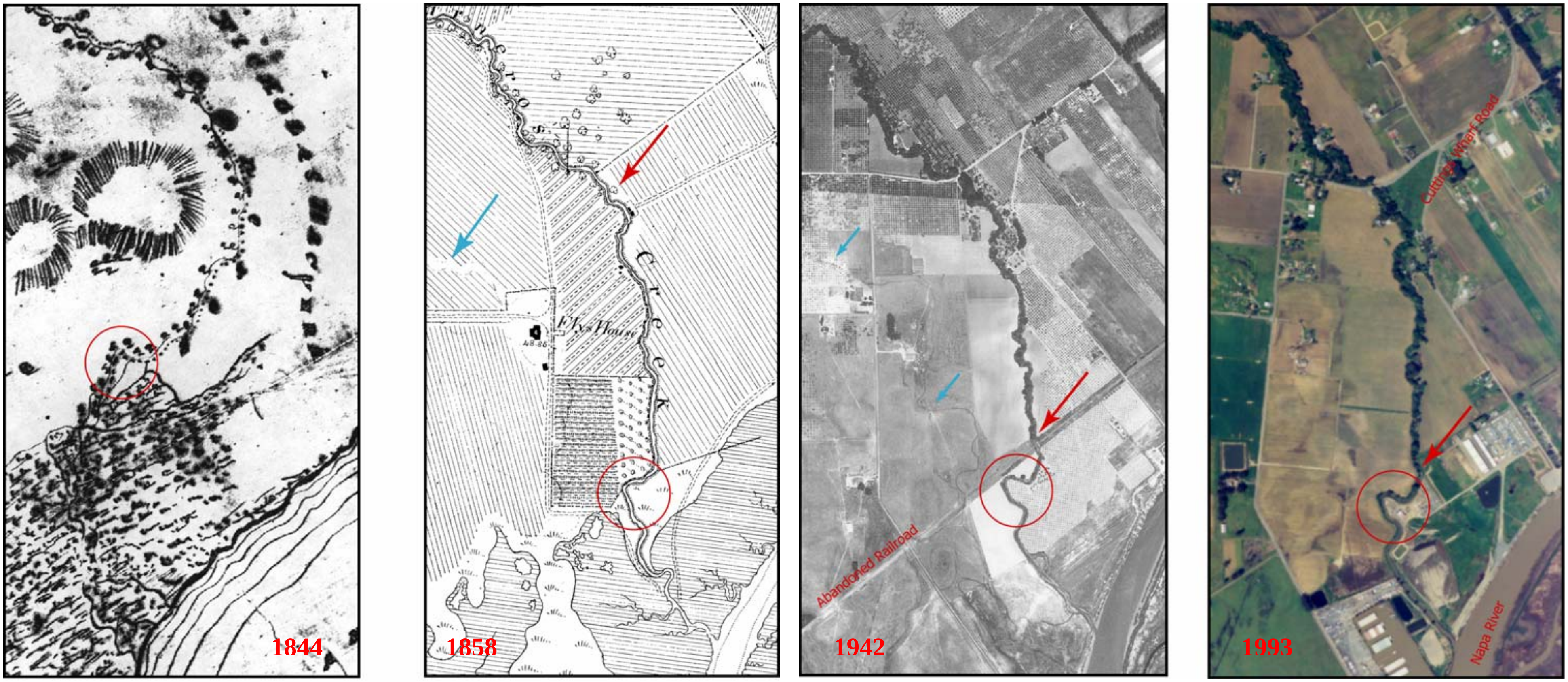


Figure 6: Time-series view of the lower reach of Carneros Creek. Note the change in the meander shape between 1858 and 1942, possibly due to the railroad (red circle), evidence of a former channel (blue arrows), and extension of riparian vegetation (from the red arrow in 1858 to the red arrow in 1942 and 1993).
Source: San Francisco Estuary Institute, 2002

Upland Ecology

Watershed health and function includes more than just the creek and its riparian corridor; many important physical processes occur in the surrounding upland landscape. Surrounding areas provide habitat for a diverse community of plant and animal species that help maintain the function of the natural ecosystem. Increased development, intensive land use, fire suppression, and altered hydrology of the watershed can all affect the functioning of terrestrial ecology. Potential watershed wide impacts include changes in vegetation patterns, amount and/or quality of habitat provided, and introduction of invasive species.

Historically, the lower portion of the Carneros watershed was open grassland with seasonal wetlands and the middle and upper watershed was a mix of grassland, brush, shrub, and woodland under native management (primarily burning), that supported native mammals. The watershed currently supports annual grasses and forbs and mixed hardwoods with smaller areas of California Bay and Pacific Douglas fir. Compared with historical records, a greater number and larger extent of invasive plant species are now found in the watershed. The change in vegetative composition coupled with vineyard and residential development has altered the types of habitat available to support various wildlife species; habitat has diminished for some species and expanded for others. For example, the open grasslands in the lower watershed historically supported Western burrowing owls and waterfowl. Vineyard and residential development in the lower watershed replaced a majority of the grassland habitat and this, in combination with an increase in the number of trees in the lower watershed, resulted in reduced habitat for grassland species and additional habitat for predatory birds that prey upon burrowing owls and waterfowl.

For species dependent upon riparian, woodland or chaparral (brush and shrub land) habitats, the change has been less dramatic. Although natural habitat areas are generally decreasing in the watershed, riparian, chaparral and woodland areas in the upper watershed are experiencing expansion into the grasslands. However, because the riparian corridor in the lower reach is dominated by a single row of mature bay trees, in the future, when these severely undercut trees fall into the channel, gaps in the habitat that connect the lower and upper watershed will be created and may negatively impact wildlife species that are dependent upon the corridor.

In addition to altering wildlife habitat, the change in vegetation and increase in development have also altered the way in which precipitation is intercepted, infiltrated and stored in the watershed. Existing grasslands in the watershed are predominantly comprised of exotic Mediterranean annuals, which are tolerant of grazing and drought and are able to suppress the growth of native perennial grasses. Native perennial grasses provide the benefit of maintaining a large living root mass through time, thus increasing soil stability and precipitation infiltration, whereas exotic annuals reproduce by seed and do not maintain the same beneficial living mass of roots. Remnants of native grassland still exist and with proper expansion and restoration, possibly including careful application of grazing and fire, could provide benefits to the chemical and physical make-up of the soil and the infiltration capacity of the hillslopes.

The factors limiting the maintenance of a healthy, functioning terrestrial ecology are historic and current development and land management practices. Changes from natural vegetation patterns and densities occurred with the advent of suburban residential development, vineyards, agriculture, and grazing. Remaining habitat is fragmented and altered by non-native tree and grass species. Important land management practices that have significant effects on terrestrial ecology include the volume of water diverted from the creek, active fire suppression, and riparian corridor management. In addition, although the topic of groundwater will be discussed in a later section, the groundwater table is sensitive to withdrawals in some areas and a lowered groundwater table will reduce the amount of water provided to the creek from groundwater storage, thus reducing the amount of water available for animal and riparian plant species, especially during the late summer and fall.

Salmonid Habitat

Many physical processes combine to create suitable aquatic habitat. Different life stages of salmonids require various habitat elements, but several elements are universal to the different stages and will benefit many other aquatic species. Steelhead trout require cool water temperatures (below 68°F), access to the ocean, year-round water, a source of food, channel complexity, pools and velocity shelters, cover from predators, adequately sized spawning gravels, and a healthy riparian corridor, amongst other factors.

The Carneros Creek watershed currently supports one species of salmonid, steelhead trout, which is a federally listed threatened species (Figure 7). Historical records go back as far as the mid-19th century, when Menefee (1873: 36), described Carneros: "The writer has caught several [trout] that weighed from 7 to 10 ½ pounds, in the Carneros, five miles from its mouth, where the water was not a foot deep." Although it is likely that Carneros Creek never supported an exceptionally large steelhead population, its relative importance, compared to other streams of similar size in the North Bay, has probably increased. This is due to the maintenance of fairly rural land uses, lack of complete migration barriers, and direct connection and relative proximity to the Bay.

Figure 7: Steelhead Trout
Source:

The middle reach is the only reach suitable for steelhead spawning and rearing. This reach contains multiple areas for spawning with appropriately sized gravels, relatively high amounts of large woody debris, suitable channel complexity, the highest number of pools, the closest average pool spacing, consistently cool water temperatures, good cover, and relatively low volumes of sediment within pools. Most importantly, the middle reach is the only part of Carneros Creek with year-round water needed to support juvenile fish. Comparatively, the lower reach acts primarily as a migration corridor and provides only very limited year-round habitat due to lack of surface flow. Many negative sediment-related impacts on salmonid habitat are also observed in the lower reach and include: deficient pool frequency and quality, and moderate sediment embeddedness. The upper reach may support steelhead spawning but it does not support rearing because it is completely dry in the summer.

As discussed above, portions of the riparian corridor are at risk, particularly along the lower reach of Carneros Creek, below the Old Sonoma Bridge. In this reach, a single row of mature trees comprises the only riparian corridor, and it is severely undercut and in danger of toppling into the creek. Bank erosion and associated channel widening are the cause of this riparian instability. Although limited, the riparian corridor in this reach does provide many benefits, including shade for the maintenance of cool water temperatures. The riparian corridor in the middle and upper reaches are not nearly so vulnerable. However, some creek reaches in the upper watershed, where cattle are not fully fenced out, are showing damage to banks and riparian vegetation. Overall, the riparian corridor is not presently a limiting factor for steelhead success, but it could become a factor when several of the larger trees fall.

Multiple factors are limiting the success of steelhead in Carneros Creek. The most important factor appears to be low stream flow. Although the middle reach maintains year-round flow, the upper and lower reaches do not, and therefore, do not provide adequate rearing habitat. Evidence suggests that much of Carneros Creek did not flow year-round during historic times and that flow was historically negligible or intermittent in the summer. There are some anecdotal descriptions that the amount of intermittent flow and persistent pools has decreased over the past several decades. A number of residents independently describe a reduction in the extent of pools and seasonal flow, reporting that: “it ran more” and “used to visibly run ... enough to get over the rocks, when I came here.” Additionally, several landowners suspect that stream flow may be influenced by the geologic fault that exists in the watershed. Several landowners have noted increases in stream flow that coincide with local earthquake activity.

Secondary limiting factors are lack of channel complexity in the lower reach, important for shelter during migration and cover from predators, as well as some partial migration barriers limiting the extent of available habitat. The most extensive barrier is the dry lower reach, where reduced flow during late spring and early summer limits the movement of young steelhead out of the creek and into the Bay and ocean (outmigration). In the middle reach of the creek, three dams and a small bedrock cascade are identified as likely obstacles during low flows, limiting both up and downstream migration. Nineteen on-stream reservoirs were also identified on tributaries to Carneros Creek, each preventing further upstream migration. However, steelhead do not appear to use these tributaries due to seasonal drying and other unfavorable conditions, so the impacts of these dams in terms of limiting habitat availability is likely very minor. Despite several partial barriers, the creek still maintains a direct path from the upper watershed to the Napa River, with no complete barriers.

Soil Erosion and Excess Sediment

Erosion is a natural process that acts to keep the landscape and stream channel in equilibrium. Some erosion is beneficial and essential to the watershed; for example, landslides and bank erosion provide sources of fresh sediment and gravel to the channel that can be utilized by spawning fish. However, intensive use of the land has the potential to increase rates of erosion and tends to supply more sediment to the creek than the system can handle, thus altering the natural balance. Excessive soil erosion can lead to costly property loss and resource degradation.

Soil erosion is a process that can take many forms including: bank erosion, gully erosion, sheet and rill erosion, and landsliding; all of which are currently occurring in the Carneros Creek watershed to varying degrees. Much of the erosion occurring on Carneros Creek is caused or aggravated by human activities. Finding solutions to minimize erosion induced by human disturbance is essential because property and soil resources are valuable and because excess erosion and the resultant sediment input to the creek can have negative impacts on channel functioning and aquatic habitat. Figure 8 shows examples of bank and gully erosion.

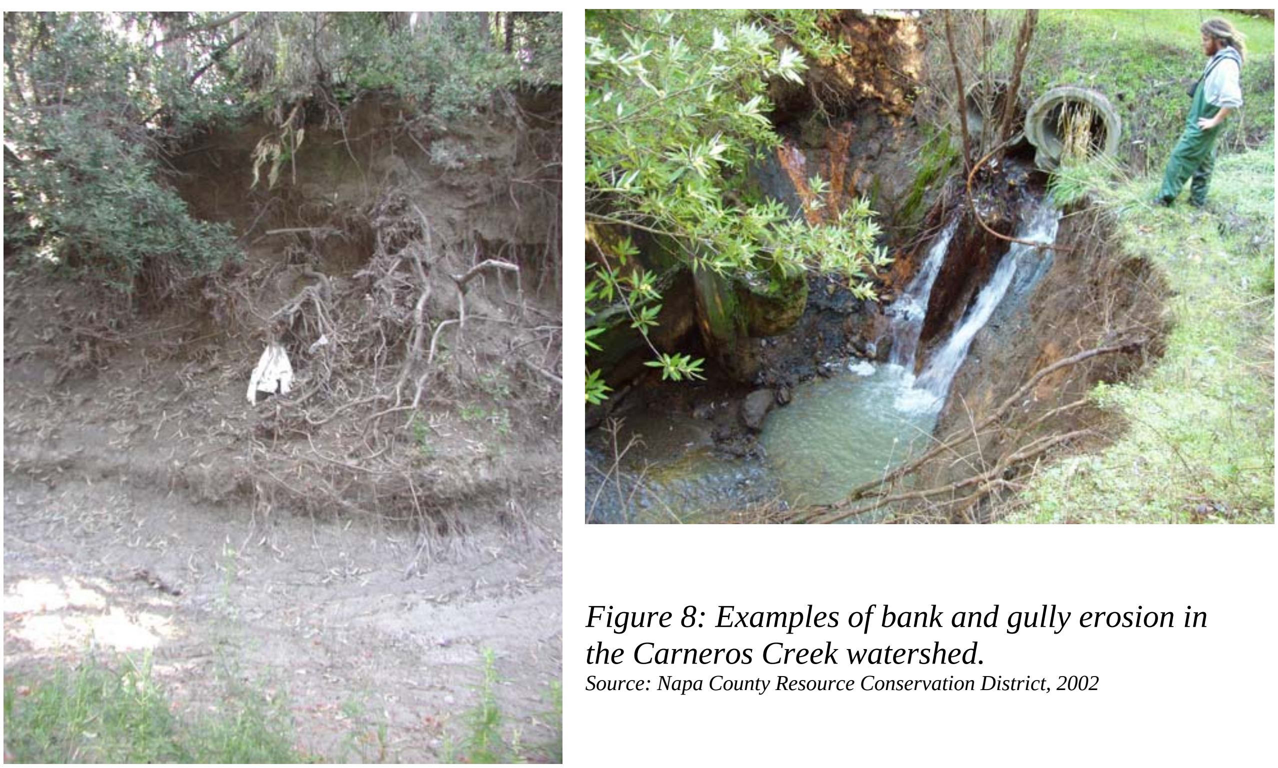


Figure 8: Examples of bank and gully erosion in the Carneros Creek watershed.
Source: Napa County Resource Conservation District, 2002

In the lower watershed, the change from grasslands, hay/grain production, and orchards to vineyards has, in some cases, led to more intensive soil disturbance and therefore increased the potential for surface erosion. Vineyard and road runoff controls such as pipelines and ditches concentrate runoff and provide ready transport of any surface erosion to the channel system. In addition, drainage pipes that discharge concentrated runoff onto channel banks without proper energy dissipation often cause bank collapse or gullying. Most of the lower watershed has been subject to some type of agricultural activity for well over a century, resulting in an increase in the erosion potential. In the middle and upper reaches, both historic and recent grazing practices cause the largest impacts to the hillslopes and banks.

Accelerated bank erosion caused by changes in land use and management is contributing substantial amounts of sediment to the creek. Localized areas in the middle reach, upstream from the Old Sonoma Road Bridge, are contributing the largest volume of sediment per unit channel length, with half occurring in the past 20 years. Tributary banks are also experiencing erosion but at a much slower rate. Most measured erosion is chronic, occurring over the past 50 to 100 years. However, bank erosion rates appear to have increased in the past 10 years. Bank material and vegetation cover determine the stability of channel banks in the watershed. Although bank material along the mainstem and tributaries is variable (ranging from bedrock to silt/clay), nearly the entire channel bank length contains at least some vegetation, including areas of dense vegetation. However, there are a few locations, especially in the lower reach, that contain bare banks with only exposed roots from the trees growing on the top of the bank. Areas with silt/sand banks and/or banks with minimal vegetation are at higher risk of eroding.

Landslides and other hillslope mass movements also contribute sediment to the creek. Approximately120 current and historic landslides have been mapped since 1942 and are contributing sediment to the creek system. Due to different underlying rock types, the east side of the watershed is more prone to hillslope failures. Most slides occur in the grasslands and appear to be associated with the underlying geology, rather than with changes in land use. Large storm events or prolonged, above-normal seasonal rains that saturate the soil are the likely triggering mechanisms. . Erosion control is recommended for seven landslide sites.

Sheet and gully erosion is occurring. The largest gullies are forming downstream of poorly designed outlets of existing reservoirs. Rilling and gullying are observed in vineyards planted perpendicular to contour before cover crop growth in the fall and especially on hillslopes steeper than 10%. However, most vineyards have existing cover crop growth, significantly reducing the amount of observed erosion. Gullies are also observed in areas grazed by cattle, on hillslopes receiving road runoff, and on stream bank slopes below culverted drainage outlets. Sheet erosion occurs primarily on bare soil areas throughout the watershed and on long stretches of unpaved rural road with poorly designed drainage and ditches that are connected with, and flow into streams.

Over 11 miles of road surface in the watershed drains directly to the channel system, delivering runoff and fine sediment. Undersized or plugged culverts and diverted streams also have the potential to contribute eroded sediment. Erosion control efforts are recommended for 10.3 miles of road, 16 of 23 ditch relief culverts, and 90 of 101 stream crossings. The erosion- and storm-proofing recommendations include a combination of such preventative treatments as re-grading roads to include rolling dips; installing wet crossings; removing or replacing undersized or damaged culverts; realigning culverts to the channel gradient; retrofitting pipes with a downspout, trash rack and/or flared inlet; and rock armoring outlets.

Many locations and types of erosion are observed throughout the watershed. Although some is attributable to natural physical conditions and processes, a portion is due to human modifications or land uses. Of the identified erosion causes, grazing practices (both historic and current), altered runoff patterns and timing created by intensive land use, road drainage and viticulture appear to be the critical causes.

Flood hazards

Floods can damage streamside property, bridges, and roads, and they often cause high rates of bank erosion and sediment transport. However, periodic flooding is also important to maintain channel function and steam ecology. Flooding occurs naturally in fluvial systems in response to climate and stream conditions with some degree of regularity over time. Reducing the damage caused by floods is possible with careful planning and implementation of key prevention strategies throughout the watershed. Human activity can alter the frequency and force of flood events through modification to the stream system. Natural and anthropogenic factors are contributing to the flood hazard in Carneros Creek. Addressing current management practices that increase the likelihood of flood hazards is important.

Overall, flood conveyance in Carneros Creek appears to be effective. Recent floods have not topped the terrace banks, even in the lower entrenched reaches. However, localized flooding does occur in the watershed and factors that contribute include: increased surface and subsurface drainage and time to peak flow associated with high intensity land use; a large number of inadequate culverted stream crossings; the large amount of woody debris in the creek and/or available for recruitment to the creek; and potentially some stream stabilization projects. In addition, catastrophic failure of an on-channel reservoir could potentially cause flooding, property damage, downstream sedimentation, bank erosion, habitat loss and widespread channel morphology changes. Limitations on building structures within flood-prone areas of the creek will assist in preventing future damages that may be caused by localized flooding.

Land use intensity is increasing and having an impact on localized flooding. Although historic cultural burning had some effect upon infiltration and evapotranspiration, recent changes in land use are having a larger impact by routing more water to the channel system in less time and increasing the likelihood of localized flooding. Land use changes include increases in agriculture, impervious surface areas, vineyard-related engineered subsurface and surface water drainage systems, and road density.

Multiple channel crossings and constrictions exist in the watershed and may also pose a flooding hazard. The mainstem of Carneros Creek has eight major crossings, either bridges or culverts, all of which appear to be large enough to accommodate flood flow. There are also several crossings located on tributaries; many of these are undersized and have the potential to constrict high water flows and cause localized flooding. Additionally, because the potential for wood recruitment to the creek is high and because the channel already contains many large woody debris pieces, plenty of debris is available to catch on bridge pilings and culvert inlets, causing a backup of floodwaters.

To some degree, bank stabilization efforts, particularly in the lower reach may also influence the likelihood of localized flooding. These hardscape revetments typically encroach upon the natural channel area, causing a decrease in the volume of flood flow that can pass, and increasing the likelihood of flooding.

The watershed currently contains 57 on- and off-stream reservoirs, which intercept and retain storm flow, acting to reduce the peak of the hydrograph and the likelihood of flooding, at least during the early part of the rainy season. However, some of these reservoirs have the potential to overflow, with the potential to cause either severe erosion or catastrophic failure of the dam and associated flooding.

Water Supply

Water is essential for all aspects of life, including agriculture, grazing, human habitation, aquatic and terrestrial habitat, and vegetation communities. Water availability is generally limited in the Carneros Creek watershed. There are many competing uses for the finite amount of water including flows for environmental benefits, diversion for storage, diversion for land uses or residential needs, and extraction from wells. Without continued maintenance of and/or increases in seasonal water flow in Carneros Creek, continued challenges for all water users will likely occur.

Precipitation is the primary source of surface water in the watershed and is driven by the natural regional flood/drought regime. Average annual precipitation in the watershed is 28 inches and it is estimated that approximately 52% of rainfall in an average year enters the creek as runoff; wetter and drier years have proportionally greater and less runoff, respectively. The rate at which the creek flows is seasonally dependent; water levels in the creek begin to rise in December and closely follow precipitation events, frequently ceasing to flow from September to November. The overall low levels of seasonal flow are likely the historical norm and are typical of many Napa region creeks. Historic stream surveys have noted lack of channel flow. However, there is evidence of recent decreases in flow. The entire channel has essentially no flow from September to November. The upper reach is completely dry throughout the summer and fall, the middle reach has perennial (year-round) surface flow that slows to a trickle in the late summer, and the lower reach contains only isolated pools, which quickly decrease in volume and quality throughout the summer. Aquatic habitat for cold-water fish is impacted by the naturally low summertime flows and exacerbated by additional decreases. Figure 9 shows an example of stream levels in the lower and middle reaches of Carneros Creek during the month of July.

Large volumes of water are being stored in reservoirs. A total of 57 on- and off-stream reservoirs exist, all having been built since 1940. Reservoir surface area ranges from 1,600 square feet to 31 acres. On-stream reservoirs intercept and retain storm flow, slowly releasing water for irrigation purposes over the growing season. Currently, over 30% of the average surface runoff is allocated for diversion.

Figure 9: Images from the lower and middle reaches of Carneros Creek. July, 2004.
Source: Napa County Resource Conservation District

Groundwater is also generally limited in some areas of the watershed. Based upon historic studies and current landowner observations, the groundwater table appears to be sensitive to overdraft. The incised nature of Carneros Creek, as well as localized use of groundwater for domestic and irrigation purposes, contributes to a localized drop in groundwater levels. Continued monitoring of well levels in Carneros and additional research are essential to establish a trend and to better understand the form and recharge characteristics of the groundwater aquifer.

A large portion of water is diverted/extracted for human uses. Although agricultural land was historically dry farmed, many diversions are apparent in historic channel surveys, presumably for grazing and household needs. Wells generally supply water for residential uses and for irrigation of some vineyards, many of which are located on the eastern side of the watershed because of a relatively higher groundwater table. The amount of groundwater being extracted and the effect that extraction is having on surface flows are unknown; groundwater pumping is not frequently monitored and permits are not needed for extraction.

To a lesser extent, changing vegetation patterns are also influencing surface flows and groundwater recharge by altering the infiltration/transpiration capacity of the watershed. This is primarily happening through expansion of chaparral/woody vegetation into grasslands and lengthening and expansion of riparian vegetation.

The factor most responsible for a limited water supply in Carneros Creek is the natural climatic and geologic characteristics of the watershed. Secondary factors are the increased population of the watershed and greater diversion and extraction associated with more water-intensive land uses.

Watershed Management Recommendations

In response to historic and existing conditions of the Carneros Creek watershed, a number of specific objectives and several watershed management recommendations are offered to improve and restore natural resources for the benefit of the community and wildlife habitat. What follows is the identification of seven specific objectives that have been developed to address the resource related concerns of the Carneros Creek Stewardship and several matrices that provide specific recommended actions to achieve each objective. The objectives strive to maintain or restore a naturally functioning creek and watershed system in the context of human land use. The recommended actions are meant to be voluntary in nature and meant to provide the Stewardship, local landowners, and local land managers with several actions that could be implemented over time to meet the various local goals that exist in the watershed.

Although these recommendations are all generally supportive of the values of the Carneros Creek Stewardship, the relative importance of each depends on the specific interests which members bring to the table. For this reason, we have prioritized the recommendations on the basis of various “watershed interests.” We hope this will satisfy the curiosity of a landowner who might want to know, for example, how valuable a proposed riparian project might be from a habitat or flood damage perspective. The priority is designated as high, medium or low for each recommendation, as it pertains to each of the identified potential watershed interests. In addition, not all recommendations should be considered necessary for the entire watershed, for that reason, the area for which the recommendation is specifically important is noted by reach. Lastly, the relative cost of each action is denoted on a scale of $ to $$$, where $ is relatively inexpensive and $$$ is fairly costly.

Further detail regarding the objectives and recommended actions can be found in the Reference Document that accompanies this plan. It includes more both more specific information regarding the recommendations and contact information for those interested in pursuing a recommended action.

Watershed Management Recommendations

Objective A: Establish and maintain an uninterrupted riparian corridor along Carneros Creek and its major tributaries, emphasizing the use of native plants which are not primary hosts for Pierce's disease.

In some ways this is the most fundamental objective, since actions taken in support of it will also indirectly support all the others; further, many of them will directly contribute to stream stability, terrestrial habitat, and in-stream habitat.

RECOMMENDED ACTIONS *Additional information regarding these voluntary actions can be found in the Reference Document.*		**Reaches of specific importance**	**PRIORITY FOR IDENTIFIED WATERSHED INTERESTS**				**RELATIVE COST OF ACTION**
			Enhance aquatic & riparian habitat (including stream flow)	**Maintain/enhance upland habitat**	**Improve streambank stability**	**Protect property from flood damage**	
A-1	Manage existing riparian corridor to maximize riparian canopy width by "stepping back" from the creek where and when possible.	all	H	M	M	M	$-$$
A-2	"Close" gaps along the riparian corridor by developing and implementing riparian revegetation plans that utilize native trees, shrubs, and grasses.	all	H	M	M	L	$$
A-3	Incorporate exclusionary livestock fencing in such a way as to allow for native mammal migration and access to the creek while keeping domestic grazing animals out of the riparian corridor. Provide alternate dispersed, shaded watering sites away from the riparian zone.	upper & middle	H	M	H	L	$$
A-4	Explore opportunities for conservation easements along the riparian corridor in exchange for property tax reductions with organizations such as the Land Trust of Napa County.	all	H	M	M	H	$$
A-5	Ensure that future planning of rural residential areas include stream side areas that enhance and emphasize natural riparian zones.	all	H	M	M	M	$$
A-6	Continue to conduct education and outreach to promote a functioning riparian corridor.	all	H	L	H	M	$

Watershed Management Recommendations

Objective B: Promote contiguous upland habitat and biodiversity.

Many actions taken in support of other objectives will also support this objective, particularly actions which increase and maintain the extent of riparian corridor along the creek and tributaries.

RECOMMENDED ACTIONS *Additional information regarding these voluntary actions can be found in the Reference Document.*		Reaches of specific importance	PRIORITY FOR IDENTIFIED WATERSHED INTERESTS				RELATIVE COST OF ACTION
			Maintain/enhance aquatic & riparian habitat (including stream flow)	Maintain/enhance upland habitat	Improve streambank stability	Protect property from flood damage	
B-1	Develop new upland migration habitats for birds and small mammals through native plantings and hedgerows along fences, fields, and property borders.	all	L	H	L	L	$
B-2	Provide terrestrial wildlife habitat enhancements such as birdhouses, raptor roosts, and bat boxes.	all	M	H	L	L	$
B-3	Continue to enhance and implement grazing, range, and grassland management plans to maximize native grassland revegetation and exotic invasive plant management. Consider prescribed burns, as appropriate.	upper & middle	L	H	M	L	$-$$
B-4	Maintain and encourage development of continuous east-west habitat corridors across the valley into other watersheds through cooperative efforts with neighboring landowners.	all	L	M	L	L	$
B-5	"Step back" from sensitive upland areas such as slides whenever possible.	middle & upper	M	H	L	L	$
B-6	"Close" gaps along the riparian corridor by developing and implementing riparian revegetation plans that utilize native trees, shrubs, and grasses.	all	H	M	M	L	$
B-7	Continue watershed education activities including guest speakers to discuss wildlife habitat and sudden oak death.	all	M	H	L	L	$
B-8	Collaborate with youth education programs such as Acorn Soupe to conduct education and outreach to promote contiguous habitat and biodiversity.	all	H	H	L	L	$

Watershed Management Recommendations

Objective C: Maintain and improve in-stream habitat.

Many actions taken under this objective will promote streambank stability

RECOMMENDED ACTIONS *Additional information regarding these voluntary actions can be found in the Reference Document.*		Reaches of specific importance	PRIORITY FOR IDENTIFIED WATERSHED INTERESTS				RELATIVE COST OF ACTION
			Maintain/enhance aquatic & riparian habitat (including stream flow)	Maintain/enhance upland habitat	Improve streambank stability	Protect property from flood damage	
C-1	Remove barriers to fish migration on the mainstem of the creek	middle & lower	H	L	L	L	$$ - $$$
C-2	Encourage formation of pools via large woody debris in ways that do not increase the risk of flooding.	lower	H	L	L	L	$ - $$
C-3	Limit low water crossings to only those that are necessary, with a preference for designs that minimize channel disturbance.	upper & middle	H	L	H	L	$$ - $$$
C-4	Continue to enhance and implement grazing management plans with an emphasis on intensive management systems that reduce grazing impacts on upland and riparian landscapes.	upper & middle	H	H	H	L	$-$$
C-5	Protect and improve water quality through general septic tank maintenance; minimized use of pesticides, chemicals and fertilizers; proper disposal of winery and industrial waste; proper storage of all chemicals, fertilizers, fuels, and debris; filtration of urban runoff; and improved road drainage.	all	H	M	L	L	$ - $$$
C-6	Implement stream restoration using 'soft' bio-engineered techniques, incorporating live plant material whenever possible. Also consider "stepping back" development from the creek to provide for natural meandering.	all	H	M	H	M	$ - $$
C-7	Conduct education and outreach regarding actions that can help improve water quality and in-stream habitat.	all	H	L	L	L	$

Watershed Management Recommendations

Objective D: Reduce soil erosion.

Actions to reduce soil erosion from upland surfaces will help protect economic resources, and have the potential to improve in-stream habitat and improve water quality in general, as do actions to prevent streambank erosion.

OBJECTIVES & ACTIONS *Additional information regarding these voluntary actions can be found in the Reference Document.*		**Reaches of specific importance**	**PRIORITY FOR IDENTIFIED WATERSHED INTERESTS**				**RELATIVE COST OF ACTION**
			Maintain/enhance aquatic & riparian habitat (including stream flow)	**Maintain/enhance upland habitat**	**Improve streambank stability**	**Protect property from flood damage**	
D-1	Use sustainable agricultural practices to minimize soil erosion, as recommended in the Napa River Watershed Owners Manual and the Fish Friendly Farming (Napa Green) Manuals.	all	H	M	M	L	$
D-2	Limit use of and abandon existing low water crossings and access points to minimize bank degradation at those sites. Where possible, exclude livestock from the creek.	upper & middle	H	L	H	L	$$
D-3	Maintain and improve roadways and culverts, and minimize new road construction.	all	H	H	M	M	$ - $$$
D-4	Explore and where preferable utilize alternatives to engineered storm drains. Attempt to retain and disperse water, rather than concentrate it).	all	M	M	H	L	$ - $$$
D-5	Consider "stepping back" development from the creek to provide for natural meandering. Where appropriate, implement streambank stability using ‘soft’ bio-engineered techniques.	all	H	M	H	M	$ - $$
D-6	Maintain and improve reservoir outlets to ensure that they are operating properly	all	H	M	M	L	$ - $$$
D-7	Conduct education and outreach regarding roads, vineyard practices, and bio-engineered streambank protection.	all	H	H	H	M	$

Watershed Management Recommendations

Objective E: Protect property and habitat using natural processes to promote streambank stability.

Many actions taken under this objective will improve in-stream habitat and the health of the riparian corridor.

OBJECTIVES & ACTIONS *Additional information regarding these voluntary actions can be found in the Reference Document.*		**Reaches of specific importance**	**PRIORITY FOR IDENTIFIED WATERSHED INTERESTS**				**RELATIVE COST OF ACTION**
			Maintain/enhance aquatic & riparian habitat (including stream flow)	**Maintain/enhance upland habitat**	**Improve streambank stability**	**Protect property from flood damage**	
E-1	Protect property and natural resources by managing channel bank erosion. Also consider "stepping back" development from the creek to provide for natural meandering.	all	H	L	H	M	$$
E-2	Protect property from flood damage through culvert and bridge abutment clearing, in-channel vegetation management, and where possible providing the creek with access to its floodplain.	all	H	L	H	H	$ - $$
E-3	Conduct education and outreach regarding bio-engineered streambank protection, floodplain functions, culvert maintenance, and management of large woody debris.	all	H	L	H	H	$

Watershed Management Recommendations

Objective F: Improve water management for the benefit of human, plant and animal communities.

This objective addresses not only the quality of in-stream and riparian habitat, which depends to some degree on water quantity, but also the needs of landowners for water for domestic use.

OBJECTIVES & ACTIONS *Additional information regarding these voluntary actions can be found in the Reference Document.*		Reaches of specific importance	PRIORITY FOR IDENTIFIED WATERSHED INTERESTS				RELATIVE COST OF ACTION
			Maintain/enhance aquatic & riparian habitat (including stream flow)	Maintain/enhance upland habitat	Improve streambank stability	Protect property from flood damage	
F-1	Plan individual water use (both surface and groundwater use) to minimize environmental disruption. Environmental values may be threatened by the timing of water withdrawals and the mechanisms used to pump and store water.	all	H	L	L	L	$
F-2	Maintain desirable low flows for fish, using the telephone connection to the streamgage on Carneros Creek. The following is a guide: • 1 foot for adult migration (Nov. – Mar.) • 6 inches for smolt outmigration (Apr. – June)	all	H	L	L	L	Unknown
F-3	Explore opportunities to use recycled water for agriculture and landscape irrigation.	all	H	L	L	L	$$$
F-4	Use water conservation fixtures and equipment in and around homes and for agricultural uses of water.	all	H	M	L	L	$-$$
F-5	Use low-water-consuming and fire-retardant native plant materials for landscaping and habitat restoration.	all	M	L	L	L	$
F-6	Explore and where preferable utilize alternatives to engineered storm drains. Attempt to retain and disperse water, rather than concentrate it).	all	M	M	H	L	$-$$$
F-7	Improve communication among water appropriators and among appropriators and community.	all	H	L	L	L	Unknown
F-8	Support continued monitoring and research regarding local water conditions.	all	H	L	L	L	$
F-9	Conduct education and outreach to promote water use efficiency practices.	all	H	L	L	L	$

Watershed Management Recommendations

Objective G: Encourage land stewardship and sustainable land use.

Actions which educate land users about stewardship and sustainability tend to support the whole range of objectives identified in this plan, because educated land users are more likely to consider the environmental consequences of management decisions.

OBJECTIVES & ACTIONS *Additional information regarding these voluntary actions can be found in the Reference Document.*		**Reaches of specific importance**	**PRIORITY FOR IDENTIFIED WATERSHED INTERESTS**				**RELATIVE COST OF ACTION**
			Maintain/enhance aquatic & riparian habitat (including stream flow)	**Maintain/enhance upland habitat**	**Improve streambank stability**	**Protect property from flood damage**	
G-1	Organize community events and develop other mechanisms to increase awareness of this plan and support for its implementation.	all	H	H	H	H	$
G-2	Develop a creek restoration demonstration site on Carneros Creek and utilize it for community events.	all	H	M	H	L	$$
G-3	Develop and distribute a "creek care guide" to landowners and managers.	all	H	M	H	H	$$
G-4	Develop and implement a means to discuss this plan with neighbors and receive feedback from the community.	all	H	H	H	H	unknown
G-5	Facilitate permitting for environmental restoration projects. Support DFG and NRCS efforts to develop a local consolidated permit program.	NA	H	M	H	M	$$
G-6	Obtain funding for watershed work done under this plan.	all	H	H	H	H	$ - $$

Future Research and Recommended Monitoring

Although a great effort was made to assess existing watershed conditions in 2002 as part of the extensive watershed assessment, some additional research needs were discovered. They include the following:

- Identify wildlife species and habitat diversity
- Identify key wildlife corridors
- Gather data to improve water budget
  - Multi-year records of monthly rainfall
  - Establish creek flow measurement stations at several locations and maintain for 5 years
  - Gather information on permitted surface water withdrawal volumes (identify those with & without bypass requirements)
  - Improve information on ground water extraction – meter as many wells in the watershed as possible
  - Identify where aquifer is recharged
  - Estimate water use for vineyard, residential, and other irrigation, and rural domestic use
- Conduct groundwater monitoring to better characterize the groundwater aquifer and locations of recharge

Beyond additional research, watershed conditions should be monitored over time to allow the community to track changes within the watershed and adapt their land management strategies accordingly. Several recommendations for on-going and future watershed monitoring resulted from the watershed assessment and are summarized in the following pages in matrix format for each of the identified objectives. For each recommendation, we have tried to identify relative priority, cost and effort; frequency of monitoring; and success criteria.

Recommended Monitoring

Objective A: Establish and maintain an uninterrupted riparian corridor along Carneros Creek and its major tributaries, emphasizing the use of native plants which are not primary hosts for Pierce's disease.

RECOMMENDED MONITORING *Additional information regarding these monitoring recommendations can be found in the Reference Document.*		**Frequency**	**Success**	**Priority**	**Relative Cost**	**Relative Effort**
A-1	Monitor vegetation growth and continuity and width of riparian corridor	Annually for 3 years then once every 5 years	corridor is 95% continuous, with no single gap larger than 66 ft in length	M	$	L
A-2	Monitor vegetation growth at restoration sites	Pre-project baseline, post project for 5 years - then once every 3 years		H	$ - $$	L - M
A-3	Observations of vines infected with Pierce's Disease should be recorded. Trend patterns should be mapped, characterized and compared to riparian PD management projects.	Annually		For Discussion		

Objective B: Promote contiguous upland habitat and biodiversity.

RECOMMENDED MONITORING *Additional information regarding these monitoring recommendations can be found in the Reference Document.*		**Frequency**	**Success**	**Priority**	**Relative Cost**	**Relative Effort**
B-1	Measure and record the shape, area and connectivity of wildlife habitat and migration corridors including riparian corridors and east-west corridors.	Annually for 3 years then once every 5 years		M	$	L
B-2	Document number of wildlife species present in the watershed	Once every 5 years		H	$	M
B-3	Monitor grazed areas, specifically grazing-related erosion; grass species composition, condition, and density; percent of area composed of exotic invasive species; and effectiveness of best management practices	Annually for 5 years then once every 3 years		H	$	L

Recommended Monitoring

Objective C: Maintain and improve in-stream habitat.

RECOMMENDED MONITORING *Additional information regarding these monitoring recommendations can be found in the Reference Document.*		**Frequency**	**Success**	**Priority**	**Relative Cost**	**Relative Effort**
C-1	Conduct a survey of complete and partial migration barriers for salmonids and other fish species	Every 3 years	Removal of all complete and partial barriers	M	$$	H
C-2	Monitor the number, depth, volume, complexity, and location of pools	Every 3 years and the dry-season following large storm events	Pool habitat quality and quantity is stable for 2 consecutive monitoring periods.	H	$$	H
C-3	Monitor restoration projects - inventory of pools and channel form	Pre-project and then post project annually for 5 years	Achievement of project design goals.	H	$	H
C-4	Document the location and condition of cattle crossings	Every 3 years	Removal and/or improvements to the crossings having an impact upon the stream	H	$ - $$	L
C-5	Conduct snorkel surveys of fish species during the summer.	Annually for 3 years, then once every 3 years.	Fish distributions and densities are documented	H	$$	H
C-6	Conduct steelhead spawning surveys during adult migration season (December – March)	Annually for 5 years, then once every 3 years.	Population estimates can be generated.	H	$$	M
C-7	Monitor all projects that potentially impact in-stream habitat	Pre-project baseline and post project for 5 years	Project limits erosion in the project reach, does not induce erosion adjacent to the project, encourages natural channel processes, and encourages native vegetation	H	$	M
C-8	Monitor water quality, particularly temperature, dissolved oxygen, pH, and conductance	Year-round	Maintain year-round temperatures below 68° F	M	$	L
C-9	Measure turbidity	Year-round	Maintain turbidity levels at less than 2 NTU when flow is present.	M	$$	L
C-10	Sample benthic macroinvertebrates	Every 3 years	Diversity and abundance of species is maintained or improved.	H	$$	H

Recommended Monitoring

Objective D: Reduce soil erosion.

RECOMMENDED MONITORING *Additional information regarding these monitoring recommendations can be found in the Reference Document.*		**Frequency**	**Success**	**Priority**	**Relative Cost**	**Relative Effort**
D-1	Monitor vineyard plots and avenues for rill and gully development throughout the wet season.	Annually throughout the wet season	Cost-effective practices are identified and problems are corrected as found	H	$	L
D-2	Monitor and remove debris from bridges and culverts to prevent the buildup of debris	Annually pre-rain and throughout the wet season	Problems are corrected as found	H	$	M
D-3	Conduct physical and biological monitoring at outlets that drain to the creek and reservoir outlets	Annually	Culverts/ditches/roads that are contributing or have the potential to contribute significant amounts of sediment to the fluvial system are repaired or removed.	M	$	M

Objective E: Protect property and habitat using natural processes that promote streambank stability.

RECOMMENDED MONITORING *Additional information regarding these monitoring recommendations can be found in the Reference Document.*		**Frequency**	**Success**	**Priority**	**Relative Cost**	**Relative Effort**
E-1	Monitor bank erosion and measure channel cross sections	Every other year	The volume of bank erosion caused by human sources is reduced by 50% over the next five years.	H	$$	H
E-2	Map locations of debris jams	Annually	Areas prone to debris jams are identified and problems are corrected.	H	$$	H
E-3	Monitor effectiveness of bank stabilization projects.	Pre-project and then post-project for 5 years on an annual basis.	Project design goals are achieved.	H	$$	M

Recommended Monitoring

Objective F: Improve water management for the benefit of watershed human, plant and animal communities.

RECOMMENDED MONITORING *Additional information regarding these monitoring recommendations can be found in the Reference Document.*		**Frequency**	**Success**	**Priority**	**Relative Cost**	**Relative Effort**
F-1	Document locations of all diversions from stream and make sure they are properly screened	Completed within 2 years	Landowners engage in self/peer analysis and diversions are located and properly screened.	H	$ - $$	M
F-2	Work with RCD to continue monitoring water level and discharge, making the information available to those who divert water.	Year-round	Minimum stream flow requirements for salmonids are met throughout the year and sufficient water is available for human, plant, and animal uses.	H	$$	M

Objective G: Encourage land stewardship and sustainable land use.

RECOMMENDED MONITORING *Additional information regarding these monitoring recommendations can be found in the Reference Document.*		**Frequency**	**Success**	**Priority**	**Relative Cost**	**Relative Effort**
G-1	Document watershed community events that support watershed awareness and implementation of actions suggested in this plan.	Annually	8 events are held and attendance goals for each event are met	H	$	L
G-2	Track progress of development of creek-care guide	within 5 years	Available on-line & distributed to 100 property owners or managers	H	$	L
G-3	Track progress of establishing a restoration demonstration site and once completed, track its use.	within 5 years	Site completed and utilized annually for community events and monitoring.	H	$-$$	M
G-4	Document, to the extent feasible, implementation of the recommendations in this management plan.	Annually	Variable	H	$	L
G-5	Document efforts to obtain funding and funding received to implement actions suggested in this management plan.	Annually	Sufficient funding is available to landowners who choose to implement suggested actions.	H	$	L

Sources of Public Funding & Assistance

Several sources of public funds are available to assist in projects or programs that protect, preserve, or restore ecosystem functions. Many of the financial assistance programs are available for implementation on private lands. Sources of funds include various resource agencies from Federal, State, and Local government as well as private foundations. Below is a list of possible funding sources with a brief description of the organization, the types of projects they might be interested in funding and a link to an appropriate website (or other contact information). Some funding programs will contract directly with landowners; others will only contract with state or local agencies or non-profit organizations. Please note that this list is not exhaustive and is subject to change over time.

US Department of Agriculture Natural Resources Conservation Service (USDA NRCS)
The NRCS maintains a local office in Napa and can provide general conservation assistance to agricultural landowners in Napa County. They also operate several grant programs that can provide cost sharing for implementation of conservation practices on agricultural land. Conservation practices may include but are not limited to: cover crops, streamside buffer vegetation, bio-engineered streambank stabilization, livestock troughs and water development, erosion control practices, management of noxious weeds, and Pierce's disease management. Additional information is available at www.ca.nrcs.usda.gov or inquiries can be made to Phillip.Blake@ca.usda.gov.

Environmental Protection Agency (EPA)
The EPA has a regional office in San Francisco. Grant programs administered by the EPA generally involve pollution prevention; terrestrial aquatic, and coastal ecosystem research and monitoring; wetland protection; and ecosystem restoration projects. Additional information about specific grants offered through EPA can be found through a federal grant site at http://fedgrants.gov/Applicants/index.html.

US Fish and Wildlife Service (FWS)

The Mission of the U.S. Fish & Wildlife Service is to work with others to conserve, protect and enhance fish, wildlife, and plants and their habitats for the continuing benefit of the American people. They generally fund projects that involve habitat protection and restoration, species status surveys, public education and outreach, and restoration of species at risk. Additional information about grant programs administered by FWS can be found at: http://grants.fws.gov. Alternatively, FWS grant programs can also be searched on a federal grant website through the Department of Interior: http://fedgrants.gov/Applicants/index.html.

National Oceanic and Atmospheric Administration – Fisheries Division (NOAA Fisheries)
NOAA Fisheries (previously National Marine Fisheries Service) is dedicated to the stewardship of living marine resources through science-based conservation and management, and the promotion of healthy ecosystems. They have a local office in Santa Rosa. They generally fund projects that involve habitat protection and restoration (particularly habitat for threatened and endangered species), public education and outreach, and restoration of species at risk. Additional information about current grants offered through NOAA Fisheries can be found at

http://www.nmfs.noaa.gov/mb/grants/. Alternatively, NOAA Fisheries grant programs can be searched on a federal grant website through the Department of Commerce at http://fedgrants.gov/Applicants/index.html.

California Bay-Delta Authority & CALFED Bay-Delta Program

The California Bay-Delta Authority oversees 23 state and federal agencies working cooperatively through the CALFED Bay-Delta Program to improve the quality and reliability of California's water supplies while restoring the Bay-Delta ecosystem. The mission of the CALFED Bay-Delta Program is to develop and implement a long-term comprehensive plan that will restore ecological health and improve water management for beneficial uses of the Bay-Delta System. The program supports 11 different elements to support its 4 objectives: Water Supply Reliability, Levee System Integrity, Water Quality, and Ecosystem Restoration. Grant opportunities available can generally be found at the Bay-Delta homepage: http://calwater.ca.gov/.

California State Water Resources Control Board (SWRCB)

The SWRCB's mission is to preserve, enhance and restore the quality of California's water resources, and ensure their proper allocation and efficient use for the benefit of present and future generations. The SWRCB and their Regional Offices administer a variety of water quality and habitat restoration funds. Available grants are posted on the following website: http://www.swrcb.ca.gov/funding/index.html.

California State Coastal Conservancy – SF Bay Area Conservancy Program

The San Francisco Bay Area Conservancy Program, administered by the Coastal Conservancy, was established to address the natural resource and recreational goals of the nine-county Bay Area in a coordinated and comprehensive way. The Conservancy may award grants to help achieve the following Bay Program goals: (1) protect, restore, and enhance natural habitats and other open-space resources of regional significance throughout the nine-county area; (2) improve public access and related facilities to and around the Bay, its surrounding hills, and the coast, through completion of bay, coast, and ridge trails that are part of a regional trail system; and (3) promote projects that provide open space that is accessible to urban populations for recreational and educational purposes. Applications for funding are accepted on a continual basis. Additional information about the Program and the application package are available on line at: http://www.coastalconservancy.ca.gov/Programs/BACP.htm.

California Department of Conservation

The Department of Conservation provides services and information that promote environmental health, economic vitality, informed land-use decisions and sound management of our state's natural resources. Most of the applicable assistance provided is offered through the Division of Land Resource Protection and includes voluntary programs that help to meet individual needs, including property tax incentives, grants for the purchase of agricultural conservation easements, and funding for conservation projects conducted by Resource Conservation Districts. Additional information is available at: http://www.consrv.ca.gov/DLRP/index.htm.

California Department of Fish and Game (DFG)

The Mission of the Department of Fish and Game is to manage California's diverse fish, wildlife, and plant resources, and the habitats upon which they depend, for their ecological values and for their use and enjoyment by the public. They administer a number of grant programs that make funds available for several types of projects including: restoration implementation, education, assessment, and monitoring. Additional information about DFG can be found at: http://www.dfg.ca.gov.

Wildlife Conservation Commission of Napa County

The Wildlife Conservation Commission awards grant funds to local projects that support the preservation, propagation, and protection of birds, mammals, fish and amphibians. Funds are generated through local fines levied by the California Department of Fish & Game and may be used for a variety of projects including, but not limited to: education, monitoring, land acquisition, or restoration work. Contact Patrick Lowe at the Napa County Conservation, Development and Planning Department for additional information: 707.253.4188.

Napa County Public Works Program

Napa County has funds available to help with watershed restoration work related to creeks for properties that are not eligible for alternative funds, such as NRCS Environmental Quality Incentive Program (EQIP). Mike Forte, with Napa County Public Works Department, can be contacted regarding these funds.

Napa County Resource Conservation District (Napa RCD)

The Napa RCD is a local non-regulatory agency whose mission is to promote responsible watershed management through voluntary community stewardship and technical assistance. The RCD is available to assist with grant writing for projects and is available on a limited basis to provide advice and assistance to landowners and managers.

Attachments

Executive Summary

Ecological, Geomorphic, And Land Use History of the Carneros Creek Watershed: A Component of the Watershed Management Plan for the Carneros Creek Watershed, Napa County, California

Draft Final Report, June 9, 2003

By Robin Grossinger, Chuck Striplen, and Lester McKee: San Francisco Estuary Institute
Elise Brewster: Brewster Design Arts

Prepared For: Stewardship Support And Watershed Assessment In The Napa River Watershed: A Calfed Project. Calfed Contract No. 4600001703 Napa County Resource Conservation District

During 2002-2003, the San Francisco Estuary Institute, with the assistance of the Napa County Resource Conservation District, carried out a study of the historical ecology of the Carneros Creek Watershed. The resulting technical report is one of seven produced to inform the development of a watershed management plan through a participatory process that includes the community, natural resource agencies, and scientists.

To assess historical land use and associated changes within the watershed, we used a multifaceted approach to collect and synthesize a diverse range of information. This process included collecting numerous historical documents from the 19th and early 20th centuries, analyzing historical maps and aerial photography, interviewing local residents, and assessing field conditions with other project team members. Interpretations were analyzed in the context of the findings of the other technical teams through project team meetings.

The Carneros Creek watershed has been shaped by a unique and intensive history during the past 200 years and before. Descriptions in the earliest European accounts of the watershed provide direct evidence of indigenous management of the watershed through the use of fire. Following Spanish conquest, Carneros Creek was characterized by a land use history that diverges from other parts of the region, with relatively early, high intensity grazing during the Mexican Rancho era and persistent ranching activity through the 20th century. Several inherent geographic and physical characteristics of the watershed have helped reduce population growth and the maintenance of ecological resources. These include relatively limited groundwater resources; a naturally narrow, single-thread channel; and Carneros' particular geographic position away from the major fertile valleys of the North Bay, and bordered by the vast Napa-Sonoma marshlands.

Direct major alterations to the stream channel, such as straightening and the removal of side channels, have been relatively limited. As a result, the channel network plan form has not been as dramatically altered as in most other local streams. The Carneros Creek watershed has maintained a relatively high level of ecological resources through historical times and displays significant potential for restoration and enhancement of stream, valley, and hillside habitats.

This Historical Ecology report presents a number of specific implications for future management of the watershed; these are listed below. The report also provides a detailed summary of land use history and historical information resources, which are intended to provide a basis for answering subsequent questions about the watershed history.

1. Carneros Creek was noted as a good spot for steelhead fishing in the 19th century, but was also probably never an exceptional steelhead stream because it is naturally "flashy" and seasonally dry. However, the massive modifications experienced by most rivers and streams in the region have

probably increased Carneros' value relative to other Bay Area and Napa Valley streams. While most migration routes through the Bay require difficult passage through agricultural or urban areas with associated contaminants and flood control channels, or past the Delta water supply pumps (Leidy pers. comm.), anadromous fish approaching Carneros Creek from the Bay have a direct route from the Napa River marshlands to the creek mouth. Once in the creek, fish encounter relatively few major road or railroad crossings and no major dams. As a result, Carneros Creek may have particular long-term importance as a viable steelhead stream.

2. Historical evidence indicates that Carneros Creek did not have a substantially broader riparian corridor prior to European land use. Also, unlike many other local streams (e.g. Soda Creek (Pearce et al. 2002), Carneros has not experienced the loss of low-gradient meanders or overflow channels. As a result, the current system is not compromised by the loss of major channel/riparian components. Restoration should focus on watershed processes responsible for the maintenance and improvement of existing channel and riparian canopy.

3. Carneros naturally maintained a well-defined, relatively incised channel across the valley floor into tidal waters. This historical characteristic is in contrast to other small streams for which connecting ditches or flood control channels had to be constructed, often resulting in persistent sediment deposition problems requiring regular dredging (SFEI 2001).

4. While the stream appears to have been relatively incised according to mid-19th century mapping, additional incision may have taken place and could be assessed by field comparison to historical data, dating of exposed tree roots, and other field indicators.

5. There is evidence that pool habitat in the lower reaches, which is currently of poor quality, was substantially better in the past. Summer stream flow, while naturally limited and intermittent during historical times, does appear to have decreased in recent decades. Groundwater levels in the lower watershed have been reported to be quite susceptible to diminishment by pumping, which would likely reduce stream base flow and pool persistence.

6. Riparian habitat in the lower watershed has been extremely dynamic. This indicates that the tree canopy can respond rapidly in response to favorable conditions. However, there is also strong indication of potential loss of riparian trees in the near future, which could have significant detrimental effects to creek shading and aesthetic value [see *Channel Geomorphology* and *Fish Habitat Assessment* reports.

7. Grazing pressure in the watershed was severe by the mid-19th century, such that impacts to sediment dynamics are likely by the time of the 1862 floods, which could have mobilized large amounts of sediment. While no specific effects could be identified at this time, a high level of grazing activity was documented, which may have present-day effects. Intensive ranching on the Alexander property prior to 1993 is also probably still having downstream effects. Assessment of current in-stream sediment problems should attempt to distinguish between sources caused (and potentially solved) by current activities and those triggered by management in previous eras.

8. Substantial parts of the watershed have been subject to over a century of agriculture and associated plowing, vegetation removal, and other practices which could also be responsible for sediment production. Obvious downstream effects were not found in this study, but as in the case of grazing, may nevertheless be present and should be considered as analysis and management of the watershed continues.

9. General extent and stand density of chaparral and woodlands appears to have increased in the upper watershed, likely due to reduced fire frequency. This change in vegetation may pose a threat for larger fires in the future. Besides the obvious cultural impacts, significant fire, particularly in late summer before substantial rains, could cause large delivery of sediment to the stream.

10. Native management activity in all likelihood had a significant influence upon the composition, distribution, abundance, and productivity of most habitats in the watershed for a very long period of time. Some aspects of native management practices may be useful tools for the future. For example, despite extensive changes remnants of native grassland still exist in the watershed (Graves pers. comm.), constituting a valuable local resource. Restoration and expansion of these native grasslands, potentially with the use of fire, could provide benefits to soil structure, stream flow, and local ecology that could be explored through further research. Trial projects to test management approaches and ecological results could be initiated and would have significance to grasslands management research in the greater region.

EXECUTIVE SUMMARY

Channel Geomorphology Assessment: A Component of the Watershed Management Plan for the Carneros Creek Watershed, Napa County, California

By Sarah Pearce and Lester McKee: San Francisco Estuary Institute
Matthew O'Connor: O'Connor Environmental, Inc.
Blaine Jones: Napa County Resource Conservation District

Prepared For: Stewardship Support And Watershed Assessment In The Napa River Watershed: A Calfed Project. Calfed Contract No. 4600001703 Napa County Resource Conservation District

In 2001 a group of concerned stakeholders formed the Carneros Creek Stewardship. The stewardship's mission is to preserve and maintain the natural, economic and human resources in watershed, provide education, initiate watershed assessment and restoration, and create a sustainable stewardship group. The group constructed a set of management questions, and helped to instigate this multi-disciplinary science project to help answer these questions. This report is one of seven technical reports written to inform the development of a watershed management plan through a participatory process that includes the community, agencies and scientists. It was made possible through funding from a project entitled "Stewardship Support and Watershed Assessment in the Napa River Watershed". The Napa RCD led CALFED project also provides the same kind of support for the Stewardship of Sulphur Creek in the head of the Valley and confluent to Napa River in the town of St. Helena.

During the summer and fall of 2002, empirical observational data was collected to assess the geomorphological condition of Carneros Creek. This technical report describes the methods, results and conclusions derived from that assessment. This report will be integrated with the other six technical reports by the project partners in close consultation with the Carneros Creek Stewardship to create a management plan for the local community and the Carneros Creek watershed.

Carneros Creek is a western tributary to the Napa River, entering the river approximately 8 km (5 mi) south of the town of Napa. The lower and middle watershed consists primarily of vineyards and suburban residential areas. The upper watershed is primarily grazing, with some open space, vineyards, and residential areas. Carneros Creek historically and currently supports salmonid spawning and rearing, while also providing habitat for other aquatic species. Data collected in this channel geomorphic assessment include surface and subsurface grain size measurements, channel cross-section geometry, channel slope, bank and riparian vegetation characteristics, bank condition, large woody debris (LWD) in the bankfull channel, debris jams, number, type and volume of bars and sediment deposits, number, type and residual depth of pools, indicators and volume of bank erosion, and type and condition of bank revetment.

Surveyed cross-sections illustrate the wide variety of channel morphologies observed throughout the watershed, including the lower entrenched reaches, the middle bedrock-dominated reaches, and the upper shallow and boulder-dominated reaches. Surface and subsurface sediment size analyses suggest that the lower reaches of Carneros Creek are storing moderate amounts of fine sediment (< 2 mm), while the middle and upper reaches are storing low amounts. The majority of Carneros Creek has a nearly continuous riparian corridor. LWD is important in pool formation, with almost 50% of all pools measured either formed by or associated with a LWD piece. In addition, Carneros Creek contains a wide range of residual pool depths, ranging from 0.2 m (0.7 ft) to 1.5 m (4.9 ft). Sediment deposits and bars were measured in all reaches of the creek, with deposit type and volume generally correlated to bankfull channel cross-sectional area. Approximately 90% of the total volume of measured sediment deposits are stored in 50% of the total number of deposits. Most (92%) sediment deposits have been active within the past five years, illustrating the mobility of sediment stored in Carneros Creek.

Despite the surface storage of moderate amounts of fine sediment in the lower reaches, the subsurface sediment samples in these same reaches reveal that sediment size distributions are within documented ranges for successful steelhead spawning. It appears that suitable gravel patches and hydraulic locations for spawning are reasonably abundant, especially in the middle reaches. Channel bank erosion is the largest contributor of sediment to the channel, especially in the middle reaches. However, reaches with large amounts of measured bank erosion also have large volumes of sediment storage. The lowest reaches, especially adjacent to residences have the largest length of bank revetments and modifications to the channel morphology.

The habitat in Carneros Creek is currently able to maintain a steelhead population. Salmonid success is primarily limited by the lack of perennial flow in all reaches. The middle reaches contain perennial discharge, fed by a groundwater spring. However, the channel is completely dry upstream of this spring, and is partially dry in the lower reaches where only isolated pools persist. The best salmonid spawning and rearing habitat is provided in the middle reaches because these reaches provide the best combinations of perennial discharge, spawning gravels, pool spacing, pool depth and cover, riparian shading and channel complexity.

The riparian corridor in the lower reaches is typically only a single mature tree in width. Because the channel is entrenched and these trees are being undercut, the riparian canopy is in jeopardy of being significantly modified in the future. The loss of the riparian vegetation would increase the number of scour elements in the channel, but would also decrease bank stability and increase the amount of sunlight to the water. Throughout Carneros Creek, LWD is important in the channel form and function. LWD pieces provide pool-forming agents, provide cover, and help to regulate the transport of sediment and nutrients. Although the middle reaches have the highest amount of measured bank erosion, these reaches also have high amounts of local sediment storage. Besides providing steelhead spawning and rearing habitat, Carneros Creek also supplies other resources to watershed residents including flood conveyance, habitat for wildlife and other aquatic species, and an aesthetically pleasing setting to live, work and play.

Executive Summary

Fish Habitat Assessment: A Component of the Watershed Management Plan for the Carneros Creek Watershed, Napa County, California

By Jonathan Koehler, Napa County Resource Conservation District

Prepared For: Stewardship Support And Watershed Assessment In The Napa River Watershed: A Calfed Project. Calfed Contract No. 4600001703 Napa County Resource Conservation District

A fish habitat assessment of Carneros Creek was performed to examine current conditions within the stream that impact aquatic organisms and fish, specifically steelhead (anadromous rainbow trout, *Oncorhynchus mykiss*). The objective of this study was to identify key elements affecting fish habitat and make recommendations to improve and restore the health of the stream. The assessment included habitat-typing surveys, water temperature monitoring, reviewing and summarizing existing data, and GIS analysis. Other habitat conditions were also examined including migration barriers, and suitability of spawning habitat. The fish habitat component is intended to integrate with other technical tasks on geomorphology, water quality, hydrology, sediment delivery, and historical ecology.

Fish habitat conditions were inventoried using CDFG habitat-typing protocols focusing on life history requirements of steelhead. This study found that perennial fish habitat is limited to the middle reaches of Carneros Creek, which begin near Old Sonoma Bridge and extend upstream approximately 4.2 miles until the channel goes dry. The portion of Carneros Creek between the Napa River and Old Sonoma Bridge functions as a migration corridor for steelhead, but does not provide adequate summer rearing habitat due primarily to the absence of stream flow. Some deep isolated pools in this lower portion may support small numbers of fish, but overall they do not contribute a significant amount of favorable habitat. The upper reaches of Carneros Creek were completely dry during the survey, which is the typical pattern during summer months according to local landowners. The upper dry reach does not provide rearing habitat, but spawning may occur in suitable sites during winter when flow is present. Young fry could then migrate downstream to suitable rearing pools in the middle reaches. Adult spawning surveys and redd counts in the upper reach would offer a more distinct upstream limit to steelhead.

Tributaries to Carneros Creek were not surveyed due to absence of water. Several spot visits confirmed the overall lack of summer rearing habitat within tributaries. Two intermittent streams are tributary to the middle reaches of Carneros Creek, and they may provide suitable spawning habitat that functions similarly to the upper dry reach of the main stem. After emerging, young fish would be forced to migrate quickly downstream into perennial main stem pools to survive the summer.

In general, pool habitat is lacking good quality cover such as large woody debris (LWD) for juvenile steelhead rearing throughout Carneros Creek. Pool cover is especially lacking in Reaches 1 and 2, where many young-of-year were observed in open water without hiding refugia from predators such as birds. Reach 3 had abundant pools with suitable cover elements including root masses and aquatic vegetation. These pools had the highest number of observed fish including several age classes of steelhead.

Fish were observed throughout the survey including juvenile steelhead, threespine stickleback, California roach, and sculpin. Several large trout were seen in reach 3, which were likely resident fish. The lower reaches had predominantly roach and stickleback in isolated pools. Only one age class of steelhead (young of year) were observed in reach 1. This suggests that few juvenile steelhead successfully overwintered due to lack of high-flow refugia, seasonal drying, or predation in this reach.

Summer water temperatures in pools appear to be suitable for steelhead rearing in reach 2 and 3. Water temperatures measured in reach 1 reached levels above the physiological "comfortable" range for steelhead; however the pools in this lower reach do not appear to provide suitable rearing habitat due to a combination of no flow and poor water quality. The duration of slightly elevated water temperatures in lower Carneros Creek was not extensive, and these conditions probably do not have chronic impacts on growth rates or fitness. In reach 2, water temperature monitoring showed a very favorable and narrow range of daily temperatures within a representative bedrock pool. Peak values in the middle reach were well below steelhead stress levels.

The best available habitat for steelhead spawning and rearing is presently in reach 3 and parts of reach 2, which span about 2 miles. Deep pools with good cover and spawning gravels are more frequent in these two reaches than lower in the stream. Steelhead habitat in reach 2 and 3 currently makes the most significant contribution to the population, and appears to be where the majority of fish are located. It is not clear whether the habitat conditions in these reaches reflect historic conditions for most of Carneros Creek. Efforts to expand the extent of this high-quality habitat could have a great benefit to the population within Carneros Creek.

Several potential migration barriers were identified along Carneros Creek including the extensive dry lower reach. It is important to maintain the extreme lower extent of the stream as a migration corridor for adults and smolts; however, in a given year, the dry lower part of Carneros probably presents a complete barrier to outward migration during late spring and early summer. Improvements to the lower part of the stream that create more favorable habitat conditions within the creek would increase the odds of a stranded steelhead smolt surviving the dry season in the lower reach. Other potential partial migration barriers include two concrete summer dams in reach 2 and 3, and a bedrock cascade with a small concrete dam in reach 2. These dams do not prevent fish passage, and likely do not present a major obstacle under most high and moderate flows. However, they have the potential to limit outmigrating smolts during low flows and possibly adults that are moving upstream at the tail end of a high-flow event. Modifying these structures to allow for complete fish passage would not be difficult.

Riparian canopy density is generally high throughout Carneros Creek. Throughout the survey, much of the immediate stream canopy is provided by mature oaks and bays with large exposed root masses along the bank. The stream has a relatively narrow riparian tree zone, and the loss of these trees may have a deleterious effect on water temperature and water quality. Improving the long term viability of the riparian canopy by stabilizing stream banks and planting second-growth trees would allow for natural succession without compromising the aquatic habitat.

Successful steelhead spawning appears to occur primarily in reach 2 and 3 where good spawning gravel is abundant. Analysis of spawning gravels in reach 1 and the areas downstream show levels of fine sediment that are not favorable to salmonids. Values for several sites indicate amounts of fine sediment that are near levels that begin to significantly impact spawning success. The amounts of fine sediment in these reaches are not as important directly to steelhead spawning however since this part of the stream does not provide suitable year-round habitat.

Executive Summary

Sediment Source Assessement: A Component of the Watershed Management Plan for the Carneros Creek Watershed, Napa County, California

By Pacific Watershed Associates

Prepared For: Stewardship Support And Watershed Assessment In The Napa River Watershed: A Calfed Project. Calfed Contract No. 4600001703 Napa County Resource Conservation District

In March 2002, Pacific Watershed Associates was contracted to conduct a sediment source assessment as a part of the watershed management plan for the Carneros Creek watershed. The assessment consisted of 3 work elements to identify past and potential sediment sources that may be affecting water quality and fish habitat. The first phase of the assessment included a historic air photo analysis of the 1942, 1985 and 2002 air photo periods. The historic air photo analysis was conducted to record road construction, land use, landslide and stream channel disturbance histories for the Carneros Creek watershed.

The second phase of the project involved a systematic field inventory of road systems in the watershed to identify road-related sites that pose a risk of sediment delivery to streams. Sites of potential sediment delivery identified in the road inventory were characterized and quantified, and prioritized treatment prescriptions were suggested to reduce or eliminate future erosion and sediment delivery. The second phase of the assessment also included a stream channel erosion assessment of selected tributaries to identify sites of past and future erosion and sediment delivery and the need for erosion control and erosion prevention treatment.

Finally, Phase 2 of the assessment also included a field review and reconnaissance sampling of non road-related sediment sources associated with a variety of other land uses including viticulture, reservoir development and maintenance, grazing and rural residential development. Land use practices were evaluated in the field for their contribution to erosion and sediment delivery to streams.

The third phase of the sediment source assessment involved the development of a prioritized erosion control and erosion prevention treatment plan to cost effectively control current and potential road-related erosion and sediment delivery. It also included a cursory evaluation of the magnitude of past sources of erosion and sediment delivery in the watershed, as well as an evaluation of current non road-related land use practices that may still be contributing erosion and sediment delivery to streams.

Phase 1- As of the 2002 air photo period, approximately 43 miles of road had been constructed in the Carneros Creek watershed. Of the 43 miles of road, 23 miles (52%) were constructed as of the 1942 air photo period, 14 miles (33%) were constructed as of the 1985 air photo period and 6 miles (14%) were constructed as of the 2002 air photo period. The majority of roads in the watershed were constructed along the mainstem of Carneros Creek and along the eastern hillslopes of the watershed. Very few roads were constructed on the steep western slopes of the watershed.

As of the 1942 air photo period, land use in the Carneros Creek watershed was dominated by grazing and agricultural activities such as orchards and other activities excluding vineyards. Between the 1942 and 2002 air photo periods, grazing activity and non viticulture activities decreased in the watershed. By the time of the 2002 air photo period, vineyard development had increased dramatically through the conversion of grazing and “other” agricultural areas. Rural residential development in the watershed increased slowly over the entire air photo period.

One hundred one (101) landslides were identified in the historic air photo analysis. Landslide types included debris landslides and debris flows. The majority of the landslides occurred on the eastern side of the Carneros Creek watershed and appeared to be controlled by the local geology rather than by management-related activities. Approximately 11,500 yds^3 of sediment was estimated to have been delivered to Carneros Creek and its tributaries as of the 2002 air photos. The majority of landslides occurred in grassland settings within steep headwall swale areas and on streamside slopes.

Phase 2-Roads- Approximately 24 miles of road were field inventoried to identify road-related sites of current and future sediment delivery to streams. Two basic types of erosion were identified in the road assessment including episodic erosion and persistent or chronic road surface erosion. Episodic erosion occurs in response to large and infrequent storms and includes stream crossing washouts and road-related landslides and gullying. Persistent road surface erosion is caused by excessive road and ditch lengths that are "hydrologically connected" to streams. Road surface erosion is generated from the mechanical breakdown of the road surface from vehicle use, cutbank erosion and failures, and ditch erosion.

A total of 147 sites of future episodic erosion and sediment delivery were identified from the 24 miles of inventoried road. Of the 147 sites, 128 were recommended for erosion control and erosion prevention treatment including 90 stream crossings, 7 potential landslides, 16 ditch relief culverts and 15 "other" sites. Approximately 11.4 miles of road were identified as "hydrologically" connected to streams along roads inventoried in the Carneros Creek watershed. Of the 11.4 miles of connected road, 10.3 miles were recommended for erosion control and erosion prevention treatment. If left untreated, it is estimated that up to 11,030 yds^3 of fine sediment could be delivered to streams. Other treatments include upgrading stream crossing culverts to handle the 100 year design storm flow, excavating potential road-related landslides that could deliver sediment to streams, and disconnecting the road surface and ditch from streams and stream crossing culverts.

Treatments in the watershed were prioritized based on their immediacy and included consideration of factors such as the potential volume of sediment to be delivered to streams, the likelihood of future erosion, the urgency of treating the site and the ease and cost of the accessing the site for treatment. Costs to implement treatments along the 24 miles of inventoried in the Carneros Creek watershed is estimated at approximately $493,000. The cost estimate includes the costs to upgrade approximately 6 miles of county maintained roads.

Stream channels- Approximately 3.7 miles of tributary channel was inventoried to identify past, current and future sediment sources that could deliver sediment to the stream system. A total of 47 sites with >20 yds^3 of past and/or future erosion and sediment delivery were identified in the assessment. From the 47 sites, approximately 2,306 yds^3 of sediment have been delivered to streams in the past and nearly 965 yds^3 is estimated to be delivered in the future. Of the 47 sites, 45% of the sites were classified as bank erosion and 41% were classified as debris landslides. Approximately 49% had no apparent management cause, 27% were associated with grazing activities, 13% were associated with reservoirs and 2% of the sites were associated with the road system. Ninety-four (94) small sites (<20 yds^3) were also identified in the assessment. Approximately 1,170 yds^3 of sediment is estimated to have been delivered to streams from these small features.

Other sediment sources- Reservoirs, grazing activities, viticulture and rural residential activities were evaluated as part of the non road-related sediment source sampling. Fifty-seven reservoirs were identified in the Carneros Creek watershed constituting approximately 2% of the total watershed area. Of the 57 reservoirs, 19 were classified as on-stream reservoirs and these collect runoff from approximately 32% of the watershed area. The majority of observed erosion from reservoirs resulted from a few reservoir outlets where flow discharged onto unprotected slopes causing large hillslope gullies.

In general, reservoirs act as large effective sediment retention traps allowing the majority of fine and coarse sediment transported from upstream areas to settle out before flow is released into a natural stream. Although reservoirs can be used as sediment traps, sediment infilling can occur and result in lowered capacity and an increase in the likelihood of failure and overtopping. Reservoirs should be monitored regularly it they are used as sediment traps.

Grazing activities were observed in the northeastern portion of the Carneros Creek watershed. The majority of erosion from grazing activity resulted from the trampling of steep stream banks in the upper portions of the watershed. No exclusionary fencing was noted to keep cattle away from unstable stream banks which resulted in stream bank failures and surface erosion.

Five vineyard plots were inspected in the watershed to assess impacts of vineyard related erosion and sediment delivery. Vineyard plots ranged in size from 1.6 acres to 28.2 acres. The majority of erosion from vineyards consisted of sheet, rill and gully erosion along bare sections of vineyard rows and along long sections of undrained vineyard avenues. Rilling and gullying on vineyard slopes was more prominent on steeper slopes (>10%). Once cover crops were established along vineyard rows, rilling and gullying were significantly reduced in the observed vineyards. Another source of erosion from vineyards resulted from slope drainage pipes that discharge flow onto stream banks above the stream channel causing local stream bank collapse and/or gullying.

Past sediment sources- The largest sources of erosion and sediment delivery in the Carneros Creek watershed over the past 50 years resulted from road-related chronic surface erosion and gullying (29%), mainstem bank erosion (26%), and vineyard surface erosion (20%). The estimate of past erosion and sediment delivery from roads is a minimum because it does not include past erosion from stream crossing washouts and small road-related landslides that have been repaired and are no longer visible. The estimate of past erosion and sediment delivery from vineyard surface erosion may be high since 35% of the active vineyards drain to reservoirs that may act as large sediment traps.

Of the past sediment sources assessed in the Carneros Creek watershed, management-related erosion and sediment delivery can be reduced through a variety of land management treatments. Road-related erosion and sediment delivery can be addressed by disconnecting road the road system from streams by applying adequate road drainage, upgrading stream crossings to the 100-year design storm flow and excavating landslides that could deliver to streams. Road-related erosion and sediment delivery is the most easily identified and the most cost effectively treated sediment source in the watershed.

Vineyard surface erosion can be reduced through the more extensive application of cover crops along vineyard rows and avenues before the winter period. In vineyards which currently drain to streams, local improvements can be made so that slope drainage discharges into sediment retention traps or is downspouted directly to streams. Vineyard avenues should be disconnected from the stream system through the installation of road surface drainage structures such as ditch relief culverts, rolling dips and/or water bars.

Surface erosion associated with grazing activities can be reduced through the rotation of cattle to prevent over grazing. Exclusionary fencing can be useful to keep cattle away from sensitive hillslope areas and erodible or potentially unstable stream channel banks.

In contrast to management-related erosion and sediment delivery, bank erosion along the mainstem and tributary stream channels can be difficult to control. Engineered structures can be constructed to control bank erosion but they can be costly and potentially ineffective. The key to reducing sediment production and delivery in the Carneros Creek watershed should not be to control natural erosion and sediment delivery, but to reduce the amount of management-related erosion and sediment delivery to the stream system through the application of relatively straightforward and cost-effective erosion prevention measures and land management actions.

Executive Summary

Water Balance Study: A Component of the Watershed Management Plan for the Carneros Creek Watershed, Napa County, California

By Bob Zlomke, P.E., Napa County Resource Conservation District

Prepared For: Stewardship Support And Watershed Assessment In The Napa River Watershed: A Calfed Project. Calfed Contract No. 4600001703 Napa County Resource Conservation District

This is one of a series of technical reports prepared under a grant from the CALFED watershed program. It is intended to provide technical support for a watershed management plan for the Carneros Creek watershed, responding to stakeholder interest in water quantity issues.

A Thornthwaite-type water balance model was developed for the watershed, using estimates of monthly precipitation and potential evapotranspiration (PET) to estimate actual evapotranspiration (AET) and runoff, based on the estimated soil storage capacity for the watershed.

Data used include long-term monthly average rainfall at Napa State Hospital (NSH) and estimated monthly average values of PET provided by the California Irrigation Management Information System (CIMIS). NSH rain data are amplified by 15%, so that the rainfall in an average year is consistent with mapped information for Napa County. PET values are multiplied by a landscape coefficient that is a weighted average of estimated values for wooded grasslands, rural residential land, and vineyards. AET is estimated on the basis of PET by use of the original Thornthwaite method.

The model distinguishes between quick runoff, which runs off immediately without infiltration, and slow runoff, which contributes to soil moisture recharge before it enters the runoff stream. Quick runoff is estimated in the model by the use of a parameter which defines the fraction of monthly precipitation which runs off immediately; it is defined only for the period from December through March. Slow runoff is estimated each month on the basis of a second parameter, which defines the fraction of available water (water beyond that required to satisfy soil moisture needs) which runs off. There is no separate accounting of groundwater storage; rather, recharge of groundwater is included in total runoff.

The model was calibrated using flow information at Old Sonoma Road Bridge collected from December 2001 through June 2002. The model showed a tendency to overpredict total runoff, which may reflect the inclusion of groundwater recharge in runoff. The sensitivity of the model to variations in landscape coefficient and soil moisture capacity was explored.

The basic water balance for an average year was calculated (Figure 5), displaying typical characteristics of California streams, with a rainy season peaking in January and a dry season at its driest in July and August. Modeled streamflow begins to rise in December; it roughly follows the rise and fall of rainfall from then until midsummer, when the stream slows to a trickle. The model shows essentially no streamflow from September through November. Actual ET follows potential ET quite closely from October through April but then is reduced from the potential, as the ground begins to dry out; when rainfall begins to pick up again in September, actual ET begins to recover immediately as well.

Of the 710 mm of rainfall in an average year, a total of 371 mm runoff is estimated by the model, for an overall runoff coefficient of 0.52.

The model was used to simulate the water balance in years that were significantly wetter or drier than average. Two recent water years were selected, 1996-97 and 1986-87, with a rainfall total approximately one standard deviation above and one standard deviation below the mean, respectively. In both these extreme years, the model gives a convincing quantitative picture of the shifting water balance resulting from this particular distribution of rainfall over the water year.

Runoff estimated by the model for an average year compares favorably with an estimate prepared by the State Division of Water Rights for Carneros Creek and with a recent application of the Thornthwaite method in the Tomales Bay Watershed. However, comparison of these modeled values with regional work would suggest that both models are overpredicting runoff. The explanation may lie in the fact that both the Tomales study and the present work follow the original Thornthwaite method in not distinguishing groundwater recharge from surface runoff.

The model can be greatly improved as more local rainfall data and more years of measured flow become available. These data will make possible much more exact calibration of the model, so that the following potential additions to the model may be considered:

- Groundwater recharge and extraction
- Timing of withdrawals from the stream and their return to the atmosphere as ET
- Variation of vegetative cover, soil moisture capacity and precipitation through the watershed

These additions will require the development of data representing the variability of the relevant processes over the watershed and over the water year.

Water Quality Study: A Component of the Watershed Management Plan for the Carneros Creek Watershed, Napa County, California

By Jonathan Koehler, Napa County Resource Conservation District

Prepared For: Stewardship Support And Watershed Assessment In The Napa River Watershed: A Calfed Project. Calfed Contract No. 4600001703 Napa County Resource Conservation District

1.0 Introduction

Water quality is a key factor affecting fish and other aquatic organisms within a stream ecosystem. This is especially true of salmonids including steelhead (anadromous rainbow trout, *Oncorhynchus mykiss*), which have narrow tolerances for a variety of water quality parameters. In reaches of Carneros Creek that experience drastic seasonal recessions of surface flow during summer and fall, water quality plays a critical role in the quality of summer rearing habitat for juvenile steelhead. As stream flows diminish in late spring and early summer, steelhead and other resident fish are forced into isolated pools for the duration of the summer. During this time, water quality can quickly degrade without the flushing effects of continuous surface flow. Subsurface flow through the substrate is a vital source of new fresh water, but in the absence of agitation it contributes little or no dissolved oxygen.

Benthic macroinvertebrates are good indicators of water quality and overall stream function over time. Samples taken from several locations along the stream will reflect environmental conditions within the aquatic ecosystem. Certain organisms are highly intolerant to a variety of pollutants including sediment, nutrients, and temperature. Taxonomic analysis of such samples yields information on the benthic community which relates to water quality in the stream. Essentially the quality of the water can be determined based on what organisms are present within a given reach of stream.

2.0 Methods

Water quality was measured in Carneros Creek to establish a limited baseline for current conditions within the stream. The objective of this study was to establish monitoring sites along the stream and to collect water quality data using field tests that can be conducted by volunteers. These tests include dissolved oxygen (D.O.), electrical conductivity (E.C.), pH, water temperature, and air temperature. Additional information on physical habitat is also collected including water color, odor, weather, stream bed appearance, water depth, flow, and habitat change.

All water quality tests were done using the Napa County RCD stream monitoring protocol. One site was selected in the lower reach (CAR-1) near Old Sonoma Road bridge where surface water was present in late summer. Another site was established in the middle reach (CAR-2) to get a satisfactory geographic range along the stream. It was obvious at the onset of the site selection process that suitable monitoring sites would be limited by the presence of water. Surface flow was present in mid June at CAR-2, but there was no surface flow in the lower site, CAR-1. Further, sites were selected based on their potential to support fish which eliminated the far upper and far lower (below Old Sonoma road) sections of the stream. Samples were collected on an approximately monthly basis at both sites.

Dissolved oxygen, electrical conductivity (*specific conductance*), and water temperature were measured using a YSI-85 meter, which was calibrated prior to sampling. A hand held pH meter was used, which was also calibrated prior to sampling. Flow was estimated and categorized as brisk, moderate, low, or stagnant. Water depth at time of sampling was visually estimated.

3.0 Water Quality Monitoring Summarized Results

PARAMETER	CARNEROS SITE 1 (CAR-1)	CARNEROS SITE 2 (CAR-2)
Sample Dates	8/1/02, 8/15/02, 9/12/02, 10/4/02, 12/6/02	8/1/02, 8/15/02, 9/12/02, 10/4/02, 12/6/02
Water Temperature (°C)		
Range	8.2 - 18.4	7.9 -16.3
Maximum	18.4 (8/15/02)	16.3 (8/1/02)
Minimum	8.2 (12/6/02)	7.9 (12/16/02)
Air Temperature (°C)		
Range	12.5 - 21	11.5 - 23
Maximum	21 (8/15/02)	23 (8/15/02)
Minimum	12.5 (12/6/02)	11.5 (12/6/02)
Dissolved Oxygen (mg/L)		
Range	1.2 - 4.2	2.1 - 8.8
Maximum	4.2 (10/4/02)	8.8 (12/6/02)
Minimum	1.2 (12/6/02)	2.1 (9/12/02)
Dissolved Oxygen (% Sat.)		
Range	10.2 - 39.1	19.9 -74.1
Maximum	39.1 (10/4/02)	74.1 (12/6/02)
Minimum	10.2 (12/6/02)	19.9 (9/12/02)
pH (units)		
range	6.3 - 7.8	7.0 - 8.0
Maximum	7.8 (10/4/02)	8.0 (9/12/02)
Minimum	6.3 (12/6/02)	7.0 (12/6/02)
Electrical Conductivity (µS/cm)		
range	923 - 1349	608 - 829
Maximum	1349 (9/12/02)	829 (10/4/02)
Minimum	923 (8/1/02)	608 (12/6/02)
Flow category	No flow during sampling period. Isolated pools	Low flow during first two samples ended in Sept. then returned in Dec.

TABLE 1. Water Quality Summary Table

Results from water quality monitoring provide limited baseline information on conditions within the stream environment during the late summer and fall. This is the period when cold water fish, including juvenile steelhead, in arid California streams experience the most stress from declining water quantity and quality. Water quality generally improves during winter as storms introduce fresh water. However a different set of water quality stressors can have an impact on both juvenile and adult fish. These are chiefly turbidity, extreme low temperatures, and the effects of urban and agricultural runoff. It is therefore important to conduct year-round water chemistry monitoring that is supplemented with macroinvertebrate samples throughout the stream.

Steelhead have a narrow tolerance range for DO and require generally well-saturated water to thrive. Temperature affects how much DO water can hold (Mitchell et al., 1995). As temperature rises, the amount of dissolved oxygen decreases and vice versa. When water holds all the dissolved oxygen it can hold at a given temperature, it is 100% saturated. Steelhead and other salmonids require high levels of DO saturation in order to thrive. Streams with DO levels above 90% saturation are considered best for maintaining healthy steelhead. There is a great deal of variation from one population to another in terms of how well the fish are adapted to tolerate reduced DO levels. Rainbow trout living in reservoirs for example often encounter water less than 90% saturation. Favorable levels of DO are 6 mg/L or greater. General guidelines suggest that stream dwelling rainbow trout (and steelhead) can tolerate DO levels as low as 4 mg/L before a metabolic compromise is initiated (Moyle, 2002).

Carneros Creek had low measured DO levels at both sites during the late summer and early fall. Rainbow trout were observed at sampling site CAR-02 throughout the study, suggesting that the fish were either able to tolerate low DO or had located a stratified area of the pool with higher levels than measured. These fish may have been able to tolerate lower DO levels due to the relatively cold water temperatures at this site, which would reduce metabolic rates during the warmest months. The DO levels at the lower CAR-01 site were too low to support even well-adapted juvenile steelhead during the summer rearing period.

The ranges of pH and electrical conductivity were within general guidelines for suitable rearing habitat. There was very little variation in pH at both sites. Electrical conductivity at site 2 increased as summer progressed into fall, then fell with the return of surface flow.

3.1 Benthic Macroinvertebrate Sampling

Benthic Macroinvertebrate (BMI) sampling was conducted in the lower reach of Carneros Creek near Old Sonoma Bridge by EcoTrust Environmental Inc in 2000 and 2001. The data from 2001 is still being analyzed by the laboratory and will be available in April, 2003. Samples were collected using the CDFG Rapid Bioassessment protocol, which collects three replicate BMI samples per site in randomly selected riffles. The protocol is designed to eliminate, or greatly reduce, sampling bias within a sample reach. Sample reaches are defined as a series of five riffles, of which three are randomly selected. Three areas along a transect within the riffle are then agitated to dislodge BMI's within the substrate and wash them into a net. The contents of the net are then emptied into an alcohol-filled jar for analysis by a laboratory.

Table 2 summarizes the data from 2000 using standardized macroinvertebrate classifications and metrics. The data from this sampling effort are being compared to a preliminary IBI (Index of Biological Integrity) for the Russian River basin to roughly determine water quality. The IBI uses 5-6 key biological metrics calculated from a sample to rank the stream reach in terms of water quality. The following metrics were selected and integrated into a single scoring criteria: Taxa Richness, EPT Taxa, Modified EPT Index, Shannon Diversity, Tolerance Value and Percent Dominant Taxa. The EPT indices represent three sensitive taxa of aquatic insects: *Ephemeroptera* (Mayflies), *Plecoptera* (Stoneflies), and *Trichoptera* (Caddisflies). These three groups are excellent indicators of various water quality parameters including temperature, sediment, and nutrient loading. To date, no IBI has been developed in Napa County, but efforts are being made to develop such a scoring system.

To calculate a ranking for any given site, the values for each metric (e.g. Taxa richness, EPT Taxa) is compared to the Visual Distribution Score ranges and given a score of 5, 3, or 1. A score is given for each of the six metrices. These scores are then added together to form a composite score (with a possible total of 30 points) that can be compared with other sites and rated using the scale below. In general, higher composite scores indicate better water quality.

Biological Metric	Visual Distribution Score		
	5	3	1
Taxa Richness	≥36	35-26	<26
% Dominant Taxa	≤14	15-39	>39
EPT Taxa	≥19	18-12	<12
Modified EPT	≥54	53-17	<17
Shannon Diversity	≥3.0	2.9-2.3	<2.3
Tolerance Value	≤3.0	3.1-4.6	>4.6

Using this preliminary IBI, a sample can be scored using the following scale:

Excellent	Good	Fair	Poor
30-24	23-18	15-11	11-6

The scale has been modified for Napa data, which does not include a modified EPT Index:

Excellent	Good	Fair	Poor
25-21	20-16	15-11	10-5

Using the modified Napa scoring criteria, the sample collected in Carneros Creek was given a score of 7, which indicates poor water quality. In order to draw conclusions based on any water quality data, including BMI samples, a sufficiently large dataset must be analyzed. In light of the very limited data currently available on BMI populations within Carneros Creek, it is prudent to only discuss the immediate implications of this data. Sampling one reach does not characterize the entire stream or even stream reach. The sample reflects conditions within a relatively narrow region of the stream and should be interpreted to reflect this limitation.

The sample contained a high number of *Baetis tricaudatus* mayflies that accounted for 67% of *Ephemeroptera* analyzed. This abundance of Baetids may reflect high levels of fine sediment. As a group mayflies are highly sensitive to pollution, but Baetids thrive in streams with large amounts of fine sediment. Baetids and Simulids accounted for 76% of the total sample, which suggests a generally unhealthy benthic distribution as reflected by this low diversity. Both taxa are relatively tolerant to pollution of various forms. In terms of abundance the sample ranked very highly, however it was dominated by these two tolerant taxa.

The dominant feeding group was collector-gatherer which accounted for 68% of the total. A more even distribution of functional feeding groups is favorable and indicates a stable stream environment. Almost no scrapers or shredders were found in the sample, which suggests a lack of organic material including woody debris.

4.0 Conclusions:

At the CAR-01 site several native minnows (California roach) were observed in early summer, but were not seen in later visits. It is likely that these fish survive the conditions present in the lower reaches, however young steelhead probably can not. Several young-of-year steelhead were observed in pools just upstream from this site in late summer, but it is unclear whether they survived the warmest months when temperatures increased and dissolved oxygen declined.

In the middle reach, water quality was significantly better but still not optimal for steelhead. Low levels of dissolved oxygen were measured during the summer when flows tapered off. Fish were observed in the deeper parts of the sampling pool, where they may have been in a slowed metabolic state to conserve energy. The temperature was consistently low, which may have contributed to the fish's ability to survive periods of depressed DO.

Very limited data are available for water quality within Carneros Creek. Observations from habitat-typing surveys were consistent with general trends seen in this limited dataset (Fish Habitat). In general the lower reach had lower habitat scores and poor water quality during summer and fall. Middle reaches provided more suitable habitat and had better water quality. To fully assess the water quality in the creek over time, sampling throughout the year combined with BMI results will yield a more detailed picture of the aquatic environment.

Although not optimal, summer water quality appears to be adequate to support young steelhead in the middle reaches of Carneros Creek and despite relatively low levels of DO (Table 1), fish were observed throughout the study. In lower Carneros Creek, water quality may not be sufficient to support juvenile summer rearing steelhead due to DO depletion and elevated temperatures. Peak water temperatures were generally elevated, which combined with the absence of flow created pool conditions with extremely low DO levels.

5.0 References

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Carneros Creek Watershed Management Plan

REFERENCE DOCUMENT

prepared for
Carneros Creek Stewardship
And Bay-Delta Authority Watershed Program

by
Napa County Resource Conservation District
with
San Francisco Estuary Institute
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Contents

Introduction

This Reference Document was developed as a companion document to the Carneros Creek Watershed Management Plan. To a large degree, the Reference Document synthesizes the information contained in the technical reports that were conducted as part of the watershed assessment that was completed in 2002 and provides the reader with information that is beyond the scope of the Management Plan. Specifically, the Reference Document provides a more thorough discussion of existing watershed conditions and recommended actions and monitoring. Much of the information contained in this document may be useful if a specific project is being considered or if a specific topic is of particular interest. However, the document is not meant to be a "stand alone" document. It is meant to be used in conjunction with the Watershed Management Plan, which is available on the Watershed Information Center and Conservancy WebCenter at www.napawatersheds.org

Existing Watershed Conditions

In the following discussion and throughout the Watershed Management Plan and this Reference Document, the term *lower* reach refers to the portion of Carneros Creek from the Napa River to Old Sonoma Road Bridge, the *middle* reach is the portion from the Old Sonoma Road Bridge to the end of the public portion of Henry Road, and the *upper* reach is the portion from there to the headwaters (Figure 5 in the Management Plan).

This section, like the Management Plan is broken down into several resource topics including riparian function, upland ecology, salmonid habitat, soil erosion, excess sediment, flood hazards, and water supply. Note that the topic of soil erosion and excess sediment where combined in the Management Plan and are separated here to allow for further detail. Additional information on each of these topics is available in the technical reports that were prepared in the process of completing the watershed assessment. These reports are available on the Watershed Information Center and Conservancy WebCenter at www.napawatersheds.org or can be provided as a CD from the Napa County Resource Conservation District.

Riparian Function

Vegetation along the creek is important to the function and health of the creek. Benefits of riparian vegetation include bank stabilization and erosion control provided by vegetation roots, water temperature regulation through shading of the creek, a source of food for the base of the food web (aquatic insects), recruitment of large woody debris (tree limbs, trunks and root wads) for fostering pool formation and channel complexity, protective cover for fish species, and a means of filtering runoff (trapping sediment and contaminants) before it enters the creek. In addition, riparian vegetation provides habitat, food, and a migration corridor for wildlife including birds, mammals, reptiles, and amphibians.

Currently in Carneros Creek:

- The riparian corridor is fairly continuous and well-developed. It provides shade essential for maintaining adequate water temperatures for cold-water fish and provides a mechanism for pool formation through potential recruitment of large woody debris. 45% of all pools in Carneros Creek are at least partially formed by scour around large woody debris. Canopy cover is generally high (averaging 91%) and is comprised of 74% evergreen tree species and 26% deciduous tree species. Tree species include: bay, eucalyptus, willow, oak, maple and alder. Some of the trees found today are non-native but still provide many of the functions that native riparian trees provide. Since historical times, significant portions of the corridor have been maintained.
- Mapping reveals that the total area of riparian vegetation along Carneros Creek and its tributaries has increased by 28% during the period from 1940 to 1993, possibly representing a re-establishment of historically present habitat, or possibly reflecting the establishment of a new condition in the watershed. It should be noted that increased vegetation along many of the tributaries to Carneros Creek account for this substantial increase in area. Average riparian corridor widths range from 26 to 65.5 feet (8-20 meters).
- Current observations show that the width of the riparian corridor is narrow along the lower reach of creek, downstream of the Old Sonoma Road Bridge. In this reach, a single row of mature bay and oak trees, many greater than 2.5 feet in diameter at the base of the trunk, comprise the majority of riparian vegetation along both sides of the creek. Some contradictory conclusions regarding riparian width along the lower reach exist. The narrow width could be due to thinning and removal. However, many Bay Area creeks historically had narrow riparian corridors and historical evidence suggests that the width has not changed significantly, despite potential width decreases associated with channel down cutting, streambank modifications, and/or clearing for land uses.
- The length of the riparian corridor along the lower reach has increased since 1858. The canopy extended 4,000 feet further downstream in 1942 than it did in 1858, and slightly further by 1999.
- Streambank erosion is threatening existing riparian vegetation. In the lower reach, bank erosion has caused many of the mature bay trees to become severely undercut, putting them at risk for falling into the channel in the near future. Normally, this type of large woody debris in the creek is viewed as a benefit; however, a single storm event could topple many of these trees. Loss of these trees would not only create a large gap in canopy cover, but also potential flood hazards, decreased bank stability, and negative effects on water temperature and quality.
- Some evidence of bank erosion and channel down cutting (incision) exists, especially in the lower and middle reaches. Evidence includes undercut trees and preserved terraces from previous channel bed elevation. Multiple terrace elevations are observed, however conclusive evidence regarding the timing of down cutting is not observed. Down cutting could have occurred as recently as during the past 50 years, or could have occurred over a much longer time frame. Tree coring in a few select locations would help clarify the timing of down cutting. Despite the evidence of potentially recent down cutting, evidence also exists that suggests that the channel has not significantly changed its form. The

channel appears to be incised on the 1858 USCS map, has not undermined the bridge at Old Sonoma Road built in 1896, and remains unchanged in the memories of local residents.
- In all three reaches, land uses have created localized gaps in the riparian corridor. Suburban and vineyard development, road crossings, other agriculture, and reservoirs are all examples of land uses creating these gaps. Naturally occurring landslides may be a contributing factor as well; 39% of all landslides mapped were adjacent to the stream channel. In addition, 11% of all blue line channels were identified as “disturbed,” which includes damage to riparian vegetation caused by channel migration, erosion, or flood events.
- Historical over-grazing and bank trampling have damaged riparian vegetation along Carneros Creek, particularly in the middle reach These past practices may be contributing to current high levels of bank erosion. At several locations in the upper reach, there is no exclusionary fencing or other management practice in place to keep cattle away from steep banks and the channel. Although livestock are not completely fenced out, some fencing efforts show improvements in vegetation growth and bank stability, when compared to non-fenced areas.
- Sudden oak death (caused by the pathogen *Phytophthora ramorum*) has killed or damaged trees along the riparian corridor as well as on the hillsides. In addition, Pierce’s disease, hosted by several trees and plants common to the riparian area, is a concern to many landowners because of its potential to harm surrounding vineyards.

The limiting factors to maintaining a healthy, functioning riparian corridor are development and land use practices combined with the possibility of many trees being catastrophically uprooted along eroding banks. In the lower reach, once the single row of mature trees has been recruited into the channel, very few other trees will remain on the banks to provide riparian vegetation functions. Depending upon future land management decisions, land uses such as vineyard management and development, grazing, rural housing, road crossings, etc. may continue to threaten the width and continuity of the riparian corridor.

Upland Ecology

Watershed health and function includes more than just the creek and its riparian corridor; many important physical processes occur in the surrounding upland landscape. Surrounding areas provide habitat for plant and animal species that are vital to maintaining the function and diversity of the natural ecosystem. Increased development, intensive land use, fire suppression, and altered hydrology of the watershed can all affect the functioning of terrestrial ecology. Potential watershed wide impacts include changes in vegetation patterns, amount and/or quality of habitat provided, and introduction of invasive species.

Currently in Carneros Creek:
- The watershed is currently described as supporting annual grasses and forbs and mixed hardwoods with smaller areas of California Bay and Pacific Douglas fir. Historically, the lower watershed was open grassland with seasonal wetlands, while the middle and upper

watershed was a mix of grassland, brush, shrub, and woodland under native management (burning), that supported native grazing mammals (deer, elk, antelope). Native people likely had a significant influence on the composition, distribution, abundance, and productivity of most habitats in the watershed.

- The upper watershed has experienced expansion of woody vegetation into the grasslands, revegetation of previously cleared areas, increases in stand density of brush, shrub and woodlands, and decreases of native grass areas. Recent increases in impervious surfaces (e.g. roads, rooftops and parking lots) and residential and vineyard development have altered or removed native vegetation communities, affecting precipitation interception, infiltration and groundwater recharge.
- Compared with historical records, a greater number and larger extent of invasive plant species are now found in the watershed. Currently, the grasslands are predominantly exotic Mediterranean annuals, which are tolerant of grazing and drought and are able to suppress the growth of native perennial grasses. However, remnants of native grassland still exist. With proper expansion and restoration, possibly including careful application of grazing and fire, native grassland could provide benefits to the chemical and physical make-up of the soil and the infiltration capacity of the hillslopes. Native perennial grasses provide the benefit of maintaining a large living root mass through time, thus increasing soil stability and precipitation infiltration, whereas exotic annuals reproduce by seed and do not maintain the same beneficial living mass of roots.
- Available habitat has diminished for some species, and expanded for others. For example, the open grasslands in the lower watershed historically supported Western burrowing owls and waterfowl. Development and vineyards have since replaced a majority of the grasslands, removing most of the habitat. In addition, the increased number of trees in the lower watershed, compared to pre-European contact, has provided more roosting locations for predatory birds to prey upon burrowing owls and waterfowl. But for species dependent upon riparian or chaparral (brush and shrub land) and woodland habitats, the change is less dramatic. Although natural habitat areas are generally decreasing, riparian, chaparral and woodland areas in the upper watershed are experiencing expansion. However, because the riparian corridor in the lower reach is dominated by a single row of mature bay trees, in the future, when these severely undercut trees fall into the channel, gaps in the habitat will be created.
- Physical conditions, such as soil type, have an effect on watershed ecology. For example, the Haire loam found primarily in the lower reach restricts drainage, limits deep-rooted crops, and fosters seasonal wetlands, making this soil unsuitable for valley oak savanna habitat. Also, much of the watershed contains soils with a shallow clay pan that limits rooting depth of plants.
- The groundwater table is sensitive to withdrawals. Regional reports state that the groundwater levels are susceptible to pumping. Within the watershed, some residents report recent decreases in well water levels. A lowered groundwater table would reduce the amount of water provided to the creek from groundwater storage, reducing the amount of water available for animal and riparian plant species, especially during the late summer and fall.

The factors limiting the maintenance of a healthy, functioning terrestrial ecology are historic and current development and land management practices. Changes from natural vegetation patterns and densities have occurred with the advent of suburban residential development, vineyards, agriculture and grazing. Remaining habitat is fragmented and altered by non-native tree and grass species. Important land management practices that have significant effects on terrestrial ecology include the volume of water diverted from the creek, active fire suppression, and riparian corridor management.

Salmonid Habitat

The Carneros Creek watershed currently supports salmonids, specifically steelhead trout, which is a federally listed threatened species. Historical records go back as far as the mid-19th century, when Menefee (1873: 36), described Carneros: "The writer has caught several [trout] that weighed from 7 to 10 ½ pounds, in the Carneros, five miles from its mouth, where the water was not a foot deep."

Many physical processes combine to create adequate aquatic habitat. Different life stages of salmonids require various habitat elements, but several elements are universal to the different stages and will benefit many other aquatic species. Steelhead trout require adequate water temperatures and quality, access to the ocean, year-round water, a source of food, channel complexity, pools and velocity shelters, cover from predators, adequately sized spawning gravels, and a healthy riparian corridor, amongst other factors. An analysis of the current status of these elements reveals the factors most likely limiting the success of steelhead in Carneros Creek.

Currently in Carneros Creek:

- Year-round flow is not present in all reaches. This condition is similar to documented historic patterns, but probably more extreme. In general, essentially no surface flow exists from September to November, with the upper reach often being completely dry and the lower reach often containing only isolated pools. The September 2002 stream survey revealed 47% of the total surveyed habitat was dry. With more on-stream reservoirs recently built on tributaries, surface flow may be further reduced because water historically contributed by smaller tributaries is now being held within reservoirs.
- Water temperatures are appropriate for supporting cold-water fish, such as steelhead trout, in some reaches of Carneros Creek. Steelhead have a low tolerance for elevated water temperatures. However, in general, water temperatures are below stress levels (68°F, 20° C) in Carneros Creek. From July to October 2002, potential rearing pools had a temperature range of 47.5°F to 70.9°F (8.6° C to 21.6° C). Pools in the lowest reach have the warmest measured water temperatures, sometimes exceeding 68°F (20° C), and typically experiencing major water level declines. Pools in the middle reach have less variation in temperature due to shading and groundwater contributions.
- Water quality may be affected by land use in the watershed. Quality may be affected by sediment, nutrients and chemicals. Excessive sediment can have negative effects on local fish populations and the function of the creek. Direct runoff from grazing can introduce

sediment, organic particulate matter, and excess nutrients, particularly ammonia. Runoff from viticulture or other agriculture and residential areas can contain chemical fertilizers and pesticides, sediment, and nutrients. Although not explicitly included in this study, many sources of runoff were observed entering the creek at different locations and from varying land uses. Water quality has a significant impact on pools in the lower reach. Once they become isolated, removed from all surface water flow, water quality quickly degrades below levels required for successful steelhead rearing.

- Obstacles to fish migration exist in several reaches of Carneros Creek. The most extensive barrier is the dry lower reach, where reduced flow during late spring and early summer limits the movement of young steelhead out of the creek and into the Bay and ocean (outmigration). In the middle reach of the creek, three dams and a small bedrock cascade are identified as likely barriers during low flows, limiting both up and downstream migration. Nineteen on-stream reservoirs were also identified on tributaries to Carneros Creek, each acting as a migration barrier to upstream migration. A single poured concrete cattle crossing exists in the upper reach. These crossings are designed to limit bank erosion, but they also may act as barriers during low-flow conditions. This particular barrier likely does not have a significant impact on aquatic habitat due to other unfavorable conditions in this reach. Despite the several partial barriers, the creek still maintains a direct path from the upper watershed to the Napa River, with no complete barriers.
- The lower reach is characterized by limited channel complexity. Except in the short tidal reach, it has experienced very little straightening or simplification. However, available habitat in the lower reach is severely limited by low summertime flows, minimal instream cover due to bank stabilization efforts, limited shelter for fish during periods of high water flow, deficient pool frequency, lack of vegetative cover, and deficient water quality.
- Pool frequency and depth is adequate for steelhead rearing in the middle and upper reaches of Carneros Creek. Throughout the surveyed reaches, many pools were observed and the spacing of these pools averaged one pool every 5 bankfull widths, with most occurring more frequently, typically less than 3 bankfull widths. Many pools are deeper than 2 feet and associated or formed by large woody debris.
- Large woody debris is providing many benefits for the aquatic ecosystem. It provides shade, instream cover and velocity shelters for steelhead, trapping of spawning gravels, regulation of organic material movement, and a mechanism for pool development through scour. Despite a single large debris jam in the lower reach, additional wood cover would greatly enhance aquatic habitat quality. Unlike the lower reach, the middle and upper reaches contain a greater number of woody debris pieces and large boulders that provide shelter and cover for juvenile steelhead.
- Excess fine sediment deposits affect pool volumes in the lower reach. These sediment deposits are due to the low-gradient of the reach, lack of adequate flow, and the resultant inability of the creek to move the fine sediment further downstream. Excessive fine sediment is not favorable for steelhead spawning. Pools in other reaches are not as affected by sediment deposits. Natural creek processes and hillslope mass-movements provide sediment to the creek. In addition, some fine sediment is provided directly from

vineyard plots and drainage pipes, sometimes causing the deposition of a small sediment fan downstream of the drainage outlet.

- As discussed above, portions of the riparian corridor are at risk, particularly along the lower reach of Carneros Creek, below the Old Sonoma Bridge. In this reach, a single row of mature trees comprises the only riparian corridor, and is severely undercut and in danger of toppling into the creek. Bank erosion and associated channel widening are the cause of this riparian instability. Although limited, the riparian corridor in this reach does provide many benefits, including shade for the maintenance of cool water temperatures. The riparian corridor in the middle and upper reaches are not nearly as at risk. But, some creek reaches in the upper watershed, where cattle are not fully fenced out, are showing damage to banks and riparian vegetation along the channel. In general, the riparian area has slightly expanded, with tributary areas contributing to most of the expansion. Overall, the riparian corridor is not presently a limiting factor for steelhead success.
- Appropriate spawning gravels exist in several areas of the creek. Overall, the size and distribution of spawning gravel are acceptable for steelhead. Gravel does not appear to be significantly affected by excess fine sediment. However, moderate levels of gravel embeddedness (where gravel becomes smothered by finer sediment) are observed and the amount of fine sediment is near the threshold at which negative impacts will begin, particularly in the lower reach. Based upon analysis of bulk sediment samples, current levels of fine sediment (<1 mm and <6.35 mm) do not excessively impact steelhead egg incubation or emergence. Further, larger gravels are within the documented range for successful salmonid spawning. However, the 19 on-stream reservoirs (located on tributaries) trap sediment that would otherwise be transported downstream, limiting the supply of coarse sediment available for spawning. Over time, this may create a shortage of adequate spawning gravels.
- A limited food supply may be affecting steelhead survival and success in the summer months, however there is little data available to assess this factor properly. Summertime low flows are limiting downstream transport of the primary food source for young steelhead, including aquatic insects and other invertebrates.
- The middle reach is the best overall reach for steelhead spawning and rearing. This reach contains multiple areas for spawning with appropriately sized gravels, relatively high amounts of large woody debris, suitable channel complexity, the highest number of pools, the closest average pool spacing, consistently cool water temperatures, good cover, and relatively low volumes sediment within pools. Comparatively, the lower reach acts primarily as a migration corridor and provides only very limited year-round habitat due to lack of surface flow. The upper reach may support spawning but, because it is completely dry in the summer, does not support rearing.

Although it is likely that Carneros Creek never supported an exceptionally large steelhead population, its relative importance, compared to other streams of similar size in the North Bay, has probably increased. This is due to the maintenance of fairly rural land uses, lack of complete migration barriers, and direct connection and relative proximity to the Bay.

Multiple factors are limiting the success of steelhead in Carneros Creek. The most important factor is decreased water flow. Although the middle reach maintains year-round flow, the upper and lower reaches do not, and therefore, do not provide adequate salmonid habitat. Evidence suggests that Carneros Creek did not maintain year-round flow during historic times and that flow was historically negligible or intermittent in the summer. However, there is evidence that in the past several decades the amount of intermittent flow and persistent pools has decreased. A number of residents independently describe a reduction in the extent of pools and seasonal flow, reporting that: “it ran more” and “used to visibly run ... enough to get over the rocks, when I came here.” Secondary limiting factors are lack of channel complexity in the lower reach, important for shelter during migration and cover from predators, as well as some partial migration barriers limiting the extent of available habitat.

Soil Erosion

Soil erosion is a process that can take many forms including: bank erosion, gully erosion, sheet and rill erosion, and landsliding; all of which are currently occurring in the Carneros Creek watershed to varying degrees and can lead to costly property loss and resource degradation. Although erosion is a natural process that helps the stream achieve or maintain equilibrium, much of the erosion occurring on Carneros Creek is caused or aggravated by land use management practices such as drainage rerouting, altered or removed vegetation cover, man-made structures, or poorly installed bank stabilization structures. Finding solutions to minimize erosion induced by human disturbance is essential because property and soil resources are valuable and because excess erosion and the resultant sediment input to the creek can have negative impacts on channel functioning and aquatic habitat.

Erosion is a natural process that acts to keep the landscape and stream channel in equilibrium. Some erosion is beneficial and essential to the watershed; for example, landslides and bank erosion provide sources of fresh sediment and gravel to the channel that can be utilized by spawning fish. However, intensive use of the land has the potential to increase rates of erosion and tends to supply more sediment to the creek than the system can handle, thus altering the natural balance. In the lower watershed, the change from grasslands, hay/grain production, and orchards to vineyards has, in some cases, led to more intensive soil disturbance and therefore increased the potential for surface erosion. Vineyard and road runoff controls such as pipelines and ditches concentrate runoff and provide ready transport of any surface erosion to the channel system. In addition, drainage pipes that discharge concentrated runoff onto channel banks without proper energy dissipation often cause bank collapse or gullying. Most of the lower watershed has been subject to some type of agricultural activity for well over a century, increasing the erosion potential. In the middle and upper reaches, both historic and recent grazing practices cause the largest impacts to the hillslopes and banks. Early grazing effects in combination with the 1862 flood could have mobilized a large amount of sediment from the hillslopes into the channel.

Currently in Carneros Creek:

- Accelerated bank erosion caused by changes in land use and management is contributing substantial amounts of sediment to the creek. Localized areas in the middle reach, upstream from the Old Sonoma Road Bridge, are contributing the largest volume of sediment per unit channel length, with half occurring in the past 20 years. Although the following volumes are merely estimates, they illustrate that accelerated bank erosion due to past and present land use is one of the largest sources of sediment supply to the channel. A total of 3,009 yd^3 (2,300 m^3) of bank erosion was measured along 0.93 miles (1.5 km) of surveyed mainstem channel. This erosion has occurred over approximately the past 150 years in the 10 sample reaches, which measure 9% of the total mainstem channel length. If this rate is extrapolated to cover the entire 11 miles (17.8 km) of mainstem channel length, approximately 35,320 yd^3 (27,000 m^3) of erosion could be measured. Tributary banks are also experiencing erosion but at a much slower rate; supplying 1,966 yd^3 (1,503 m^3) of sediment from 3.7 miles (6 km) of surveyed channel. A total of approximately 10.5 miles (17.0 km) of USGS blue line tributary channel length exists in the watershed; extrapolating would yield 5,625 yd^3 (4,300 m^3) of sediment supplied from tributary bank erosion. Erosion in the tributaries is associated with: no active management (lands managed in the past, but not currently actively managed; for example, previously grazed land) (49%), grazing (27%), reservoirs (13%), viticulture (9%), and roads (2%). Most measured erosion is chronic, occurring over the past 50 to 100 years. However, erosion rates appear to have increased in the past 10 years.
- Bank material and vegetation cover determine the stability of channel banks in the watershed. Although bank material along the mainstem and tributaries is variable (ranging from bedrock to silt/clay), nearly the entire channel bank length contains at least some vegetation, including areas of dense vegetation. Some locations, especially in the lower reach, contain bare banks with only exposed roots from the trees growing on the top of the bank. Areas with silt/sand banks and/or banks with minimal vegetation are at higher risk of eroding.
- Landslides and other hillslope mass movements also contribute sediment to the creek. There are 120 current and historic landslides mapped that have occurred since 1942, contributing approximately13,000 yd^3 (9,938 m^3) of sediment to the creek system. Due to different underlying rock types, the east side of the watershed is more prone to hillslope failures. Most slides occur in the grasslands, while few occur in oak woodlands. Most slides appear to be associated with the underlying geology, rather than changes in land use. Large storm events or prolonged, above-normal seasonal rains that saturate the soil are the likely triggering mechanisms. Landslides decrease hillslope stability, which in turn may threaten structures, improvements, roads, and reservoirs. Seven sites are recommended for erosion control and erosion prevention treatments, to prevent an additional 314 yd^3 (240 m^3) of sediment from entering the stream network. These sites are all associated with road building and maintenance and are identified as sites that are likely to deliver sediment to the channel system.
- Sheet and gully erosion is occurring. The largest gullies are forming downstream of poorly designed outlets of existing reservoirs. Rilling and gullying are observed in vineyards planted perpendicular to contour before cover crop growth in the fall and

especially on hillslopes steeper than 10%. However, most vineyards have existing cover crop growth, significantly reducing the amount of observed erosion. Gullies are also observed in areas grazed by cattle, on hillslopes receiving road runoff, and on stream bank slopes below culverted drainage outlets. Sheet erosion occurs primarily on bare soil areas throughout the watershed and on long stretches of unpaved rural road with poorly designed drainage and ditches that are connected with, and flow into streams.

- Over 11 miles (17.7 km) of road surface in the watershed drains directly to the channel system, delivering runoff and fine sediment from unsurfaced roads and ditches. Undersized or plugged culverts and diverted streams also have the potential to contribute eroded sediment. Erosion control efforts are recommended for 10.3 miles (16.6 km) of road, 16 of 23 ditch relief culverts, and 90 of 101 stream crossings. The erosion- and storm-proofing recommendations include a combination of such preventative treatments as re-grading roads to include rolling dips or insloped ditches; installing wet crossings; removing or replacing undersized or damaged culverts; realigning culverts to the channel gradient; retrofitting pipes with a downspout, trash rack and/or flared inlet; and rock armoring outlets. An estimated 18,324 yds^3 of sediment could be prevented from entering the stream system through implementation of road-related erosion control.

Observed and measured erosion is due to many different physical processes and land uses. The most important factors contributing to soil loss in the Carneros watershed include:

- Natural stream processes and channel entrenchment. In highly entrenched channels, bank and terrace erosion produce large volumes of sediment because destabilization at the bottom of the bank (the toe) causes erosion of the entire bank height. Scour around in-channel large woody debris pieces and localized bed incision (down cutting) also contribute.
- Grazing. Currently, only a small number of cattle are grazed in the upper watershed limiting the cumulative negative effects. Grazing reduces vegetation cover, often creates patches of compacted bare soil, and reduces the capacity of the soil to absorb water, ultimately increasing runoff and therefore erosion, especially in conditions of overgrazing or drought. The existing high rate of bank erosion in the middle reach is likely due to bank trampling and extreme vegetation removal associated with past major cattle operations.
- Hydromodification. Increased subsurface and surface drainage for agricultural and rural residential land uses and increased impervious surface area associated with roads and rural residential development are increasing the volume and speed of surface runoff reaching the channel. This, in turn, is increasing surface erosion and the channel's erosive ability. However, the number of reservoirs, which temporarily hold water and slowly release it over the growing season, dampens the effects of hydromodification.
- Limited or altered vegetation cover. Although the watershed is no longer experiencing cultural burning, intensive land use generally decreases the density and extent of native vegetation, thus increasing the potential for surface erosion.
- Drainage from roads, ditch relief culverts, or undersized culverts at stream crossings.

- Viticulture and other agriculture. Currently 20% (1,850 acres) of the watershed is planted in vineyards. In 1993, 58 of these acres were used for other agriculture. Tilling, cultivation and soil aeration contribute to soil loss if soils are exposed during rainfall and runoff events. Many of the vineyard developments are located on the eastern side of the watershed, which is prone to landslides and mass movements. Bank collapses, rilling, gullying, and fine sediment delivery result from some vineyard drainage pipes and avenues.
- Bank revetment/stabilization. Typically designed to control bank erosion, poorly-planned or failing bank revetments in a few areas, primarily in the lower reach, contribute to increased amounts of localized erosion.

Many locations and types of erosion are observed throughout the watershed. Although some is attributable to natural physical conditions and processes, a portion is due to human modifications or land uses. Of the identified erosion causes, grazing practices (both historic and current), altered runoff patterns created by intensive land use, road drainage and viticulture appear to be the critical causes.

Excess Sediment

Increased sediment volumes supplied to the creek system can cause decreases in water quality, increases in sediment storage (bars, pool deposits) and/or even raise the level of the channel bed along certain reaches (aggradation). Many negative impacts can result from increased sediment storage, including flood hazards due to the decreased channel capacity for water routing, property loss through bank erosion and increased channel widths, and habitat degradation through decreased channel depth, decreased pool volumes, general decreases in bed grain size distribution, and decreases in summer surface flows. Controlling sources of excess erosion and sediment supply is important for protecting, maintaining, and restoring channel form and function for human benefits, safety, and aquatic habitat quality. Sources of erosion and the existing condition of the watershed relative to erosion sites are discussed above. This section will focus on other aspects of sediment in the watershed.

Currently in Carneros Creek:

- Overall, a large amount of sediment is currently stored in the creek and available for transport. Sediment is being stored in deposits of accumulated gravel and sand in pools and along the banks of the creek. Overall, pool deposits, with most located in the lower reach, comprise the largest number of deposits, but the middle reach stores the greatest total volume of sediment, mostly in the form of accumulations at the meanders in the creek (point bars). As described above, volumes and size distributions of sediment in the middle reach currently appear to be adequate for successful salmonid spawning. However, the lower reach appears to be temporarily storing large volumes of fine sediment. These fine grain sizes are not adequate for utilization by salmonids. Analyses suggests that these deposits are easily mobilized and transported, but are likely redeposited during waning flood flows.

- Approximately 2.7 mi (4,300 m, or 11% of the total mainstem and tributary channel length) of channel is identified as "disturbed," including riparian vegetation removal and channel aggradation, with over half occurring in tributary channels. Most of the sediment supplied from tributary channels is from bank erosion or debris slide locations. Most of the "disturbed" sites are associated with underlying geology, flood events, bank erosion or channel migration rather than directly caused by identifiable man-related actions.
- Because the watershed no longer experiences regular burning (either natural or cultural), the potential for a large wildfire exists. A wildfire, when paired with the right climatic conditions has the potential to release/mobilize large volumes of sediment into the channel.
- Many sediment-related negative impacts on salmonid habitat are observed. These include: deficient pool frequency and quality, moderate sediment embeddedness, and low summertime surface flow. Additional sediment will exacerbate these problems.

The factors most responsible for causing excess sedimentation are high rates of bank erosion and ongoing increases in land use intensity. Although the channel is not significantly aggrading (raising its bed elevation), the lower reach does contain many pool deposits and locations of decreased surface flow and increased subsurface flow.

Flood hazards

Channel shape and many fluvial, biological and ecological processes are dependent upon periodic flooding. However, floods can also damage property adjacent to the creek, damage bridges and other structures that cross the creek, and cause large amounts of bank erosion and sediment transport. Addressing current management practices that increase the likelihood of flood hazards is critical. Potential causes of flooding include: undersized bridges, backup associated with large woody debris caught on bridge pilings and culverted crossings, undersized culverts at road crossings, channel modification or simplification, channel aggradation (buildup), and other types of modifications that influence water movement. Specifically, human actions that confine creek flow and land use changes that alter the rate at which water enters the creek can exacerbate localized flooding beyond that which is beneficial to the functioning of the watershed. Changing the hydrologic regime in this way can cause excess erosion and scour of the channel bed and banks, increase water velocity, and decrease water quality. Clearly, this type of flood occurrence can have negative impacts on surrounding property and aquatic habitat.

Currently in the Carneros Creek watershed:

- Land use intensity is increasing. Although historic cultural burning had some effect upon infiltration and evapotranspiration, recent changes in land use are having a larger impact by routing more water to the channel system in less time and increasing the likelihood of localized flooding. These changes include increases in agriculture, increases in impervious surface area, an increase in vineyard-related engineered subsurface and surface water drainage systems, and increased road density.

- Multiple channel crossings and constrictions exist. The mainstem of Carneros Creek has eight major crossings, either bridges or culverts, which appear to be large enough to accommodate flood flow. In addition, there are many crossings located on tributaries. Many of these smaller crossings and culverts have been identified as undersized and have the potential to constrict high water flows and cause localized flooding. Because the potential for wood recruitment to the creek is high and because the channel already contains many large woody debris pieces, plenty of debris is available to catch on bridge pilings and culvert inlets, causing a backup of flood waters. Also, the potential for major wood recruitment exists in the lower reach; numerous large trees are severely undercut, many of which could enter the channel in a single large storm event. Both the hazards and benefits of in-channel large woody debris should be considered when making decisions about what to do with "downed" trees that fall into the creek.
- Channel modifications, including reservoirs, bank stabilization projects, and storm and subsurface drainage systems, are altering runoff patterns and timing. The watershed currently contains 57 on- and off-stream reservoirs, which intercept and retain storm flow, acting to reduce the peak of the hydrograph, at least during the early part of the rainy season. However, some of these reservoirs were found to have the potential to overflow, which would cause either severe erosion or catastrophic failure of the dam and associated flooding. Bank stabilization efforts, particularly in the lower reach may also influence the likelihood of localized flooding. These hardscape revetments typically encroach upon the natural channel cross sectional area, decreasing the volume of flood flow that can pass at that location. Increases in storm and subsurface drainage systems and impervious surfaces from residential development, roads, and vineyards in the watershed decreases the amount of time it takes for rainfall to enter the creek, thus causing water levels in the creek to rise and fall more rapidly, increasing the potential for flash flooding.
- Overall, flood conveyance appears to be effective. Recent floods have not topped the terrace banks, especially in the lower entrenched reaches. Future limitations on building structures within flood-prone areas of the creek will prevent additional damages caused by flooding.

The factors most responsible for increasing flood hazards are increased surface and subsurface drainage and time to peak flow associated with high intensity land use, a large number of inadequate culverted stream crossings, and the large amount of woody debris in the creek and/or available for recruitment to the creek. The catastrophic failure of an on-channel reservoir could potentially cause flooding, property damage, downstream sedimentation, bank erosion, habitat loss and widespread channel morphology changes.

Water Supply

Water is essential for all aspects of life, including agriculture and viticulture, grazing, human habitation, aquatic and terrestrial habitat, and vegetation communities. Water availability is generally limited in the Carneros Creek watershed. The many competing uses for the finite amount of water available include flows for environmental benefits, diversion for storage, diversion for land uses or residential needs, and extraction from wells. Without continued maintenance of and/or increases in seasonal water flow in Carneros Creek, continued challenges for all water users will likely occur.

Currently in Carneros Creek:

- Precipitation is the primary source of surface water in the watershed and is driven by the natural regional flood/drought regime. Many large storms and notable droughts have occurred historically in the Napa Valley region (e.g., *floods*: 1852, 1890, 1940, 1942, 1958, 1983, 1986, 1995, 1997, and 2003; *droughts*: early 1860's, 1900 to 1930 and 1986-1990). Average annual precipitation in the watershed is 28 inches (710 mm). It is estimated that approximately 52% of rainfall in an average year enters the creek as runoff; wetter and drier years have proportionally greater and less runoff, respectively.
- The rate at which the creek flows (discharge) is seasonally dependent; water levels in the creek begin to rise in December and closely follow precipitation events, frequently ceasing to flow from September to November. While discharge varies from year to year depending upon annual precipitation and intensity, discharge with a recurrence interval of 1.5 years is approximately 530 cubic feet per second (cfs). The 1.5-year recurrence interval is commonly used because it represents the flow occurrence that accounts for much of the way the creek transports and stores sediment and gravel. There is a 73% chance of experiencing this rate of flow in any given year.
- Surface flow and groundwater is generally limited. Few natural springs and seasonal creeks exist and surface flow in creeks has been and is currently limited. In addition, based upon historic studies and current landowner observations, the groundwater table appears to be sensitive to overdraft. The incised nature of the lower reach of Carneros Creek contributes to a localized drop in groundwater levels.
- Changing vegetation patterns are altering the infiltration/transpiration capacity of the watershed. Expansion of chaparral/woody vegetation into grasslands, lengthening and expansion of riparian vegetation, and change from native to more drought-resistant grass communities all influence the amount of precipitation that reaches the creek.
- The overall low levels of seasonal flow are likely the historical norm and are typical of many Napa region creeks. Historic stream surveys have noted lack of channel flow. However, there is evidence for recent decreases in flow. The entire channel has essentially no flow from September to November. The upper reach is completely dry throughout the summer and fall, the middle reach has perennial (year-round) surface flow that slows to a trickle in the late summer, and the lower reach contains only isolated pools, which quickly decrease in volume and quality throughout the summer. Aquatic habitat for cold-water fish is impacted by the naturally low summertime flows and exacerbated by additional decreases.
- Large volumes of water are being stored in reservoirs. A total of 57 on- and off-stream reservoirs exist, all having been built since 1940. Reservoir surface area ranges from 1,600 square feet to 31 acres. On-stream reservoirs intercept and retain storm flow, slowly releasing water over the growing season.

- A large portion of water is diverted/extracted for human uses. Although agricultural land was typically dry farmed historically, many diversions are noted in historic channel surveys, presumably for grazing and household needs. Currently, over 30% of the average surface discharge is allocated for diversion. Wells currently supply water for residential uses and some vineyards, many of which are located on the eastern side of the watershed because of a relatively higher groundwater table. The amount of groundwater being extracted and the effect that extraction is having on surface flows are unknown; groundwater pumping is not frequently monitored and permits are not needed for extraction.

The factor most responsible for a limited water supply in Carneros Creek is the natural climatic character of the watershed. The secondary factor is the increased population of the watershed and greater diversion and extraction associated with more water-intensive land uses. Balancing the increasing demands for land uses with flows necessary to support environmental amenities is becoming more difficult.

Watershed Management Recommendations

The Carneros Creek Stewardship group has recognized a set of five goals as fundamental to their activities. These goals guided the watershed assessment completed in 2002 and also provided the implicit framework for recommendations made in management plan and expanded upon in this reference document. The goals of the stewardship group are as follows:

GOAL 1: Assess the physical features of the watershed on an ongoing basis
GOAL 2: Provide education about the watershed
GOAL 3: Protect and restore natural resources, including native fish and wildlife species
GOAL 4: Protect and enhance economic and human resources
GOAL 5: Create a sustainable and enduring watershed stewardship

In order to attain these goals and in response to existing and historic watershed conditions, seven specific objectives have been identified by the Stewardship group. This section expands upon the recommendation matrices in the Watershed Management Plan, providing more specific detail and identifying sources of assistance and additional information, where available. The numbering of recommended actions is the same in both documents for ease in cross-referencing (e.g. recommendation A-1 in the Management Plan is the same as A-1 in the Reference Document).

Objective A: Establish and maintain an uninterrupted riparian corridor along Carneros Creek and its major tributaries, emphasizing the use of native plants which are not primary hosts for Pierce's disease. A healthy riparian corridor will function as naturally as possible and perpetuate itself. There may be areas along the lowest portion of the lower creek reach where the riparian corridor may be naturally interrupted.

Linkages: In some ways this is the most fundamental objective, since actions taken in support of it will also indirectly support all the others; further, many of the actions will directly contribute to stream stability, terrestrial habitat, and in-stream habitat.

A-1: Manage existing riparian corridor to maximize riparian canopy width by "stepping back" from creek where and when possible. A good general rule is to allow the creek an overall meander belt width of four times the *bankfull width*, counting the channel itself and both sides of the stream; note that bankfull width is *not* measured at the top of bank. Check with the RCD or NRCS for help in estimating the bankfull width at your site. In the headwaters of Carneros Creek, the riparian corridor will probably be narrower. This recommendation is derived from the Napa Green Farm Certification Program.

A-1-1: Where the riparian corridor is thin or overmature, especially along the lower reach, plant the top of bank in native trees and shrubs that support a diverse and mature plant community. This will provide for bank stabilization and tree cover for creek shading. Consult the RCD or NRCS for examples of what species to plant.
A-1-2: Where residential development is close to the creek, limit clearing of vegetation and landscaping unless restoring native vegetation.
A-1-3: Avoid constructing homes or permanent structures within the 100-year floodplain zone of all stream channels.
Setbacks are addressed under A-1 above
A-1-4: Design and implement revegetation projects in areas of bank erosion in the middle reach of the creek.

A-2: "Close" gaps along the riparian corridor by developing and implementing riparian revegetation plans that utilize native trees, shrubs, and grasses.
A-2-1: Minimize continued development of stream crossings, in-stream reservoirs, or use of agricultural practices that create riparian discontinuities.
A-2-2: Decommission or upgrade old creek crossings and remove partial migration barriers.
A-2-3: Manage existing in-stream ponds and ditches as wildlife habitat by encouraging native plant growth.
A-2-4: Especially in vineyard settings, select native plant species that are not vectors or act as host plants for Pierce's Disease. Use guidelines from Riparian Vegetation Management Information Manual, or seek advice from the RCD or NRCS for selection of native non-PD host plants.
A-2-5: For all revegetation projects, include a 5-year minimum maintenance plan including water conserving irrigation schedules to ensure the survival of new seedlings.

A-3: Incorporate exclusionary livestock fencing in such a way as to allow for native mammal migration and access to the creek while keeping domestic grazing animals out of the riparian corridor. Provide alternate dispersed, shaded watering sites

away from the riparian zone. Refer to the California Department of Fish and Games *"Wildlife Friendly Fencing Guidelines"* for specific fencing suggestions.

A-4: Explore opportunities for conservation easements along the riparian corridor in exchange for property tax reductions with organizations such as the Land Trust of Napa County.

A-5: Ensure that future planning of rural residential areas include stream side areas that enhance and emphasize natural riparian zones.

A-6: Continue to conduct education and outreach to promote a functioning riparian corridor.

A-6-1: Provide a forum to discuss and clarify issues related to riparian buffer areas.
A-6-2: Encourage current efforts to manage PD in the middle and upper reaches of the creek in a way that increases the diversity and complexity of riparian understory and overstory.
A-6-3: Utilize the demonstration site developed under Action **G-2** as an outreach tool to encourage riparian corridor reestablishment.
A-6-4: Support vineyard participation in the Napa Green Farm Certification Program.

Objective B: Promote contiguous upland habitat and biodiversity

Linkages: many actions taken in support of other objectives will also support this objective, particularly actions which increase the extent of riparian corridor along the creek and tributaries. Water management will ensure/increase year-round water supply for wildlife.

B-1: Develop new upland migration habitats for birds and small mammals through native planting and hedgerows along fences, fields and property borders.

B-2: Provide terrestrial wildlife habitat enhancements such as birdhouses, raptor roosts, and bat boxes.

B-3: Continue to enhance and implement grazing, range, and grassland management plans to maximize native grassland revegetation and exotic invasive plant management. Consider prescribed burns, as appropriate.

B-4: Maintain and encourage development of continuous east-west habitat corridors across the valley into other watersheds through cooperative efforts with neighboring landowners.

B-5: "Step back" from sensitive upland areas such as slides whenever possible.

B-6: "Close" gaps along the riparian corridor by developing and implementing riparian revegetation plans that utilize native trees, shrubs, and grasses. See action **A-2** above.

B-7: Continue watershed education activities including guest speakers to discuss wildlife habitat and sudden oak death.

B-7-1: Recruit wildlife speakers for presentations at Stewardship meetings.
B-7-2: Provide landowners with information on how to identify sudden oak death and care for affected trees
B-7-3: Identify key wildlife corridors within the watershed and educate landowners on the value of conserving and protecting these as continuous habitat
B-7-4: Provide landowners with information and assistance in creating new upland habitat (specifically, recommended actions B-1 and B-2 above.)

B-8: Collaborate with youth education programs such as Acorn Soupe to conduct education and outreach to promote contiguous habitat and biodiversity.

Objective C: Maintain and improve in-stream habitat

Linkages: many actions taken under this objective will promote streambank stability. Actions taken under objectives A, D, E, and F will also improve in-stream habitat, especially in the lower reach. Maintaining the riparian corridor stabilizes water temperature and traps sediments and pollutants; reducing soil erosion and preventing bank failures reduces sediment deposition in the lower reach; increasing late season flows provides water for fish habitat.

C-1: Remove barriers to fish migration on the main stem of the creek.

C-1-1: Modify bridge crossings, culverts, and concrete crossings to allow full access to available stream habitat under a wider range of flows.
C-1-2: Minimize continued development of stream crossings.
C-1-3: Decommission or upgrade old crossings and remove or modify partial migration barriers when possible.

C-2: Encourage formation of pools via large woody debris (LWD) in ways that do not increase the risk of flooding.

C-2-1: For fallen trees that do not present an immediate flood hazard, practice minimal interventions acceptable to regulatory agencies. Encourage modification rather than complete removal of LWD jams that pose erosion and flood risks (i.e. leave select pieces of LWD within the stream system, and consider anchoring them in place).
C-2-2: Create favorable rearing/spawning pools using LWD and boulder habitat enhancement structures in reaches with suitable flow.

C-3: Limit low water crossings to only those that are necessary, with a preference for designs that minimize channel disturbance. Refer to NOAA Fisheries Guidelines for Salmonid Passage at Stream Crossings.

C-3-1: Where a crossing is necessary in an active salmonid spawning area (middle and upper reaches) install full span bridges or bottomless arches to allow for natural stream processes within the crossing.

C-3-2: To minimize stream impacts, limit crossing to occur during dry seasons, and reduce or eliminate cattle movement through the channel during winter.

C-3-3: Maintain seasonal crossings to allow fish passage during high flows. Seasonally installed cattle exclusion fencing that crosses the stream should be removed or modified before high winter flows.

C-4: Continue to enhance and implement grazing management plans with an emphasis on intensive management systems that reduce grazing impacts on upland and riparian landscapes.

C-5: Protect and improve water quality.

C-5-1: Inspect and maintain septic systems for leaks and limit development near watercourses.

C-5-2: Minimize use of pesticides and fertilizers in agricultural, residential, industrial, public, and recreational, areas.

C-5-3: Capture and appropriately discard winery and industrial waste to prevent discharge into storm water system.

C-5-4: Store any chemicals, fertilizers, fuel, and debris in areas away from riparian zones and floodplains.

C-5-5: Use fencing and riparian buffer strips to help dampen the impact of nutrients from livestock.

C-6: **Implement stream restoration using 'soft' bio-engineered techniques, incorporating live plant material whenever possible Also consider "stepping back" development from the creek to provide for natural meandering.** Refer to DFG California Salmonid Habitat Restoration Manual. Utilize stream restoration design and permitting assistance from the NRCS, DFG, the RCD and other local agencies. This style of restoration is particularly recommended for bare eroding banks in the middle reach of the creek. It is also important in the lower reach, where any hard revetment could aggravate erosion on adjacent banks. Because of the degree of entrenchment in the lower reach, and risk of failure or causing aggravated erosion, ensure that restoration projects are professionally designed.

C-7: Conduct education and outreach regarding actions that can help improve water quality and in-stream habitat.

C-7-1: Educate landowners on the impacts of dumping trash, organic debris, and agricultural waste into streams.

C-7-2: Support vineyard participation in Napa Green Farm Certification Program.
C-7-3: Educate rural residential landowners and others on LWD via tours and workshops.

Objective D: Reduce soil erosion.
The primary concern of this objective is with the accelerated soil erosion caused by human activities, and specifically with the transport and supply of eroded material to the stream.
Linkages: Actions to reduce soil erosion from upland surfaces have the potential to improve in-stream habitat and improve water quality in general, as do actions to prevent streambank erosion.

D-1: Use sustainable agricultural practices to minimize soil erosion, as recommended in the Napa River Watershed Owners Manual and the Fish Friendly Farming (Napa Green) Manuals.
D-1-1: Maintain permanent, non-tilled cover crops in vineyards; where tillage is necessary, use annually-seeded cover crops.
D-1-2: Leave vineyard perimeter avenues untilled. Where traffic prevents maintenance of strong vegetative cover, fill in bare spots with post-harvest straw mulch and seed applications. Protect very high traffic routes with a permanent, crushed rock surface.
D-1-3: Install water bars to divert concentrated flows from vineyard avenues and roads to protected outfalls, or use road shaping or other means to disperse flows.

D-2: Limit use of and abandon existing low water crossings and access points to minimize bank degradation at those sites. Where possible, exclude livestock from the creek.

D-3: Maintain and improve roadways, and minimize new road construction.
D-3-1: Reduce sediment delivery from public and private roads, culverts and other improvements associated with human land use by implementing the recommendations made by Pacific Watershed Associates over the next 15 years.
D-3-2: Decommission abandoned roads by removing old crossings and eroding fill slopes and revegetating them.
D-3-3: Maintain and clear debris from culverts prior to and during the rainy season and monitor for plugging during heavy rainfalls.
D-3-4: Design roadway maintenance systems and erosion control practices for existing private roads using the Handbook for Forest and Ranch Roads in conjunction with USDA NRCS assistance.

D-4: Explore and where preferable utilize alternatives to engineered storm drains (to disperse, rather than concentrate, water).
D-4-1: When subsurface drainage is used, route drainage into settling or infiltration basins or install adequate energy dissipaters and downspouts at outlets.

D-4-2: Design drainage to disperse runoff and encourage groundwater recharge by using vegetated swales, rolling dips, and other methods.
D-4-3: Minimize soil disturbance on stream banks, such as when it is required by such activities as utility installation. Seed and revegetate all disturbed areas.

D-5: Consider "stepping back" development from the creek to provide for natural meandering. Where appropriate, implement streambank stability using "soft" bioengineered techniques. See A-1 and C-5 above.
D-6: Maintain and improve reservoir outlets to ensure that they are operating properly.

D-7: Conduct education and outreach regarding roads, vineyard practices, and bio-engineered streambank protection.
D-7-1: Hold a rural roads workshop in the watershed.
D-7-2: Encourage vineyard participation in the Napa Green Farm Certification Program.
D-7-3: Encourage landowners to allow access for future road assessment in areas not assessed to date.
D-7-4: Encourage Napa County Roads Department to apply for grants and implement road improvements recommended for public roads.
D-7-5: Establish a demonstration site for road-related erosion control, including road decommissioning and upgrading.

Objective E: Protect property and habitat using natural processes to promote streambank stability
Linkages: many actions taken under this objective will improve in-stream habitat and the health and continuity of the riparian corridor.

E-1: Protect property and natural resources by managing channel bank erosion.
E-1-1: Where the riparian corridor is narrow or missing, add vegetated buffer strips to help stabilize stream banks and prevent bank failures.
E-1-2: When bank failures threaten improvements to property, make repairs using bio-engineered methods which foster revegetation of the bank. Be sure to coordinate bank stabilization efforts with adjacent property owners.
E-1-3: Wherever possible, exclude livestock from the creek and correct any culverts that drain directly onto the bank.

E-2: Protect property from flood damage through culvert and bridge abutement clearing, in-channel vegetation management, and where possible providing the creek with access to its floodplain.
E-2-1: Maintain and clear debris from culverts prior to rainy season and monitor for plugging during heavy rainfalls.
E-2-2: Coordinate with Napa County Flood Control and DFG to control excess in-channel vegetation while limiting removal of LWD. See objective **C-2**.

E-2-3: Where possible, plant tree cover along flood control channels and drainage ditches, to maintain water quality and discourage in-channel vegetation while protecting against bank failure.
E-2-4: Provide the creek with access to its floodplain where possible. Where the stream is heavily incised, the incised stream will try to reestablish its floodplain by eroding banks. Where this has begun to happen and the landowner is willing to step back, a floodplain can be created at a lowered elevation appropriate for the incised stream. This process can be assisted by careful grading in the context of restoration work. Do this only on the basis of a thorough site analysis and professional design.
E-2-5: Avoid development within the 100-year floodplain. When opportunity arises, move existing structures and/or vines out of the floodplain.

E-3: Conduct education and outreach regarding bio-engineered streambank protection, floodplain functions, culvert maintenance, and management of large woody debris.
E-3-1: Educate landowners on bio-engineered streambank repairs via the demonstration site under G-2, if appropriate
E-3-2: Educate rural residential landowners and others on LWD via tours and workshops.

Objective F: Improve water management for the benefit of human, plant and animal communities
Linkages: this objective addresses not only the quality of in-stream and riparian habitat, which depends to some degree on water quantity, but also the needs of landowners for water for domestic use.

F-1: Plan individual water use (both surface and groundwater use) to minimize environmental disruption. Environmental values may be threatened by the timing of water withdrawals and the mechanisms used to pump and store water.
F-1-1: Design pump intakes to avoid harming fish, following the NMFS Fish Screen Criteria.
F-1-2: Register and upgrade or eliminate illegal or non-permitted water diversions.

F-2: Maintain desirable low flows for fish, using the telephone connection to the RCD-maintained streamgage at Old Sonoma Road Bridge to schedule withdrawals from streams.
F-2-1: Maintain a depth of one foot during adult steelhead migration (November - March) and six inches during smolt outmigration (April – June). NMFS cites seven inches (0.6 feet) as the bare minimum water depth to allow for adult steelhead passage.
F-2-2: In reaches that have flow during summer rearing periods, maintain flowing water over riffles to support invertebrates and improve water quality.

F-3: Explore opportunities to use recycled water for agriculture and landscape irrigation.

F-4: Use water conservation fixtures and equipment in and around homes and for agricultural uses of water

F-5: Use low-water-consuming and fire-retardant native plant materials for landscaping and habitat restoration.

F-6: Explore and where preferable utilize alternatives to engineered storm drains (to disperse, rather than concentrate, water).

F-7: Improve communication among water appropriators and among appropriators and the community.

F-7-1: Establish a communication network among water appropriators to discuss bypass requirements and best management practices for water withdrawal.
F-7-2: Establish a communication link between appropriators and the community to discuss surface water use.
F-7-3: Conduct field tours to demonstrate water use practices and procedures.

F-8: Support continued monitoring and research regarding local water conditions.

F-9: Conduct education and outreach to promote water use efficiency practices.

F-7-1: Encourage vineyard participation in Napa Green Farm Certification Program.
F-7-2: Continue to invite guest speakers to Stewardship meetings to cover topics related to water use efficiency, in-stream flows, and groundwater management.

Objective G: Encourage land stewardship and sustainable land use

The goal of this objective is to recruit active watershed management participants, so that every property owner takes responsibility for actions that affect the watershed.

Linkages: actions which educate land users about stewardship and sustainability tend to support the whole range of objectives identified in this plan, because informed land users are more likely to consider the environmental consequences of management decisions.

G-1: Organize community events and develop other mechanisms to increase awareness of this plan and support for its implementation.

G-2: Develop a creek restoration demonstration site on Carneros Creek and utilize it for community events.

G-3: Develop and distribute a “creek care guide” to landowners and managers.

G-4: Develop and implement a means to discuss this plan with neighbors and receive feedback from the community.

G-5: Facilitate permitting for environmental restoration projects. Support DFG and NRCS efforts to develop a local consolidated permit program.

G-6: Obtain funding for watershed work done under this plan.

Future Research and Recommended Monitoring

Although a great effort was made to assess existing watershed conditions in 2002 as part of the extensive watershed assessment, some additional research needs were discovered. They include the following:

- Identify wildlife species and habitat diversity
- Identify key wildlife corridors
- Gather data to improve water budget
    - Multi-year records of monthly rainfall
    - Establish creek flow measurement stations at several locations and maintain for 5 years
    - Gather information on permitted surface water withdrawal volumes (identify those with & without bypass requirements)
    - Improve information on ground water extraction – meter as many wells in the watershed as possible
    - Identify where aquifer is recharged
    - Estimate water use for vineyard, residential, and other irrigation, and rural domestic use
- Conduct groundwater monitoring to better characterize the groundwater basin and better understand locations of recharge and connectivity with surface water

Beyond additional research, watershed conditions should be monitored over time to allow the community to track changes within the watershed and adapt their land management strategies accordingly. Several recommendations for on-going and future watershed monitoring resulted from the watershed assessment and are summarized in matrix format in the Management Plan. The information that follows provides additional information regarding recommended monitoring. The numbering of recommended monitoring activities is the same in both documents for ease in cross-referencing (e.g. recommendation A-1 in the Management Plan is the same as A-1 in the Reference Document).

Objective A: Establish an uninterrupted riparian corridor along Carneros Creek and its major tributaries, emphasizing the use of native plants that are not primary hosts for Pierce's disease

A-1: Monitor vegetation growth and continuity and width of riparian corridor
Riparian continuity is one of the keystones for improving the channel condition and functioning. Wildlife habitat, channel stability, water quality, water temperature and aquatic habitat will all improve with established riparian vegetation. Monitoring vegetation growth over multiple growing seasons will provide a relatively quick indicator of success. Riparian continuity data should be collected for the entire reach annually for the first three years, and then once every five years following.

- Monitoring of the corridor should be based on the three defined reaches. Information should be recorded for each bank. Channel reaches longer than 15 m (50 ft) that are devoid of canopy should be considered riparian gaps, and areas of potential restoration. Locations of these gaps should be noted and photographed.
- Data collection should be keyed into channel length distances, working successively upstream. Data should be segregated by bank, and should include dominant riparian species/dominant composition, approximate age/age class, and condition. Secondary species should be noted. Notes should include approximate riparian corridor width, degree of undercut (if applicable) under individual trees, and potential for recruitment into the channel. Percent canopy cover (as measured in the centerline of the creek using a spherical densiometer) is a good quantitative metric.
- Success is reached when the corridor is 95% continuous, with no single gap larger than 20 m (66 ft) in length.

A-2: Monitor vegetation growth at restoration sites
At restoration project sites, initial baseline data should be collected followed by post-project data collected annually for five years following project completion. After the first three years of data collection, trends will be observable. Longer-term data collection will serve as checkups, and will identify new problem locations due to development, vegetation disease, or bank instability.

A-3: Observations of vines infected with Pierce's Disease should be recorded
Pierce's disease (caused by the bacterium *Xylella fastidiosa*) is hosted by many common riparian plant species, including: California grape, periwinkle, Himalayan and California blackberry, stinging nettle, mugwort, mulefat, and blue elderberry (http://www.cnr.berkeley.edu/xylella/hostptable.html). Vectors include the blue-green sharpshooter and the glassy-winged sharpshooter. Observations of infected vines will be important in slowing the spread of the disease. Data should be collected from vineyards throughout the watershed once every other year, with more frequent inspections during epidemics. Monitoring for the disease is primarily intended to slow the spread of the disease and should continue until Pierce's disease is not a significant problem/issue in the Napa Valley region. Restoration sites in proximity to vineyards should choose plants that are not hosts for Pierce's disease.

Objective B: Promote contiguous upland habitat and biodiversity

B-1: Measure and record shape, area, and connectivity of wildlife habitat and migration corridors including riparian corridors and east-west corridors connecting habitat to adjacent watersheds.

Areas should be measured following the same schedule as the riparian corridor monitoring (annually for the first three years, once every five years thereafter). Trends should be apparent during the first three years of data collection. Methods should use the most recent aerial photographs available, in concert with field measurement.

B-2: Document number of wildlife species present in the watershed
Monitoring the watershed area available for wildlife habitat will help in understanding the status and condition of wildlife. Consider working with a wildlife biologist to document numbers and species of wildlife currently present in the watershed.

B-3: Monitor grazed areas, specifically grazing related erosion; grass species composition, condition, and density; percent area composed of exotic invasive species; and effectiveness of best management practices.

- Working with the NRCS or other resource professionals, develop a monitoring plan for grazed areas of the watershed. Monitoring should be field-based, and the following observations should be recorded: grazing-related erosion (bank trampling, gully and headcut development, etc); grass species composition, condition, and density; percent of area composed of exotic invasive species; and effectiveness of employed best management practices.
- Monitoring should occur annually for the first five years, and once every three years thereafter. Work with agencies/local experts to create a plan to eradicate non-native invasive species and replace them with native species, ultimately reducing problematic invasives by 75 %. Possible other goals: reduce grazing-related erosion (total number of erosion sites or total volume of erosion by 50%).

Objective C: Maintain and improve in-stream habitat

C-1: Conduct a survey of complete and partial migration barriers for salmonids and other species.
An initial survey of the main stem creek observing both complete and partial migration barriers for salmonids and other fish species was completed in 2002. Similar surveys should be completed once every three years. Landowners should work with the RCD and the Department of Fish and Game in designing and implementing the removal of any barriers. For future surveys, photographic records of the barriers at low- and high-flow; information on the height of the barrier, the depth of the pool, if any, beneath the barrier; and monthly estimates of the amount of flow over the barrier should be collected. Success is reached when anadromous fish are able to access the portions of the creek that provide appropriate habitat value. Significant improvements to fish migration would occur with the removal of 50% of

the partial barriers. Prioritization should be given to the removal of barriers in the lower and middle reaches.

C-2: Monitor the number, depth, volume, complexity, and location of pools.
Monitoring the number, depth, volume, complexity, and location of pools will provide important data on channel function, available aquatic habitat, and the outcome of any restoration projects or changes in land management. The dataset collected for this project (see Channel Geomorphology Technical Report) can serve as baseline data for pools in the 10 sample reaches. Continued monitoring in these same reaches will provide information on pool trends through time. Monitoring should occur during the dry season, once every three years, or during the dry season following an unusually large flood event (5 year recurrence interval or greater). Success will be reached when pool habitat quality and quantity is stable for two consecutive monitoring periods.

C-3: Monitor restoration projects – inventory of pools and channel form.
For specific reaches with projects planned, an inventory of pools and other channel features (e.g., gradient, sediment storage, large woody debris, channel bed grainsize) should be completed before and after the restoration project, as well as annually for five years after the project. Monitoring at project locations will provide data on the level of success of the project for meeting its habitat and physical processes goals.

C-4: Document the location and condition of cattle crossings.
Landowners should develop a monitoring program to document the location and condition of cattle crossings across tributaries and the mainstem of Carneros Creek. Monitoring should occur annually, and could utilize photographic records and/or bank pins to document the extent of erosion.

- Measures of channel bed grainsize distribution downstream of major crossings could also be employed to quantify any effects of management efforts enacted.
- Management plans to reduce the total number of crossings by 50% and/or to improve all of the major crossings to reduce the impact upon the stream should be enacted. Landowners should work with the appropriate permitting agencies during planning of removal/upgrade of any crossings. RCD and NRCS may be available to assist.

C-5: Conduct snorkel surveys of fish species during the summer.
Conduct annual snorkel surveys of fish species during the summer. The data would be used to describe what fish species are present, which age classes of steelhead are found, and the distribution of juvenile steelhead throughout the creek. Annual results could be compared with successive years to refine understanding of long and short-term variability and impacts of water levels on the population. Surveys should also focus upon other habitat requirements and factors affecting the success of fish in the watershed. These other factors may include: availability and transport of fish food (macroinvertebrates), water levels, water temperature, etc.

C-6: Conduct steelhead spawning surveys during adult migration season (December – March).

C-7: Monitor all projects that potentially impact in-stream habitat.
Monitoring of bank erosion on the adjacent bank, upstream and downstream of a restoration project would provide data on the success of the project. Baseline data should be collected in the proposed reach before a project begins. Monitoring could include photographic records and bank pins/scour chains to document erosion. Success is reached when the restoration proves to limit erosion in the project reach, does not induce erosion adjacent to the project, encourages natural channel processes without negatively affecting water or sediment transport, and encourages growth of native vegetation in the project area.

C-8: Monitor water quality, particularly temperature, dissolved oxygen, pH, and conductance.
The group should continue to monitor water temperature in key reaches, particularly the middle reach, which is important for providing aquatic habitat. Water temperature monitoring with continuous dataloggers in reaches with seasonal drying would reveal the relative importance of elevated stream temperatures, especially in the middle and lower reaches. Year-round monitoring could be implemented to document stream temperatures during salmonid spawning, egg incubation, rearing, and migration. This would identify important seasonal variations and allow the group to isolate those periods during the year that are most critical to maintaining water levels sufficient for healthy cold-water fish populations. The goal would be to maintain year-round temperatures below 68° F (20° C) for juvenile steelhead, currently found in the middle reaches. Hobo brand temperature loggers should be used, anchored in place, in a pool that will not completely dry up over the summer/fall. Data loggers should collect at least one data point every hour, potentially every 15 minutes during the summer and fall. Data should be downloaded once every month. Data should be collected for two consecutive years, in the same locations, with a decision to continue or to modify the methods at that point.

- Monitor water quality under supervision of the Napa County RCD's volunteer monitoring program. Data should be collected at three established sites at least monthly and include: dissolved oxygen (DO), temperature, pH, specific conductance, and other physical observations. One established monitoring site is located at the Old Sonoma Rd Bridge, and two more sites should be established upstream.

C-9: Measure turbidity.
Sampling should be conducted during high flow periods.

C-10: Sample benthic macroinvertebrates.
Sampling should be conducted in the spring and/or fall.

Objective D: Reduce soil erosion

D-1: Monitor vineyard plots and avenues for rill and gully development throughout the wet season.
Monitoring should occur annually, and should utilize photographic records and quantitative measures of erosion.

D-2: Monitor and remove debris from bridges and culverts to prevent the buildup of debris.
Preceding and throughout the wet season, monitoring of bridges and culverts should occur to prevent the buildup of debris. Work with the Napa County Flood Control and Water Conservation District to coordinate debris removal. RCD may also be available to assist.

D-3: Conduct physical and biological monitoring at outlets that drain to the creek and reservoir outlets.
Utilizing the work of Pacific Watershed Associates (see Hillslope Geomorphology / Sediment Budget Technical Report) the number of culverts/ditches/roads that are contributing or have the potential to contribute significant amounts of sediment to the fluvial system should be reduced by 50% over the next five years. Success will be reached with a significant decrease in the amount of road-related erosion that is routed into the fluvial system. This can be assessed by conducting physical and biological monitoring, including measures of ditch, culvert, and bank erosion; measures of bed sediment grainsize distribution at locations of drainage input; and measures of the benthic macroinvertebrate community composition and health. Additionally, increased awareness and education regarding the potential impacts of road-related drainage will increase the likelihood of success.

Objective E: Protect property and habitat using natural processes that promote streambank stability.

E-1: Monitor bank erosion and measure channel cross sections.
Utilizing the data collected in this study as a baseline (see Channel Geomorphology Technical Report), biennial monitoring of bank erosion and measurement of channel cross sections in the 10 sample reaches will provide data on the trend of bank erosion. In addition, in high-erosion locations, bank pins can be installed to monitor erosion on an event or annual basis. Success is reached when the volume of bank erosion caused by human sources (road, vineyard, or residential drainage, channel modifications, vegetation removal, etc) is reduced by 50% over the next five years.

E-2: Map locations of debris jams. Monitor locations with excess in-channel vegetation and amount of in-channel woody debris.
As described above, monitoring and maintaining culvert and bridge locations for debris during the wet season will help prevent flood damages. Monitoring of locations with excess in-channel vegetation as well as monitoring of volumes of in-channel LWD should also

occur on an annual basis. Success will be reached when the maximum amount of vegetation and LWD can remain in-channel without causing significant flood hazards and damage.

E-3: Monitor effectiveness of bank stabilization projects.
See C-7 above.

Objective F: Improve water management for the benefit of human, plant and animal communities

F-1: Document locations of all diversions from the stream and make sure diversions are properly screened.

F-2: Work with RCD to continue monitoring water level and discharge, making the information available to those who divert water.
The stream gage will allow calculation of the total annual streamflow and will provide water level data so that even with water withdrawals, minimum flow depths for fish are maintained. For specific seasonal depth requirements see Objective F-1-2. The gage records data continuously, and can be accessed via telephone. Data should be collected for a minimum of five full water years. Success will be reached when minimum stream flow requirements for salmonids are met throughout the year and sufficient water is available for plant and animal species and human uses.

Objective G: Encourage land stewardship and sustainable land use

G-1: Document number of watershed community events that support watershed awareness and implementation of actions suggested in this plan.
Watershed community events might include project work days, stewardship meetings, demonstration workshops, etc. Success will be met in years when 8 events are held and attendance goals for each event are met.
G-2: Track progress of development of creek-care guide.
A creek-care guide and restoration demonstration site should be developed within 5 years. The creek-care guide will be successful when it is available on-line and distributed to 100 property owners or managers within the watershed. Greater success will be achieved when practices or suggestions in the care-guide are implemented by several landowners or managers (a survey instrument could be used to evaluate implementation).

G-3: Track progress of establishing a restoration demonstration site and once completed, track its use.
The restoration demonstration site will be successful when it is utilized annually for community events and possibly for monitoring.

G-4: Document, to the extent feasible, implementation of the recommendations in this management plan.

Tracking could be accomplished through surveys and/or direct communication & coordination with resource professionals and landowners/managers involved in implementation.

G-5: Document efforts to obtain funding and funding received to implement actions suggested in this management plan.
Success will be met when sufficient funding is available to landowners who choose to implement suggested actions.