DRAFT
WEB PAGE MOCK-UP

of

CARRIGER CREEK WATERSHED SCIENCE APPROACH

by

By Laurel Collins, Donna Morton, and Paul Amato
San Francisco Estuary Institute

SUMMARY CONCLUSIONS AND HYPOTHESES

1. Over an estimated 165 year period in Carriger Creek Study Site, fluvial erosion along 81% of the length of the banks (76% eroding banks + 5% revetted) has supplied 635 cu yd/ yr of sediment to the channel network. Bed incision occurring over 100% of the Study Site length has supplied 578 cu yd/yr. The total long-term combined sediment supply rate of the bed and banks has been 1212 cu yd/yr. We consider this rate to be greatly accelerated above the rate of supply that existed before settlement of non-indigenous peoples. The amount of retreat of the eroding banks ranges from about 1.5 ft to 56 ft, the latter representing over two bankfull widths of erosion. The maximum amount of incision observed has been about 8 ft, representing nearly three bankfull depths of incision. The average is closer to two bankfull depths.

2. The channel has widened and deepened as a result of several instream and adjacent land use impacts. The instream impacts include 1) the destruction of distributary channels that used to subdivide Carriger Creek into three separate channels (all the flow below Arnold Bridge is now funneled into the previous southern distributary); 2) the construction of the original Arnold Bridge that caused backwater flooding and had insufficient capacity for transporting water an sediment during flood events; 3) the channel straightening activities that were conducted for flood control upstream of Arnold Bridge; and 4) the removal of wide riparian buffers along agricultural fields that has increased rates of bank erosion. The most significant adjacent land use impacts include the minimization and clearing of a once wider riparian corridor for increased acreage of crop fields and pasturelands, and the destruction of willows from grazing pressures in and along the channel.

3. Following the destruction of distributaries when Carriger Creek became a single thread channel, the hydraulic geometry had to adjust to increased flows which established a cycle of bank erosion, bed incision, and movement of very large boulder to cobble-sized sediment into the newly incising bed of Carriger Creek. We call this an "incision and armored aggradation sequence" that has been exacerbated by the loss of riparian vegetation. If Sonoma Creek has also incised its bed during the last 165 years, then it could also be driving some bed incision in Fowler and Carriger Creeks. We suggest that channel incision is being driven by both in situ incision from more flow contained in the channel after the distributaries were destroyed, and from headward propagation of incision initiated by base level lowering at the Sonoma Creek confluence. In the reaches above Arnold, steepening of the gradient from channel straightening activities was also driving incision.

4. It is presently unclear how much the channel incision in the Study Site might also be influenced by potential increases in runoff upstream of the Study Site. Based upon our upstream reconnaissance above the Study Site, between Grove St. Bridge and the culvert at Grove Extension, we observed that this reach

has also incised during the last century. The amount of incision appears less than that observed in the Study Site, but whether recent incision is pervasive, extending all the way to the approximately 65 ft high waterfall below Grove Extension, has not been determined. Without further study of the rest of the watershed, the impacts of suburban development, such as increased runoff cannot be assessed. There is no dense residential development in the watershed, and only a small portion of the watershed is impervious. During a brief reconnaissance of the residential area, we did not observe significant impacts from increased runoff from existing impervious surfaces. We did observe incision below culverts that caused erosion at poorly designed outfalls. Again, the volcanic soils may ameliorate some of the typical effects of increased runoff from development.

Along the lower alluvial fan and Sonoma Valley, we did not see abundant evidence of increased surface flow from the vineyard and crop lands. This is probably because the land is fairly flat. We did see numerous cattle trails into the creek that probably function as ephemeral channels that transport fine sediment from the uplands directly to the channel. If conversion of land to vineyards occurs on the steeper lands there could be increases in both runoff and fine sediment supply if ground cover is minimized. Increases in runoff are associated with loss of interception by plants.

Although there is a history of cattle ranching in the canyon portion of the watershed, extent and magnitude of grazing activities is also not clear without further historical research. Our initial impression about the soils of the canyon and alluvial fan area is that they are not very erodable or responsive to typical impacts associated with grazing. Because the soils are very rocky and porous, trampling and loss of infiltration are less likely to occur. However, grazing has ~~contributed to the loss~~ of riparian vegetation, and to declines in base flow and water quality.

5. Carriger Creek is dramatically different upstream of Steelhead Reach than it is downstream. Upstream there is clear perennial flow during the seasonal drought. Juvenile steelhead are abundant in this part of the creek, which indicates that water quality must be relatively good. In contrast, excessive bank erosion along some downstream reaches has degraded the quality of habitat and diminished available flow for fish. Loss of available flow has been partly caused by creating an extremely wide cross sectional area and by incision and subsequent armored aggradation of the bed surface that causes the late autumn flow to go subsurface. Below Steelhead Reach, the flow is intermittent and there are only a few isolated pools. Below Arnold Reach, the pools are notably of poor water quality, as indicated by turbid water color, fetid odors, and algal blooms.

6. Without better development of the historical picture of Carriger Creek, the previous amount of perennial flow cannot be estimated. We do think that historically, Carriger Creek along its principle distributaries was perennial to

Sonoma Creek. This is indicated by remnant mature riparian vegetation found at fragments of distributary channels. We expect that the water table throughout the Sonoma Valley is lower today than it was during the early 1800's, before the advent of wells, reservoirs, and diversions. The influence of channel incision along Carriger Creek has contributed to water table draw down, along with well pumping and consumptive agricultural uses in the valley. During low flow conditions reaches below Steelhead Reach may be now functioning as "losing" reaches rather than "gaining" reaches in terms of total discharge.

7. Several of the reaches downstream and upstream of Arnold Bridge have few if any riparian trees. The loss of woody vegetation has caused a loss of root strength in the banks, causing them to be more erodable, thereby contributing to extreme channel widening. This widening has caused the channel to straighten its meanders, and increase stream gradient and water velocity. We have observed that along many of the vineyards and pasturelands, the riparian corridor is often only as wide as one tree. Before fields were cleared for agricultural practices, a much wider riparian zone probably existed, perhaps as wide as three or more trees on each side. By diminishing the riparian zone to a narrow corridor, the buffer to bank erosion that is created by the added root strength of trees is lost. Thus, when bank erosion caused the loss of one row of riparian trees, the rate greatly accelerated because the network of roots beyond one tree row was missing. Essentially, the removal of riparian buffers along agricultural fields has lead to increased and unchecked rates of bank erosion.

8. The reaches near Arnold Bridge on the lower alluvial fan are still highly unstable. This instability may continue as a result of the armored bed, where large floods mobilize very large sediment that can cause bankfull flows to erode into fine-grained banks. This explains the "cross-channel stair-stepped morphology". It also explains why patches of fine-grained Quaternary clays are interspersed with veneers of boulders and cobble.

9. In the farthest downstream reaches where the gradient is flatter and the bed has not been armored by large-sized coarse sediment, the channel assumes a narrower width between its terrace banks and becomes much more deeply entrenched than the middle reaches. At the upstream reaches near the apex of the alluvial fan, the channel is also more deeply entrenched than in the middle reaches. This has caused the supply of sediment from bed incision to exceed that from bank erosion at the upstream and downstream ends of the Study Site. The apex of alluvial fans is a common area of natural instability and should be regarded as such in any future planning efforts.

10. The number of pools through the overall Study Site during autumn drought is considered very low. Spacing is within the expected realm only for Distributary and Diversion Reaches. Most of the pools in Carriger Creek have natural causes but wood contributes to 30% of the total.

11. LWD is most abundant in the channel where there are reaches with riparian vegetation. We expect the recruitment of LWD to diminish through the Study Site until bank erosion rates are decreased and until sufficient maturity of existing riparian vegetation is gained. Accelerated bank erosion must be reduced in order to give time for tree to take hold and grow in the sections of bank that are devoid of riparian trees. Recruitment of LWD is primarily from bank erosion processes. This mechanism was probably much less important in the past.

12. After many years of relative stability, landowners along the channel upstream of Arnold Bridge have observed very recent bank erosion and changes in channel configuration during the 1990's. Some of these landowners have experienced recent flooding of their properties as well. We conclude that the channel may be just starting to undergo a new period of destabilization. This could be a lag time response to the downstream "straightening" activities. Overall, the classification of the Study Site into different Rosgen Stream Classes shows that currently over 52% of the channel length has an unstable geometric form of F and G classes.

13. Land use changes during the last 165 years have greatly increased rates of sediment production in Carriger Creek, particularly downstream of Steelhead Reach. Without a complete watershed analysis, we cannot quantify the total sediment supply from different sources nor de we feel that conditions on the alluvial fan can be extrapolated to conditions in the canyon. Because most of the changes that we have discussed have been instigated by instream changes caused by man during the last 165 years, we conservatively project but confidently state that greater than 60% of the sediment supply from the Study Site has been caused by anthropogenic influences.

14. The very low percentage of sand found on the channel bed surface is attributed to: 1) the volcanic nature of the canyon that has produced an abundance of rounded cobble to boulder-sized rocks (their rounding may be more associated with explosive volcanic events and weathering than from alluvial processes); 2) the low percentage of fines in the bank materials throughout most of the canyon zone; and 3) the lack of surface erosional features in the soils. It is also possible that land use activities in the canyon have not been heavy-handed or extensive. Without further study, this impression is tentative. We do not find that sand and finer-sized sediments have impaired pool or spawning habitat within the study reach. Bank erosion along the lower alluvial fan has contributed to a supply of sand and finer-sized sediment to the channel, most of which is transported out of the Study Site. Its downstream impact upon downstream reaches of Fowler and Sonoma Creek, including the tidal reaches has not been assessed.

RECOMMENDATIONS

1. Protect the upper watershed. The creek in the canyon has abundant ecological value that should be conserved.
2. Consider restoration of the system of distributary channels across the alluvial fan. Natural distributaries formerly prevented the concentration of flow that now erodes the single remaining channel. This restoration will reduce the risk of floods in downstream Sonoma Creek and increase in-stream ecological values.
3. Where possible, reshape the channel to create a stable cross section; use biotechnical methods of bank stabilization or use boulder veins to direct flow away from eroding banks. A narrower width-to-depth relationship may restore perennial flow in some portions of the creek and minimize migrational barriers to fish that get trapped in isolated pools.
4. Restore the riparian forest on the alluvial fan to reduce future bank erosion, to create a renewable source of LWD for in-stream habitat enhancement, and to minimize increases in water temperature that can be fatal to fish. This will require fencing cattle out of the riparian zone.
5. Increase the amount of LWD from existing sources by not removing LWD unless it threatens a structure or causes backwater flooding at bridges.
6. The longitudinal profile of the mainstem channel should be surveyed to establish future monitoring stations within stable reference reaches (Rosgen B-type channels) and unstable reaches (Rosgen F- and G-type channels) that will show differences and future changes in dimensions and profile. It will also allow correctly delineation of local reach gradients. This information can also be used to develop design standards for restoration. Realistic projections of the extent of backwater floods associated with past and present bridges should also be determined.
7. The upper watershed in the canyon should be assessed for sources of sediment resulting from land use and in-stream management activities. This will help protect the existing ecological values in the canyon. It is important that these values be sustained.
8. The historical ecology of the watershed should be described, including native land use practices, patterns of historical land use change, and the chronology of local development, including diversions, impoundments, and engineered stream crossings. Such a perspective would improve everyone's ability to direct management initiatives and to understand the relationships between land use and watershed conditions. See SFEI's *How to Guide for Local Historical Ecology (SFEI 1998).*

ACKNOWLEDGEMENTS

Technical staff from both the Southern Sonoma County Resource Conservation District and Sonoma Ecology Center that included David Luther, Caitlin Cornwall, Patricia Preston, Amy Goldstein, and Richard Dale assisted in the collection of field data. We thank Josh Collins and Paul Jones for their commitment to watershed science. Steve Norwick and Bill Cox provided stimulating conversation and endured a day of drenching rain to join us in an upstream field reconnaissance. Luna Leopold and Jeffrey Mount are gratefully acknowledged for their review of the manuscript.