Post Project Evaluation, Miller Creek, California: Assessment of stream bed morphology, and recommendations for future study

Introduction

Miller Creek, located in Marin County, California, begins on Big Rock Ridge about five miles north of San Rafael, and runs roughly due east through Las Gallinas Valley and on into the San Pablo Bay. The watershed, about 4 square miles, consists of forested or grazed land in the upper watershed and higher elevations, with residential subdivisions lining its middle reaches, and largely agricultural use on the alluvial plain (See Maps 1 and 2). The restoration project we evaluate in this paper is one of the earliest examples of this multi-stage channel approach in California, and is located in the upstream portion of the subdivisions.

The lower hills of the watershed have been grazed continuously since Mexican settlement in the 1800s, and grazing can largely be blamed for the degraded condition of the stream. The effects of grazing include compaction of the land surface and destruction of native hillside vegetation, leading to reduced infiltration and thus increased rate and volume of sediment delivery. In addition, trampling by animals in the creek has degraded the banks and destroyed riparian vegetation. The result has been a dramatic deepening and widening of the channel, with steep, nearly vertical banks in excess of 20ft. In more recent decades, the watershed has seen urbanization in the form of residential subdivisions. Although the creek was well degraded before these subdivisions were built, the general effects of urbanization are similar to grazing. Impervious surfaces dramatically decrease infiltration, leading to higher volumes of discharge and more flashy flows that exacerbate bed incision.

Hydrologists at Philip Williams Associates, the firm that oversaw the initial project design, report that the creek is currently in the midst of its second down cutting cycle (Vandivere, 1985). The report does not detail the timing or cause of these cycles, but states that during the early stages of the second episode, discharge increased at a greater rate than sediment supply, leading to hungry water and accelerated bank erosion. However, more recently, incision of the tributaries has led to greater sediment supply, and may stabilize the incision.

Our purpose in studying this project was to identify how the channel form has responded since project implementation, and to qualitatively evaluate the improvement to habitat within the project reach.

Project Description

The Miller Creek restoration project was designed and constructed during the 1980s, in conjunction with a residential subdivision that was being built on either side of the stream. This subdivision, first known as Deerfield Park and later as Lucas Valley Estates, is currently the upstream most subdivision in a series of developments along Miller Creek. The purpose of the project was to protect the housing development from further channel widening, and to do so in a manner that was more ecological than traditional engineering treatments and provided habitat value within the stream corridor (Haltiner et. al., 1996).

Table of Project Details

Title	Location	Agency	Year	Purpose	Lenth of reach	Size
Miller creek restoration project	Marin county , CA	Marin county	Initial conceptual design was developed by Jeff Haltiner and Philip Williams of PWA in 1979-1980, with flood modeling and additional concepts by William Vandivere (then of PWA) in 1980-1984, with detailed design and construction plan development completed by William Vandivere, with various firms, from 1985-1988. Construction was completed during the summers of 1989 and 1990 (Vandivere, 2003). The creek experienced a major flood in 1995 (Haltiner, 2003).	Increase stream bank stabilization/protection	2 km	10 km^2

The project created a low flow channel flanked by a floodplain terrace, and banks receding back at a 3:1 slope (Figure 1:Typical cross section). At the top of the slope, individual property lines are set back 10-50 ft., providing the stream with a corridor of about 200ft., within which to meander or flood (I.L. Schwartz Associates, 1989). In selected reaches, an un-reinforced low-flow channel was graded through the overly wide creek bottom, which was to serve as the new floodplain. In the majority of the reach, the overly wide channel bottom was not graded, but the designers hoped that the stream would naturally achieve a narrower configuration based on influent water and sediment regimes (Vandivere, 2003). At bends, or where mature trees or the road was threatened, the toes of the banks were stabilized with rock and willow cuttings to prevent channel migration. At one bend a crib wall protects Lucas Valley Road, and at another bend a series of spur dikes protects some mature trees. The entire channel was completely re-shaped (Figure 2, Construction), and the banks were then planted with willows and a mixture of native trees and shrubs, and hydro seeded with native perennial grasses (Guzzardo, 1989).

Methods

Review of Project Documents

To document project design and construction, we obtained and reviewed the initial hydrologic analysis and conceptual design drawings (Vandivere, 1985), and a further hydrologic analysis with more design drawings completed in 1988. We also obtained the grading plan for the upper portion of the project reach, and the landscape plans for the revegetation, both dated 1989. Because no as-built surveys were conducted, the design documents are our best reference for comparing the current channel conditions to the built conditions.

Field Survey and Comparison to Design

From the grading plan, we drew eight cross-sections, at stations 23, 26, 30, 34, 38, 40, 43, and 46, of both pre-project conditions and designed conditions (Figure3: project plan). Our stationing is based on the stationing established by the original pre-project survey and indicated on the grading plan. From these eight, we chose three that represented different levels of intervention, and surveyed them in the field. We located the sections approximately by comparing the plan to an aerial photo. We tied our survey into a benchmark on the site, so we are able to compare them by elevation with the sections we cut from the plan. We used the surveyed cross sections to analyze the evolution of channel form since project construction.

There are two potential sources of error in our use of surveyed cross sections to analyze the evolution of the channel form. First, we expect a discrepancy between the shape as specified on the grading plan and the actual as-built condition. In the absence of an as-built survey, however, the plan is our only source of information on the designed channel form. Second, there is probably a discrepancy between where we cut the surveys on the plan and where we actually measured them in the field, as we located ourselves based on the plan and an aerial photo. Despite these potential sources of error, we feel that our comparisons are basically valid.

<u>Habitat Assessment</u>

We also conducted a visual analysis of the site to assess how the project as a whole has evolved, and how the habitat characteristics of the site have been altered as a result of the project. We re-occupied three specific photos of the site, taken by Jeff Haltiner in Philip Williams & Associates, to document the evolution of the stream channel and the vegetation since project completion. Also, while walking the site, we took note of characteristics such as shade, frequency and depth of pools, and diversity of substrate. For these characteristics, we compared conditions in the project reach to creek conditions upstream and downstream of the project. The upstream comparison reach resembles pre-project degraded conditions on the site, and is a useful reference point for pre-project habitat characteristics. Downstream of the project reach, where Miller Creek passes to the south side of Lucas Valley Road, conditions are less disturbed and the creek is shaded by a mature riparian canopy. We used it as a reference point for how habitat on this creek could potentially develop.

Results

Channel Form

As the eight sections cut from the plan show (Figure 4: Cross Sections), the designers used a combination of cut and fill to re-slope the banks, establish a low flow channel, and provide a flood plain (Figure 5: Typical floodplain drawing). The three sections that we surveyed give some indication of how the channel has evolved. In section 26, the grading plan does not include a low flow channel. Currently, a low flow channel about 3 feet deep and 15 feet wide has formed at the toe of the left bank. There has been some undercutting along the toe of this bank, and there are sand and gravel deposits on the flood plain. From the surveyed section, we can see that the low flow channel has remained in the same location but is a bit wider. At section 46 as well, the grading plan shows no new low flow channel. The surveyed section shows a rather wide (24 ft) low flow channel with a floodplain terrace on either side. The terracing on the right bank does not appear in the grading plan, but on site it appears to be a designed feature (Figures 6: Comparison of surveyed and designed cross section, Figures 7-8, Section images).

Vegetation and Instream Habitat

When the vegetation currently existing at the cross sections is compared to the vegetation indicated on the landscape plan, it appears that a large number of the trees have died. While the planting plan shows the banks covered by trees such as alder, ash, buckeye, and box elder (Guzzardo, 1989), the banks of our sections were dominated by coyote bush and annual grasses, with some willow near the active channel (Figure 5: photo of typical floodplain).

In the project reach as a whole, there is evidence that the channel has been evolving naturally within the constructed floodplain. For example, revetments are hard to find, and at first glance it is hard to determine if the floodplain is constructed or deposited.

The upstream portion of the project reach is mostly unshaded, with occasional clumps or short stretches of willow. Pools are primarily associated with these willow clumps, and in some unshaded reaches the channel is homogenously straight and flat for long stretches, with dried algal mats indicating warm and stagnant water earlier in the year (Figure 9). In the channel, the substrate is mostly coarse gravel and cobble, with bedrock exposed in some places, and deposits of sand and fine gravel in others. In the downstream portion of the project reach, thick willow growth shades the channel.

<u>Re-occupied photos</u>

The reoccupied photos show a dramatic change from a clearly re-worked bed to a very natural appearing channel. The spur dikes and the crib wall are both located in the downstream portion of the project reach, where willows have sprung up in great abundance, and the early stage of a riparian forest has begun. The spur dikes have been completely hidden by willow, but have induced some scour pools at their tips. The "bend" is located in the upstream portion of the project, willows are present only intermittently, and some of the other riparian trees, such as alders, have died. Coyote bush, fennel, and annual grasses dominate the floodplain (Figures 10-15: Reoccupied photos).

Habitat Comparison

In the upstream comparison reach, the creek channel is wide and deep, with banks about 20 feet high. Shade is infrequent, occurring only when a mature riparian tree is being severely undercut. Pools are shallow and infrequent; there is no willow growth in the bed to induce scour, and so it is limited to linear scour features at the outside of bends. The bed itself looks similar to the bed in the project reach, with the same course gravel substrate, and bedrock exposed in some places. To a limited extent, a floodplain terrace is forming within the creek banks (Figures 16-18: Upstream conditions).

In the downstream reference reach, there is water in the stream year round. The creek banks are tall and steep, the result of historical incision, but they are less steep than the nearly vertical banks upstream, and they are vegetated with a mixture of native and exotic understory and a mature overstory. This mature canopy shades the creek bed almost continuously, with sun and new willows where there has been a landslide. Within the streambed, pools are spaced closer together than upstream, and there is recent point bar deposition and woody debris in the channel. The substrate is still primarily gravel (Figures 19-20: Downstream conditions, Map3: site context observation).

Discussion

Channel Morphology

The designers of this project did not attempt to impose a new meander form on this channel, but merely created a smaller channel within the existing plan form of the creek. Perhaps for this reason, our cross sections did not show significant lateral migration of the channel within the flood plain. Our cross sections, in conjunction with our other observations, do indicate that some minor bank erosion and bar deposition has occurred. These processes reflect natural channel-floodplain interactions. We observed little evidence of incision since project construction. Whether this is a result of project design, or that the channel has reached equilibrium with its watershed, is unclear.

The evolving streambed has formed some riffles and pools, but compared to the developed habitat in the down stream comparison reach, the bed is still fairly flat and homogeneous. If the conditions in the upstream reach reflect pre-project conditions, and if conditions in the downstream reach are used as potential ideal future conditions, the current conditions of the project reach fall somewhere in between. Habitat within the reach is somewhat better shaded and more complex than it was, but it does not yet have the morphological complexity or the developed canopy of the downstream reach.

Vegetation

Two immediately noticeable conditions on the project are the flat and homogeneous nature of much of the streambed, and the scarcity of woody riparian vegetation along much of the project reach. According to Hill and Platts (1998), "riparian habitat strongly influences geomorphic processes and must develop ahead of in-channel habitat to maximize complexity and sustain habitat." As the pools that were observed along the project reach were associated with clumps of willow, this claim seems pertinent to conditions on our site.

Our observations and photographs suggest that of the riparian trees planted as part of the project, very few have survived. The trees are planted primarily on the banks above the flood plain, and irrigation is not mentioned in any of the project documents that we have reviewed, so the low survival rate of these riparian species is not surprising. There are at least two different conclusions that could be drawn from this situation. The first is that the project should have been irrigated while the trees were young, to allow them to establish. This could have improved the current situation in terms of shade in the channel and complexity brought on by roots influencing the channel banks. The second possible conclusion is that the planting plan is moot and habitat within the corridor will adjust optimally to the existing conditions.

The fact that the trees are planted primarily on the banks means that they would have been up to 40 ft away from the active low flow channel. Thus the design itself does not, in the absence of volunteer tree establishment, provide for a shaded low-flow channel. For this reason, the real factor affecting channel morphology is likely the scant volunteer willow establishment in the upper portion of the project, compared to conditions further downstream. A preliminary hypothesis is that in the upper portion of the project, a low summer water table has limited the establishment of thick riparian vegetation on the floodplain. Casual observation supports the notion that there is a difference in water table along the length of the stream. In the upper portion of the project, coyote bush, tolerant of dry conditions, is a very common shrub on the flood plain, while sapling alders are dead. At the downstream end of the project, there is very thick willow establishment, indicating that conditions are somehow different. Further downstream, in the comparison reach, there is water in the channel.

Further Study

A more complete evaluation of this project would include a quantitative assessment of the terrestrial and aquatic habitat features that have developed since project construction, and an investigation of the factors contributing to the evolution of the project. For this restoration project, areas worthy of further study include: riffle pool sequence on the project reach versus the two comparison reaches, the relationship of woody vegetation in the low flow channel to channel complexity, and the relationship of groundwater to vegetation establishment in the project reach.

To evaluate habitat, a longitudinal profile surveying every pool and riffle should be completed for representative segments within the project reach, and in the upstream and downstream comparison reaches. Within the representative segments, vegetation density, placement, and species should be mapped. These results should be compared with the re-vegetation plan, to determine survival rate. Piezometers should be installed to monitor the water table from the beginning to the end of the dry season. In the spring, seedling recruitment and survival should be monitored. This level of research would provide a much more complete set of information about how this project has evolved since construction, and what factors affect the success of projects such as these.

Conclusion

The uncertainty in our analysis of the surveyed cross sections demonstrates the importance of post project surveys to facilitating further study of restoration projects. Even with this uncertainty, however, we were able to identify the manner of evolution that this channel has undergone. Overall, the project is a success, with both the stream and its ecosystem evolving within the bounds of wide banks. The bank stabilization goal has been met, with no evidence of threat to structures on the banks. The project is also a success geomorphically, as the low flow channel is allowed to meander and develop naturally, and incision does not seem to be a problem.

The habitat value of the project reach has also been improved, when compared to previous conditions, because the actively meandering channel gives opportunity for diversity of habitat within the stream bed, and some vegetation has established near the channel and has begun to shade it and to promote the development of more habitat complexity. However, compared to the downstream reach, habitat in the project reach could be much more developed. It may only require time to allow the trees to mature, but there are some important differences between the two reaches. In the project reach, most of the young trees are located relatively far away from the active channel, so will probably never shade the stream. The evolution of the vegetation on this site seems relevant to the morphology, and is worthy of further study.

References

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