Flood Control and Wetland Restoration: Meeting environmental and drainage requirements for multi-objective channels

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Abstract

Drainage channels in California have progressed from trapezoidal channels to multi-terraced corridors, primarily as a result of Federal and State wetland and other environmental requirements. The environmental benefits of these more complex channels are significantly greater than those that would have been present with the standard projects that would have been built at these sites and they have also generally provided the drainage benefits predicted. However, costs for two channels assessed in this analysis were much higher than trapezoidal channel projects originally proposed. Essentially, where the sponsor is willing to incur the higher capital costs and has an appropriate design which considers the relevant factors, multi-objective channels can meet all appropriate criteria and will assist the sponsor with permitting and other works.

Introduction

California has had extensive and significant flooding over the past two centuries. In the mid-18th century, the new capital in Sacramento was 11 feet under water after a particularly serious deluge. As noted by Kelley (1989), these and similar floods were at least partially the result of a long and tumultuous affair between California's local governments and their efforts to maintain intensive uses in the floodplain on one hand and flood control planning on the other. In the heyday of development in California after World War II, flood control needs were often met by excavating the waterways (which had often already been channelized by farmers) into relatively narrow, trapezoidal channels. These channels were relatively inexpensive to build, required

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much less maintenance than levees, and confined flooding, thereby allowing other uses in the old floodplain. In short, these channels were highly efficient.

In the past three decades, though, environmental requirements have greatly modified flood agency objectives. As well as efficiency, local agencies have had to meet riparian restoration and similar goals. These have been rigorous in California, whether due to the great extent of riparian loss in California, up to 90% according to some authors (Katibah *et al*, 1984); the high value of riparian systems (see Holstein, 1984); or the strong environmental constituency, permits for riparian projects are hard to come by. Zentner and Zentner (1995) found that in the Corps of Engineers San Francisco District of California, only one individual Section 404 permit was issued per year between 1989 and 1994. As even minor flood control projects have been required to apply for the more difficult individual permits (as opposed to nationwide 404 permits or Letters of Permission), flood control and drainage work has been seriously effected by wetland regulatory procedures in California.

The result of these more rigorous environmental challenges was the development of modified designs to incorporate added mitigation requirements. These projects helped spawn the term "multi-objective" in that environmental goals were now added as one of the project objectives. Of course, most flood control works had already been subject to multiple objectives in the preceding decades and these projects were often not truly adding an objective but simply reacting to outside pressures. In any case, the first of these new projects were merely expanded trapezoidal channels. That is, the width of the channel bottom was expanded to meet the mitigation acreage requirements.

The success of these projects varied considerably based primarily on maintenance needs. One of the more significant and least studied issues in all combined drainage and restoration projects is sedimentation. An expanded trapezoidal channel provides an excellent settling basin due to the greatly reduced channel velocity experienced as flows move into channels that are often wider than the pre-construction "natural" channels. And, the expanse of new sediment, which is generally kept moist in the summer by runoff from the new subdivisions, often becomes an excellent growing medium for shrubby willows, a poor vegetation association for passing floods.

In Sacramento, for example, the Strawberry Creek channel (downstream reach) was constructed in 1985 as an expanded trapezoidal channel. Even though sediment loads in this system are relatively low, the channel bottom rapidly developed a thick veneer of new sediment which soon supported a forest of willows. In this case, flood modeling assumed that the channel would become relatively thick with willows and their growth has not become problematic. Other communities were not so fortunate. Either through a miscalculation of the rate of growth or extent of willows, or deferred maintenance, clearance of these trapezoidal channels became a pressing need. However, when wildlife agencies were asked to approve permits for the clearance of channels which now often had extensive willow woodlands, their reactions were almost uniformly negative.

Multi-terrace Channels

The experience with these projects led local agency staff to begin contemplating more naturalistic channels that would be self-maintaining to the maximum extent practicable. Conceptually, these mimic natural channels: the low flow channel is kept relatively narrow and deep to provide maximum capacity for heavier bed load materials (sands and gravel) while the overflow terraces are kept at an elevation that encourages wetland development (for mitigation) but discourages willow growth.

Laguna Creek

The Laguna Creek project, built by the City of Sacramento in 1988, was one of the first drainage projects in California to contend with the more stringent 1986 revisions to the Section 404 (Federal Clean Water Act) wetland regulations. Laguna Creek flows for approximately 40 km through Sacramento County, CA. This part of the State has a Mediterranean climate with almost all of the 46 cm of average annual rainfall occurring between November and March. Runoff and flood volumes increase dramatically during storms and what appears to be a minor creek under normal conditions may become a major river during larger storms. These conditions are exacerbated in this region due to the relatively impermeable soils (primarily stiff clays, often with a hardpan only inches below the soil surface) and the flat landscape. Laguna Creek has also been significantly modified by farming practices over the past century. In many reaches, including that portion within the City, the creek was actually a narrow ditch. These features make flooding inevitable but the extent difficult to predict.

By the mid-1980s, drainage plans completed for the City reach by the planning branch of the Corps of Engineers and other entities proposed confining the Creek within a concrete-lined flood channel. By 1986, though, the regulatory branch of the Corps had begun to extend its authority over isolated wetlands in the region, especially vernal pools. Vernal pools are seasonal wetlands endemic to California that consist of shallow ponds during the winter, often no more than 400 to 500 square feet in extent, which dry by early summer. This unique environment may support a number of native plants, invertebrates, and amphibians, including Federally-protected species. In 1987, a City study found about 98 acres of wetlands on the site, including 71 acres of vernal pools, 25 acres of seasonal freshwater marsh, and 2 acres of riparian woodland.

In final negotiations with the Corps, the City agreed to preserve 33 acres of the wetlands and build almost 138 acres as compensation for the loss of 65 acres of wetlands. In essence, the City had committed to creating a complete native landscape including vernal pools, freshwater marshes, and oak woodland within a flood channel. Further, the performance of these habitats would be evaluated through specific standards with potentially expensive remedial actions should the project fail to meet these standards.

Wetlands and flood channels are often incompatible, though. The dense plant growth characteristic of many wetlands greatly increases channel roughness and flood elevations. Research done by Zentner and Zentner and Bill Gill of Gill Water Resource Engineering found that the most problematic species, primarily willows and cottonwoods, were found only below the mean annual flood line in this region due to soil and seed viability factors. Accordingly, the creek corridor was designed to maximize the relatively open vernal pool and seasonal marsh zone (N value of .045 to .055), provide for a substantial amount of open oak woodlands (N value of .05 to .065), a lesser amount of perennial marsh (N value of .06 to .07) and to greatly limit the riparian woodland zone (N value of .10 to .12). It is important to note that Laguna Creek was also blessed, from a flood control standpoint, in that while the soils were so impermeable as to increase runoff, they were also generally too tight for significant tree growth, except where perennial water occurs. Accordingly, flood control planning could predict the locations of significant tree and shrub growth with some accuracy.

Construction costs were relatively low compared to many wetland creation projects. Although projects vary significantly in their scope and character, relevant literature and our experience suggest that similar wetland construction projects in California range from about $10,000 to $30,000 per acre with an average over $20,000. Costs at Laguna Creek totaled $565,000, about $4,100 per acre, not including grading costs. These also did not include land costs; the land was dedicated by the developers adjacent to the Creek who received a flood reduction benefit. Costs (primarily grading) for construction of the previously proposed trapezoidal channel would have been about one-third the cost of the constructed channel.

By the end of the five year monitoring period, the constructed freshwater marsh and riparian woodlands completely met all performance standards. The extent and value of these habitats was significant; in addition to supporting more than 100 species of birds (compared to 8 prior to construction) they created habitat for a wide variety of wildlife, including the Federally-listed giant garter snake (*Thamnophis couchi gigas*).

Pre-construction predictions with regard to flood heights and roughness values have also been verified. The riparian woodland has been successfully confined to a relatively narrow band near the center of the creek, not through yearly maintenance but through appropriate design. During the floods of 1994, this portion of Laguna Creek was one of the few streams in this region that did not experience out-of-bank flooding.

Prior to construction, the project site was characterized by degraded marshes and vernal pools; Laguna Creek was a channelized ditch which promoted flooding. The City has successfully created wetland and riparian woodland habitats that did not exist on-site prior to construction and a large area of vernal pools. Wetland functions and values such as flood reduction, habitat diversity, fisheries habitat, nutrient production and export, wildlife habitat, shoreline protection, and erosion control have all been significantly increased by the Project while still providing flood protection for adjacent homes and businesses.

Green Valley Creek

Green Valley Creek flows for approximately 22 km from its origins in relatively steep mountains of Tertiary volcanics and Eocene sandstone to its outlet at Cordelia Slough. By the 1930's, the lowlands adjacent to the Creek were converted to rural agricultural uses; the tributary creeks were channelized to reduce flooding and provide irrigation supplies and most of the extensive stands of valley oaks (*Quercus lobata*) and native grasses were eliminated. The Creek itself was not significantly altered during this period, probably because it had cut a relatively deep canyon into the alluvial deposits of the valley that provided a channel deep enough to contain those storms which might be significant to local farmers. In the 1960s, though, the Corps of Engineers channelized the lower reach of the Creek, replacing the relatively natural canyon with a broader and steep-sided channel to provide flood protection for the Town of Cordelia.

By the 1970s, suburban development began to assert significant pressure on the lower reaches of the Creek. The City of Fairfield, which had jurisdiction over this portion of the Creek, was faced with a significant dilemma--how to provide flood protection and wetland mitigation for development on those adjacent lowlands without seriously damaging the remaining riparian corridor. Working with City engineers, Zentner and Zentner, Philip Williams and Associates, and Ken Tappin and Roy McCloud (both then of MacKay and Somps) designed a bypass channel to carry flood flows around the existing riparian woodlands and a reconfigured creek channel in that portion of the Creek that had been previously "improved" by the Corps.

Construction was completed in 1995 at a cost of just over $3 million, including grading and ancillary features. The wetland mitigation costs averaged about $12,500 per acre, much higher than at Laguna Creek, due primarily to the greater number of trees and shrubs planted and the cost of the irrigation system. As at Laguna Creek, though, a simple trapezoidal channel would have been about one-third of the cost.

The design of this "compound" channel was complex. At the uppermost reach of the project area, an overflow terrace was built parallel to the natural channel. The entries from the natural channel are at the mean annual storm level, about 1 m above the invert of the natural channel, and relatively broad (20 to 25 m). This ensures that, once waters reach flood stage, they can siphon off to a broad floodplain where velocities slow considerably. Sedimentation is slight to non-existent in the overflow terrace because most of the sediment is gravel and sand; the natural channel has enough capacity to retain this relatively heavy material. Growth of low terrace riparian species, such as willows, that can greatly reduce capacity are also almost non-existent in the overflow terrace because the soils are relatively compact clays and the terrace is high enough to ensure that any seedlings that do reach the terrace do not receive enough summer moisture to survive.

As importantly, the overflow terrace provides a highly suitable environment for the development of seasonal marshes and wet meadows, two types of wetlands requiring restoration under the Corps permit. These were constructed as shallow basins within the overflow terrace and designed to hold 15 to 20 cm of water after flood flows passed through the terrace. These dry up by early summer but still provide important habitat for migratory waterfowl, other birds, and native amphibians adapted to seasonal ponds.

Construction was completed during the winter of 1993-94, just in time to meet some of the worst storms in this part of California in the past three decades. However, over the past three years, the natural features of the Creek have been preserved, anadromous fish runs have remained stable or even slightly increased, and flood protection has been assured for adjacent lands.

Summary

Compound channels such as this will not work in all cases and, even where enough land is available, the terraces must be carefully configured and sedimentation and vegetation analyses completed to refine the design. However, in both cases, the Cities have developed a program which both provides flood protection for newly developing areas and preserves and restores important natural features.

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