Post-Project Appraisal of Low-Flow Channel and Revegetation, Arroyo Seco, Pasadena, California

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Abstract:

In the mid-1990s, Browning Ferris Industries, Inc. (BFI) hired Harding Lawson Associates (HLA) to design the restoration of twenty-six acres of streamzone and riparian woodland along the Arroyo Seco in Lower Arroyo Park, Pasadena, California. As mitigation for habitat lost in expanding Sunshine Canyon Landfill in northwestern Los Angeles County, the project conformed to the standards of the permitting agencies (U.S. Army Corps of Engineers and California Department of Fish and Game). The Arroyo Seco, a tributary of the Los Angeles River, is confined in a concrete channel for nearly all of its length in urban areas and retains little of its former riparian habitat and braided character. Nevertheless, the river holds potential for restoration, since most of its floodplain is dedicated as parkland and is bounded by steep canyon walls. The City of Pasadena had been studying restoration options in Lower Arroyo Park, such as building low-flow channels or even removing the concrete channel, whose construction replaced the alluvial soil with a poor gravelly backfill. The quarter-mile reach immediately upstream of the project site was never channelized; it supports lush vegetation and provides rich habitat for wildlife. In Lower Arroyo Park, sinuous low-flow channels were built on either side of the existing concrete channel and were planted with native riparian plants. New structures at an existing spillway divert up to 25 cubic feet per second (cfs) to the low-flow channels. Sedimentation has blocked the structures occasionally, requiring maintenance to sustain flows. Four years after construction, the revegetation is already meeting five-year objectives, but the trees are not yet tall enough to shade out the linear wetland of cattails that thrive in the constant shallow flows. Bentonite barriers prevent seepage loss, and low water velocity and cobble armoring of the banks reduce erosion, but also allow siltation and vegetation encroachment, and prevent a natural pattern of adjustment and migration. Although this project has met its goal of creating terrestrial habitat, the secluded location of Lower Arroyo Park could have accommodated more dynamic geomorphic and hydrologic processes, which produce the most diverse habitat.

Introduction

In the mid-1990s, Browning Ferris Industries, Inc. (BFI), hired Harding Lawson Associates (HLA) to design the restoration of twenty-six acres of streamzone and riparian woodland along the Arroyo Seco in Lower Arroyo Park, Pasadena, California. The project was a mitigation for lost riparian habitat at Sunshine Canyon Landfill in northwestern Los Angeles County. The project intended to reinstate the natural character of the Arroyo Seco, using constructed low-flow channels with planted riparian vegetation.

The Arroyo Seco ("dry canyon" in Spanish), a tributary of the Los Angeles River, is confined in a concrete channel for nearly all of its length in urban areas. However, the Arroyo Seco holds great promise for urban stream restoration. Not all of the stream is channelized, much of it is lined with open space and has steep banks outside the floodplain, and bridges over the canyon predate the concrete channel and would not obstruct flows if the channel were demolished.

In this report, we evaluate how well this habitat replicated the conditions typical of the Arroyo Seco before channelization. We focused on hydrology, geomorphology, vegetation, and wildlife, comparing the conditions in the project reach to those in the remaining unchannelized reaches of the Arroyo Seco.

Watershed Setting

Several documents, such as *Master Plan for the Lower Arroyo Seco* produced by graduate students in the landscape architecture program at California State Polytechnic

University, Pomona (hereafter cited as Cal Poly 1988) and *Arroyo Seco Watershed Restoration Feasibility Study, Summary Report: Phase I* (North East Trees 2001) give a comprehensive history and description of the Arroyo Seco, its watershed, and Lower Arroyo Park in particular, but for this paper we present a summary.

The Arroyo Seco, a tributary of the Los Angeles River, drains a watershed of about forty-seven square miles (Brick 2002). Half of its twenty-two-mile length exists within the Angeles National Forest in the San Gabriel Mountains, a steep and highly erodible range. The Arroyo Seco flows southward from the mountains, through the cities of La Cañada Flintridge, Pasadena, South Pasadena, and Los Angeles, before joining the Los Angeles River (Figures 1 and 2). The valley of the Arroyo Seco, bounded by steep slopes for most of its length, is underlain by more than 20 (ft) of cobble and boulder alluvium over granitic bedrock (Cal Poly 1988). Many Craftsman-style houses built in the early 1900s include this "Arroyo stone" in retaining walls, columns, and chimneys.

The climate of the watershed is Mediterranean, with hot, dry summers and cool, wet winters. Summer highs in Pasadena are often above 100°F; winter freezes are rare. Rainfall in Pasadena averages 18 inches per year, but the upper watershed receives more rain because of the orographic effect of the mountains (Cal Poly 1988).

Devil's Gate Dam separates the upper and lower watersheds of the Arroyo Seco (Figure 3). The dam, completed in 1920 for water storage and groundwater recharge but damaged in the 1971 Sylmar earthquake, no longer retains a reservoir on the Arroyo Seco (Swanson 1991, Brick 2002). The stream flows through the large basin, now called Hahamongna Watershed Park, and proceeds through the outlet of the dam. Large sediment (cobbles and boulders) cannot pass through the dam to downstream reaches (Swanson 1991).

The County of Los Angeles rehabilitated the dam in 1997, restoring the ability of the dam to retain floods, but the basin remains dry most of the year (Brick 2002).

Downstream of the dam, the Arroyo Seco flows freely for 0.4 miles (mi) in a narrow, steep valley, before entering a concrete-lined channel, built in 1935 for flood control and expanded in 1938 (Brick 2002). This stretch of channel runs 3 mi, through Brookside Golf Course and Brookside Park (next to the Rose Bowl), and then empties into its only other unchannelized reach, 0.3 mi long. The two unchannelized reaches, both under freeways, still include beds of cobbles and boulders and support riparian vegetation that existed before the concrete channel was built. This vegetation includes western sycamore (*Platanus racemosa*), white alder (*Alnus rhombifolia*), and willows (*Salix* spp.). Since the channelization, most of the riparian vegetation along the Arroyo Seco has disappeared, giving way to exotic annual grasses, exotic trees, and invasive groundcovers, which escaped from the gardens of adjacent houses (Cal Poly 1988).

Project Site

The project occupies a 0.7-mi reach in Lower Arroyo Park in the city of Pasadena. The park contains trails for hiking and horseback riding, as well as an archery range and a casting pond. The City of Pasadena designated this reach as a natural preservation area in 1965 (Brick 2002). Two historic arched bridges, the grand Colorado Street Bridge and the smaller La Loma Street Bridge, bound the reach to the north and south, respectively. Built before 1920, these bridges accommodated the floods of the Arroyo Seco before the concrete channel was built. An existing concrete spillway under the Colorado Street Bridge makes the transition between the unchannelized reach, 0.3 mi long, and the concrete channel. The average slope of the concrete channel in the reach is 0.0125 (Harza 1991), and an aerial photograph from 1921, before channelization, shows the stream as braided (Figure 4).

When the concrete channel was built in 1948, the floodplain was stripped of its original soil and backfilled with a gravel soil (Cal Poly 1988, Brick 2002). The water table now lies 20 ft below the floodplain. Due to the poor soil and lowered water table, exotic annual grasses and a woodlot of eucalyptus trees (predating the concrete channel) survived instead of the riparian woodland, and coastal sage from the slopes moved onto the former floodplain (Cal Poly 1988, Harza 1991, Brick 2002). By the 1980s, only remnants of the riparian communities survived, such as sycamores, coast live oaks (*Quercus agrifolia*), and poison oak (*Toxicodendron diversiloba*) (Cal Poly 1988).

Flow in the reach varies greatly. Urban runoff and flow from springs keep a trickle in the channel even in the dry summer months. Monthly average flows in the Lower Arroyo Seco range from 0.2 cubic feet per second (cfs) in summer to 61 cfs in winter (Cal Poly 1988). The average annual peak flow is 1,100 cfs; a 5-year storm yields 3,250 cfs and a 10-year storm, 5,000 cfs (Swanson 1991).

The concrete channel has a capacity of 15,400 cfs. According to the U.S. Army Corps of Engineers, the 50-year flow (48-hour duration) is 9,080 cfs, well within the capacity of the channel, but according to the Los Angeles County Flood Control District, the 50-year flow (24-hour duration) is 23,200 cfs, which would flow out of banks and inundate several houses in the Busch Gardens neighborhood of southern Pasadena (Cal Poly 1988).

Methods

To have a basis for appraisal and comparison, we read reports about pre-project conditions and the design intent. An extensive Environmental Impact Report (EIR) covered the conditions—hydrology, geomorphology, vegetation, and wildlife—at Sunshine Canyon. Several earlier reports examined restoration opportunities on the Arroyo Seco. We obtained an aerial photograph showing the conditions of the Lower Arroyo Seco in the 1920s, before channelization.

Environmental consultants Zander Associates, formed after project manager Michael Zander left HLA, inherited the task of monitoring the project. At the office of Zander Associates, Mr. Zander and Chris Politan helped us find relevant documents and clarified information through interviews.

We compared the information from the reports and interviews with observations in the field. We traveled to Pasadena for a two-day site visit, to directly observe the low-flow channels, the vegetation, and the diversion structures at the restoration site. For context, we also observed the adjacent conditions upstream and downstream, including the unchannelized 0.3-mile reach just upstream of the project, Hahamongna Watershed Park upstream of Devil's Gate Dam, and public parks along the Arroyo Seco in South Pasadena and Los Angeles. While in the Los Angeles area, we visited the office of North East Trees, to talk about the feasibility study and to obtain other reports on the project and the Arroyo Seco watershed.

Results

Project Background and Design

The Lower Arroyo Seco project was a habitat mitigation for the expansion of Sunshine Canyon Landfill, about 24 mi away in northwestern Los Angeles County. The expansion destroyed 3.8 acres (ac) of "streambed and adjacent wetland habitats" and 4.5 ac of "associated riparian habitat" (HLA 1991). Permits from the U.S. Army Corps of Engineers and the California Department of Fish and Game governed the scope and goals of the mitigation (Mike Zander, interview, Dec. 14, 2001). In 1991, BFI, which operated the landfill, hired Harding Lawson Associates (HLA) to write a mitigation plan. Since Sunshine Canyon had no sites suitable for "in-kind, on-site" mitigation, BFI pursued "in-kind, off-site" mitigation (better than "out-of-kind" mitigation, whether on- or off-site). BFI considered two sites in Los Angeles but chose Lower Arroyo Park in Pasadena. Although far from the lost habitat, Lower Arroyo Park met all of BFI's criteria: a source of water for creation of habitat, dedicated open space, "alluvial soils suitable for revegetation" (HLA 1991) (apparently not suitable enough, since the project profoundly changed the soil profile), adjacent wildlife habitat, and a local government that supported restoration. The project at the Lower Arroyo Seco site created 4.2 acres of streamzone and 22.4 acres of riparian woodland, so the mitigation met the one-for-one goal of area-gained to area-lost.

The Sunshine Canyon EIR included dozens of cross-sections, vegetation and wildlife assessments, and studies of hydrology and geomorphology. Although the landfill habitat once connected to the surrounding Santa Susana Mountains, the freeways and landfill operations had interrupted the corridors. The EIR stated that no rare or endangered species of plants of animals had been observed during ten person-hours of scientific observation, but neighbors doubted that the observations were thorough (Ultrasystems 1990).

The City of Pasadena was already committed to restoring the Arroyo Seco from a concrete-lined channel to a more natural state. Several existing studies guided the mitigation project. The city had hired Takata Associates in 1984 to study the potential for creating low-flow channels on the floodplain. In the 1988 *Master Plan for the Lower Arroyo Seco*, the Cal Poly graduate students recommended removing the concrete channel throughout Lower Arroyo Park and building check dams and a spillway at the downstream end. In a 1991 report for the city, Harza Engineering concluded that these two options—the Diversion Stream Concept and the Main Stream Concept—were feasible without a loss of flood protection, but the Main Stream Concept would cost over ten times more than the low-flow option, at $3.4 million to $0.3 million (1991 dollars), would eliminate the archery range and casting pond, and would prevent car access into the park. (We did not learn the final cost for the BFI project; it was not necessarily the $0.3 million suggested by Harza.) Nevertheless, the city favored the Main Stream concept for true restoration of the stream (Harza 1991). In the past few years, the non-profit organization North East Trees and the Arroyo Seco Foundation have been studying watershed-scale restoration and habitat connection. Restoring Lower Arroyo Park would be an important step toward this goal (North East Trees 2001).

The mitigation project will have taken more than ten years from the first reports to the end of monitoring. HLA designed the project between 1991 and 1996. Construction began in spring 1996, the first round of planting ended in fall 1997, and additional plantings continued through September 1998. The five-year monitoring program will end in 2002.

On both sides of the spillway under the Colorado Street Bridge, structures divert water through eight-inch (0.67 ft) pipes to the low-flow channels (Figure 5). The sinuous channels simulate the historical shape of the stream, with meanders, islands, and braid-like forms (Figure 6). The channels have a trapezoidal section (Figure 7), with an average width of 30 ft, 4:1 sideslopes, and minimum freeboard of 1.5 ft (Swanson 1991). Cobbles armor the banks, but the center of the channel is armored less securely to allow the stream to migrate slightly. The designers assumed a Manning's roughness coefficient of 0.080, but expected roughness to increase temporarily until trees shaded out encroaching vegetation (Swanson 1991). At each outlet lies a shotcrete-bottomed settlement pool, but the cobbles embedded in the shotcrete make dredging more difficult than in a smooth pool (Mike Zander, interview, Dec. 14, 2001).

Impermeable bentonite barriers (maximum infiltration $1x10^{-5}$ cm/s) (Swanson 1991) were installed about 4 ft below finished grade of the channels, to reduce seepage losses. Geotechnical Consultants, Inc. (GC), working for Takata Associates in the 1984 study of low-flow channels, recommended such a liner (cited in Harza 1991). The barrier also prevents an increase in hydrostatic pressure on the concrete channel from a higher water table, but weep holes in the concrete channel already alleviate pressure. On top of the liner, clay amendments (8 to 10 percent) created a loamy backfill that holds more water and reduces the need for irrigation (Swanson 1991). Amending all the soil to eliminate the need for liners was never seriously considered, due to the expense and threat to the few existing large trees (Mike Zander, interview, Dec. 14, 2001).

The low-flow channels receive up to a total of 25 cfs: 10 cfs in the west channel and 15 cfs in the east channel (Figure 8). Stream flows above 25 cfs bypass the diversion structures, into the central concrete channel. The project reach experiences flows above 25 cfs an average of 35 days per year (Swanson 1991). These low flows minimize erosion and the potential failure of the constructed banks and bentonite liner (HLA 1991). As GC recommended in 1984, the maximum flow velocity is 1.5 feet per second (fps) (cited in Harza 1991). Hydraulic modeling (Figure 9) indicated that velocities would stay below 1.5 fps, except for peaks of 2.5 fps at short steep runs, where the design provided more armoring.

The revegetation featured a palette of native plants in the streamzone and the riparian woodland habitats. The streamzone palette included native willows (*Salix* spp.), mulefat (*Baccharis glutinosa*), and herbaceous species. Cattails (*Typha latifolia*) were planted in the streamzone from upstream cuttings, but only "on an experimental basis" (HLA 1991), since HLA did not expect them to survive outside of a few isolated pools. The riparian woodland palette included sycamore, alder, coast live oak—all present at the site or immediately upstream—as well as black cottonwood (*Populus trichocarpa*), California black walnut (*Juglans californica*), and several species of shrubs and vines.

The design included several measures to foster young trees. Wire-mesh cages were installed to protect the trees from deer and rodents. A temporary system of drip irrigation, to be removed after five years, helped to establish the roots. Weeds were pulled by hand at first, but they grew so rampantly that the city resorted to using herbicides. The city also resorted to using rodenticides to prevent damage to roots (Zander 1999).

Monitoring and performance standards were focused on the survival and growth of the plants, as required by the permitting agencies (Mike Zander, interview, Dec. 14, 2001). After five years, the new native plants were to achieve 90% cover and 80% survival, and volunteer seedlings would count toward survival rates. New trees were to grow to specified heights in five years, depending on their size at planting: for example, a sycamore planted from a 5-gallon container should be at least 13 ft tall, while one planted from a 15-gallon container should reach 18 ft (HLA 1991).

Zander Associates wrote the first annual monitoring report in 1998 and has just completed the fourth report. BFI maintains the project, including removing sediment that blocks the diversion structures, as well as operating valves and removing accumulated trash.

Observations at Project Reach

We visited the site on November 2 and 3, 2001. A small rainstorm, the first of the season, had occurred a few days before.

The flow in the east channel was about 0.25 cfs: 3 ft wide, an average of 0.33 ft deep, and a velocity of 0.25 fps, as gauged by the movement of a leaf on the surface of the water. The flow in the west channel appeared of similar magnitude. According to the project plan, the stream channel was covered with cobble-size aggregates to protect against erosion, but we saw only a layer of silt, which presumably obscured the cobbles. At maximum flow of 15 cfs in the east channel, shear stress $\tau = \gamma RS = (62.4 \text{ lb-ft}^{-3})\ (0.4 \text{ ft})\ (0.02) = 0.5 \text{ lb-ft}^{-2}$. This shear stress is too low to move the cobbles and may be too low even to carry the silt. In the 1999 monitoring report, Zander recommended flushing flows, but the diversion structures cannot permit larger flows than the system has already experienced (Zander 1999; Mike Zander, interview, Dec. 14, 2001).

We observed the vegetation in a qualitative way, since the monitoring reports quantify this aspect of the project. The most recent report, that of the fourth year, includes observations made by Zander Associates the week before our visit. The data in the reports include the height, survival rates, and canopy cover of the vegetation. According to the report, the trees are meeting or exceeding their expected rates of growth, and some volunteer seedlings have sprouted. Many of the alders and sycamores, no more than 10 ft tall at planting, were already more than 20 ft tall. More than half of the 142 walnuts, however, died in the first year (Zander 1998) and fewer than 50 remain (Zander 2001). The absence of walnut trees in the unchannelized reaches upstream implies that the project site may not be suitable for walnuts. Some of the trees showed signs of poor maintenance, such as improper pruning or scars on the lower bark of an alder, indicating that the wire cage had been left in place too long.

A dense growth of cattails occupied nearly all of the streamzone (not in the hard-bottomed settlement pools), far more than the designers expected (HLA 1991). The constant shallow flow was effectively creating a linear wetland. Mike Zander would not have planted any cattails if he had known how they would dominate the system, but he still believes that the riparian trees will grow tall enough to shade out the cattails in a few more years (Mike Zander, interview, Dec. 14, 2001).

Plants grew lushly in the saturated soil along the low-flow channels: willows and mulefat in the streamzone, alders and sycamores on the islands. Outside the zone of the bentonite liner, where the soil could not hold water well, the plants showed signs of stress. The monthly monitoring records, collected in the first-year report (1998), noted problems with the irrigation system: "…irrigation lines to plants continue to be indisrepair. …[S]ome type of animal is digging them up and chewing the lines." (Zander 1998) (The animals were probably ground squirrels or gophers. (Brick 2002)) The lines had been fixed by 2001 (Zander 2001), but these early problems could explain why the peripheral trees were not growing as well as the trees closer to the channel.

We encountered a few birds but did not see other wildlife. Perhaps the wildlife stayed away from us in the denser vegetation. Since the channels connect hydrologically to the upstream reach only by pipes and since flow was so low, aquatic habitat was poor. While we observed the spillway under the Colorado Street Bridge, an officer of the Pasadena Humane Society released a raccoon and a striped skunk (which are native to California), trapped from residences in Pasadena. He explained that the Lower Arroyo Seco was the designated site for such releases.

Observations Above and Below the Project Reach

The bed of the quarter-mile unchannelized reach, directly upstream from the project reach, was made up of large rounded cobble and gravel, with infrequent boulders (up to 24”), implying a system associated with high flows. One pool above the spillway was covered in algae; other small pools were covered with a film of oil, probably from urban runoff. Sand bars were present, with an especially large deposit just upstream of the spillway.

The 2001 monitoring report included photographs of workers digging a channel through sand that blocked the east diversion structure in March. Clearing the sediment will require perpetual maintenance. This is an important lesson in the design of low-flow channels: the design of diversion structures should allow the system to function properly even through changes in sedimentation. Here, sediment dams can easily cut off one of the diversion structures because of the configuration of the inlets.

This reach was heavily vegetated with large, healthy riparian trees: white alders, western sycamore, and willows. These native species were also the ones growing best in the project area.

We also found exotic species thriving, such as Canary Island date palm (*Phoenix canariensis*), edible fig (*Ficus carica*), tree of heaven (*Ailanthus altissima*), and *Eucalyptus* spp, probably escaped from the adjacent residential lots. Fan palm seedlings (*Washingtonia* sp.) grew in some sand bars, but they appeared less than a year old and would probably be scoured away in typical winter flows.

We inferred that Lower Arroyo Park could support a similarly healthy riparian system under appropriate geomorphological conditions, including soil with better water-holding ability than the coarse fill. The lush vegetation in this reach may result from the spillway retaining water, from a natural soil condition, or both. Lack of baseline information before channelization makes it difficult to determine how natural the condition is (Mike Zander, interview, Dec. 14, 2001).

Although we did not detect wildlife along this reach, reports state that it provides habitat for several species of mammals, reptiles, and amphibians, and for over 100 species of birds (HLA 1991, second-hand citation).

In Hahamongna Watershed Park, the old reservoir basin, the streambed consists of coarse sand, with thick localized deposits of silt. Willow thickets grow along the banks but most of the basin supports sparse alluvial sage scrub, which has had only four years to recover from gravel operations (Brick 2002). At the moist toes of willow-shaded slopes, we found juvenile California toads, but none of the endangered Arroyo Toads that live along the Arroyo Seco upstream of Devil's Gate.

Downstream of the project, the Arroyo Seco continues in its concrete channel, lined by parks or other open space. In Sycamore Park, South Pasadena, the section changes from rectangular to trapezoidal. The slopes of the trapezoidal channel were extended upward with a visible change of material (boulders set in concrete); the original channel was built in the late 1930s and expanded in 1943 after a flood (Brick 2002). Large western sycamores also stand on both sides, and some young sycamores were planted among them on the west bank, apparently in an effort to restore a riparian overstory.

Conclusions

The lessons of the Lower Arroyo Seco Park project could guide future designs that propose low-flow channels for stream restoration.

According to the vegetation-centered objectives and criteria of the monitoring plan, the project has been a success. Trees are already exceeding the expected heights for five-year growth and some seedlings have sprouted. Ten or more years from now, the trees may be tall enough to shade out cattails or other encroaching groundcovers and maintain a clear streambed. Tall trees may attract raptors, which would prey on the gophers that have been a threat to young vegetation. These changes would reduce the need for maintenance, but this artificial system would not sustain the full range of processes of a stream ecosystem.

The new habitat meets the criteria for mitigation, as it occupies a larger area than the habitat lost from Sunshine Canyon, but area alone does not determine habitat value. There is extensive baseline information on the habitat at Sunshine Canyon, which connects to the Santa Susana Mountains. The project planning for the Lower Arroyo project did not make the same rigorous biological assessment. The new habitat, in a corridor surrounded by cityscape and disconnected from the larger streamzone, does not truly replace what was lost.

This project represents a missed opportunity to restore the geomorphic and hydrologic processes that make stream restoration sustainable in the long term. The steep canyon walls already provide a contained area where floods could occur without damage to houses. Removing the concrete channel altogether would be the best way to restore the Arroyo Seco and it is still feasible, but the project could have taken other measures to improve the reach. The constant low flows create a static system, supporting the cattails and permitting fine sediment to accumulate. High flows would flush the channels of fine sediment and reduce the encroachment of the vegetation, and the silt deposited in the flood control channel would quickly wash away in a winter flood. But even a high flow would not mobilize the low-flow channels: the bentonite liner prohibits the migration and braiding typical of the historical stream, and it is also susceptible to erosion by higher flows. Replacing or amending the permeable gravel fill to a more natural structure would have allowed the dynamic processes that produce the most diverse habitat.

The feasibility study by North East Trees envisions a continuous web of habitat in northeastern Los Angeles County: the San Gabriel Mountains and the Arroyo Seco course, the Verdugo Mountains, and the Santa Monica Mountains. The Lower Arroyo Park project may be a good start toward a goal of connecting habitat along the entire Arroyo Seco, but so far it is an artificial island in a sea of urbanism.

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Figures (Click on the link to view the Figure)