# Return of the Floodplain:
## Santa Ana River Offers Lessons on Ecological Restoration to Benefit People, Wildlife

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## Introduction

Prior to European colonization, Southern California's rivers created a highly dynamic mosaic of meandering channels and vast floodplains that shifted over seasons, years, and decades. Floods carrying water from winter storms in inland mountains regularly reshaped the landscape. Free-flowing rivers supported diverse biotic communities, including robust fisheries, lush riparian zones, and vast mosaics of wetlands.

Since the 18th century, Southern California's rivers have been increasingly dammed, straightened, channelized, and rerouted, completely transforming the landscape. These changes paved the way for the agricultural, industrial, and urban growth that made Southern California the economic powerhouse it is today (Miller, 2010). But the ecological and biodiversity costs of this transformation have been devastatingly high. Rivers can no longer perform important ecological functions like sediment transport and water infiltration, leading to challenges in infrastructure maintenance and water supply. Biodiversity has plummeted, with many species on the brink of extinction. And people have become increasingly disconnected from our rivers and the recreational, aesthetic, and cultural services they provide.

In recent decades, our understanding of the ecological impacts of water management and infrastructure has grown. Land and water managers are finally acknowledging the immense value of biodiversity and functioning river ecosystems. This new perspective has led to a rise in river conservation and restoration, but much work remains. Given the current state of Southern California's highly modified rivers, conservation and restoration of sensitive species and habitats is more important than ever. Floodplain restoration can be an important tool to reverse some of the harms of historic river management in Southern California for the benefit of nature and people.

## Floodplains: Invaluable Ecosystems in Decline

Floodplains—generally defined as areas of the landscape that are periodically inundated by water from an adjacent river—are some of the most productive ecosystems on earth (Opperman et al., 2010). Among their many ecosystem services, they provide flood water storage and flood control, improved water quality, water temperature regulation, food and fiber production, erosion control, carbon sequestration, groundwater recharge, and cultural and recreational opportunities (Biddle et al., 2022; European Environment Agency, 2020). They support high levels of aquatic, riparian, and terrestrial biodiversity, including many threatened and endangered species (Opperman et al., 2010; Ward et al., 1999). For example, southwestern willow flycatchers nest in healthy riverside forests, while arroyo toads breed in pools scattered across the sandy soils of floodplain terraces. Numerous culturally and economically significant fish like salmon and steelhead are extremely dependent on floodplains, which provide nutrient-rich and slow-flowing habitats that support growth and development of young fish (Bayley, 1991; Jeffres et al., 2008; Opperman et al., 2010). This diversity and productivity results from the dynamic and variable nature of the connectivity between floodplains and rivers, which sustains important hydrological and biogeochemical processes and creates diverse habitats that support countless wildlife and plant species (Opperman et al., 2010).

Floodplains are also highly desirable for human development. Their proximity to water and the flat fertile land make them ideal for human settlements (Christopher et al., 2024). River valleys provide suitable terrain for transportation infrastructure, which has boomed throughout the western US (Blanton & Marcus, 2009). In California, floodplain development has vastly expanded in the past several decades. For example, a 2005 study noted that in Sacramento, at least 60,000 new homes and billions of dollars of new infrastructure had recently been built or planned in the American, Feather, and Sacramento rivers floodplains (Pinter, 2005). As a result, floodplains have significantly declined, leading to biodiversity losses, groundwater pollution, erosion, and a lack of ecosystem function (Christopher et al., 2024). In California, less than 10% of existing habitat remained by the 1990s (Opperman et al., 2010); this number is likely even lower today. The Center is combatting this troubling trend and advocating for floodplain protection by challenging poorly planned development projects in floodplains. For example, our engagement with the Newhall Ranch development resulted in a historic settlement reducing floodplain development and protecting thousands of acres of habitat.

To allow for this increased development within floodplains, land and water managers have sought to control rivers in numerous ways. Rivers were impounded by dams, which completely stopped the natural flow and allowed resource managers to control the quantity and timing of water flows downstream. Rivers were contained by levees, which were constructed along vast lengths of waterways to prevent flood waters from spreading beyond a small footprint. And rivers were straightened and channelized with the intent of moving water as quickly as possible, and in some cases (like some of the lower Santa Ana River in Orange County), entire riverbeds were lined with concrete.

Such engineered water control measures (often termed “gray” solutions) can eliminate small-scale floods, but remain vulnerable to extreme flood events, which are expected to increase in frequency and magnitude with climate change (Huang & Swain, 2022). Additionally, small-scale floods provide ecosystem services that are lost with the implementation of gray flood control systems, including aquifer recharge, sediment deposition, and soil fertility (Christopher et al., 2024).

Importantly, gray flood control measures may actually increase flood risk—once such measures are implemented, they provide a sense of security that incentivizes floodplain development, even though flood measures can and do fail (Auerswald et al., 2019; Pinter, 2005). For example, extreme flooding along the Missouri River in 1993 led to more than 500 levees (81%) being overtopped or breached, causing $12 billion-$16 billion in damages (Galat et al., 1998). Channelization can also increase flood risk, as well as erosion and destabilization, downstream (Auerswald et al., 2019; Christopher et al., 2024). And recent floods have continued to cause significant human life and infrastructure costs (Christopher et al., 2024).

## Floodplain Restoration in Theory and Practice

Scientists and communities have begun to recognize the value of natural floodplains for many ecosystem services including flood control, and have implemented ways to restore natural floodplain function in numerous watersheds.

Floodplains are naturally dynamic and adapted to natural disturbances that occur over relatively long timescales, which can present a challenge for restoration efforts (Hernandez & Sandquist, 2019; Opperman et al., 2010). Ecologically functional floodplains require connectivity with the adjacent river, a flow regime of sufficient variability to provide both minimum low flows and intermittent high flows necessary to maintain floodplain processes, and a sufficient spatial scale to allow important hydrological and geological processes to occur (Opperman et al., 2010). In some cases, one or more of these components are no longer feasible; but even when complete floodplain restoration is not possible, efforts targeting different components of floodplain function can still provide tangible benefits for wildlife and people (Roni et al., 2019). Not all floodplain restoration strategies will work for all rivers, but the toolbox of flood restoration is continuing to expand, creating new opportunities for restoration along varying rivers with different land use patterns and water demands.

### *"Room for the River"*[1]

For many years, the goal of river restoration in the United States was a single, meandering channel (Kondolf, 2012). However, this goal fails to account for the dynamic nature of rivers, which naturally change course over time. A more effective restoration strategy is to set aside space along a river in which natural riverine processes can function without impacting human uses (Kondolf, 2012). This can be accomplished by setting back existing levees, preserving existing riparian areas and floodplains and preventing future development, or changing land use decisions to move development and agriculture away from the river channel.

Levee setbacks are one of the most direct approaches to floodplain restoration. Levee setbacks allow floodwaters to spread out over a greater land area, creating linear floodplains that support a more natural mosaic of wetland, riparian, and riverine habitats (Auerswald et al., 2019). These setback areas would also contain more floodwaters, preventing flooding downstream, and could also be farmed with crops like rice and cereals when not flooded (Auerswald et al., 2019). Levee setbacks have been successfully applied along numerous rivers in California and beyond, and provide a promising approach that is effective in rural and semi-rural river reaches (Biddle et al., 2022; Kondolf, 2012; Opperman et al., 2010; Thieme et al., 2024).

As described above, land use decisions have allowed significant encroachment of development and agriculture into historical floodplains. Redirecting housing and economic development onto lands with less severe flood risk is an important policy strategy (Auerswald et al., 2019). However, such policies are generally unpopular, especially in areas that would require relocation of existing infrastructure or communities. In highly modified watersheds—including much of Southern California—much of the land in historical floodplains has been completely converted to development, making it difficult or impossible to establish more "room for the river." Importantly, these limitations mean it is even more important to preserve and restore areas with existing functional floodplains.

### *Dam Removal and Reoperation*

Perhaps the most impactful restoration strategy in rivers that have been dammed is simply dam removal. Dam removal very quickly (if not exactly immediately) restores natural flows, and early studies of large-scale dam removals suggest that other natural ecological processes like plant community establishment and recolonization by native fish soon follow (Duda et al., 2021; Shafroth et al., 2024). However, in highly modified watersheds, in which all available space in the river floodplain is dominated by development, dam removal is not realistic.

In many cases, modification of dam operations, also known as dam reoperation, is a more feasible strategy. It is widely recognized that all elements of the natural flow regime, including not only minimum low flows but flood flows as well, impact biodiversity and ecosystem functioning of river systems (Acreman et al., 2014; Poff et al., 1997). Dams completely alter these natural flows, with severe consequences for biodiversity and ecosystem function (Poff et al., 1997; Poff & Zimmerman, 2010; Ward & Stanford, 1995). Dams, particularly large-scale

[1] Here, we borrow the term "Room for the River" from a Dutch program whose "approach is to restore the river's natural flood plain in places where it is least harmful in order to protect those areas that need to be defended." (Dutch Water Sector, n.d.). This concept of restoring a "zone within which riverine processes can function without conflicting with human uses" is also known as the 'espace de liberté', 'erodible corridor', 'fluvial territory', or 'channel migration zone' (Kondolf, 2012).

hydropower, water storage, and flood control dams, closely control the flow of water downstream. Most dam operations regulate flows to maximize water storage, flood control, or both, without consideration for the impact of flows on ecosystems or species. However, it is entirely possible to plan dam releases such that they meet the needs of the river ecosystem while also providing human benefits (Richter & Thomas, 2007).

Modification of water releases for ecosystem benefits has become more common, but most applications have focused on aquatic ecosystem benefits, and few incorporate floodplain restoration as a goal (Rood et al., 2005). Yet, opportunities for changing flow operations to support floodplain restoration are promising, especially during high-flow years that provide sufficient water to both meet water demands and reestablish natural pulse flows (Rood et al., 2005). Reoperations should manage water releases to maintain mean flows, flow pulses, and floods, all of which are significantly impacted by dams and water abstraction (Hayes et al., 2018). Flow modification projects have been successfully implemented in numerous regions including California, Arizona, Washington, Kentucky and the midwestern United States (Rood et al., 2005; Warner et al., 2014). For example, various controlled flooding strategies have been implemented on the lower Missouri River floodplain since the 1980s. Strategies include varying speeds of reservoir drawdown, maintaining water levels through the summer, and timed flooding of certain habitats, each of which targets different species and/or ecosystem services (Galat et al., 1998). Dam reoperations prioritizing floodplain inundation can be combined with more traditional restoration activities including channel restructuring, planting, and sediment modification.

***Success Stories***

Fortunately, floodplain restoration efforts are on the rise. Here, we provide a non-exhaustive list of examples in which floodplain restoration has provided important co-benefits for people, including flood control or water supply, while supporting healthy ecosystems and wildlife.

- In 2019, severe flooding caused numerous levee breaches along the Missouri River. Rather than repairing the levees, a setback program was implemented that reconnected over 1,000 acres of the floodplain and reduced flood risk (Biddle et al., 2022).
- In 1996, heavy floods in Portland, OR damaged numerous homes. In response, the city created the Johnson Creek Willing Seller Land Acquisition Program that helped move flood-prone residents to homes outside of the floodplain. The program helped 60 families relocate away from the floodplain and restored 63 acres of wetland habitat (City of Portland, n.d.).
- Over the last 30 years, residents of Hamilton City, CA have had to evacuate six times due to flooding. A recently completed collaborative restoration project—the first riparian restoration effort led by the U.S. Army Corps of Engineers—included a 6.8-mile levee setback and 1,500 acres of habitat restoration. The project successfully absorbed floodwaters after heavy storms in February 2025 (River Partners, n.d.).
- The Yolo Bypass in California was established in the early 1900s for flood control. The bypass provides an example of preservation, not restoration, but also highlights the compatibility between agriculture and habitat. Rice cultivation is well-suited to the

periodic inundation, and modifications to make agriculture more compatible with juvenile fish habitat are currently being explored (Serra-Llobet et al., 2022).

- In Norfolk, UK, river embankments were removed along 400 meters of the River Glaven to restore its connection to the historical floodplain. A study modeled groundwater infiltration in the river and found that groundwater levels and subsurface storage within the floodplain were both increased after restoration (Clilverd et al., 2016).

**Case Study: Santa Ana River**

The Santa Ana River watershed is the largest in Southern California. It drains a 2,650 square-mile area and is home to over 6 million people including major population centers in Orange, Riverside, and San Bernardino counties, as well as a sliver of Los Angeles County. It is also home to numerous threatened and endangered species including the Santa Ana sucker, arroyo toad, San Bernardino kangaroo rat, Santa Ana woolly star, least Bell's vireo, coastal California gnatcatcher, and numerous others. The river provides valuable riparian habitat in a dry Mediterranean climate. It was once perennial, but surface and groundwater withdrawals for agriculture and urban development have caused it to become an intermittent river along much of its reach. After floods in the early 1900s caused dozens of deaths and significant damage to surrounding towns and settlements (Miller, 2010), the Prado Dam was constructed in the lower Santa Ana River watershed in 1941, and the vast majority of the lower reaches of the river were channelized by 1947. Once the river was "contained," urban development in Orange County boomed, and the region has continued to grow. To further control flooding, the Seven Oaks Dam (the 10th largest earthen dam in the world; Hernandez & Sandquist, 2019) was constructed in 2000 to control floodwaters in the upper Santa Ana River, opening the historical floodplain in San Bernardino County to more development in this fast-growing region.

Now, flows in the upper Santa Ana River are entirely controlled by the Seven Oaks Dam, as well as several water treatment facilities that release treated effluent into the river. Much of the historical floodplain has been modified by channelization, levees, urban encroachment, and lowering of the water table (Burk et al., 2007). The prevalence of urban development on the historical floodplain limits the potential for restoration activities, but some areas of the upper river remain relatively undeveloped and provide a valuable opportunity for ecological restoration.

Below the Seven Oaks Dam lies the Santa Ana River Wash, one of the last remaining large open areas adjacent to the Santa Ana River with potential for ecological restoration. Historically, the wash was shaped by intermittent floods of varying frequencies and magnitudes (Hernandez & Sandquist, 2019; Lucas et al., 2016). Open areas directly adjacent to the river experienced flooding more frequently, and areas at increasing distance from the river experienced decreasing frequency of flooding. Different plant and animal assemblages occur along these gradients, and species are adapted to the varying flood regimes in different ways.

The wash supports a critically endangered plant community known as Riversidean Alluvial Fan Sage Scrub. This community is composed of three distinct plant successional communities that occupy the floodplain along an elevational gradient, from the areas immediately adjacent to the river that are frequently flooded to the highest terraces that are only flooded during extreme events (Burk et al., 2007). These habitats support a diverse assemblage of specialist plants and animals that are now at risk of extinction, including the Santa Ana River woolly star, slender-horned spineflower, and San Bernardino kangaroo rat, all of which are listed as both state and federally endangered. The Santa Ana River woolly star is an early successional perennial shrub species that colonizes disturbed areas of the floodplain after infrequent large floods, which deposit fresh sediment and create suitable habitat (Hernandez & Sandquist, 2019). The slender-horned spineflower is an intermediate-successional annual that similarly relies on periodic flooding to maintain suitable habitat (US Fish and Wildlife Service, 2010a). The San Bernardino kangaroo rat relies on infrequent scouring by floods to maintain suitable habitat, as well as enough upland habitat to provide refugia and population resilience after large flood events (US Fish and Wildlife Service, 2024). The wash is also included in the critical habitat designated for the federally threatened Santa Ana sucker. The sucker does not occupy the wash but resides downstream in the perennial section of the river. Their breeding habitat relies on gravely substrate from the upstream wash being moved into the river by floodwaters (US Fish and Wildlife Service, 2010b).

Due to the construction and operation of Seven Oaks Dam and other modifications and impoundments that have caused “head cuts,” the wash and the river have become disconnected. The Seven Oaks Dam has led to highly controlled water releases that are more spatially and temporally concentrated than historic flows. These releases have exacerbated riverbed channelization, and the resultant increased depth and narrowness of the channel has prevented flows from reaching most of the historical floodplain. Terrestrial & aquatic habitat is now almost entirely disconnected, leading to severe consequences for the sensitive species that persist in the wash and river. Without an artificial re-establishment of flood pulses in these diverse habitats, sensitive species are likely to go extinct.

In the Santa Ana River, a return to a fully natural state is no longer possible without dam removal. But it is possible to restore some functions to the floodplain and protect these endangered species and the ecological processes on which they rely.

For years the Center for Biological Diversity has collaborated with other organizations to advocate for better water management and take legal action to better protect threatened and endangered species. As a result, new multi-agency efforts between water districts, nonprofits, and local, state and federal agencies are working to improve management of the dam and the wash and restore the connectivity between the river and its historical floodplain for the benefit of wildlife.

While many of these efforts remain in the early stages, progress has been made on several fronts. In response to a settlement agreement, a Seven Oaks Dam technical advisory committee has been established to advise agencies on how to optimize flows and geomorphology for habitat enhancement. The Center is represented on this committee, and we will continue to collaborate and advise on new and ongoing projects in the wash.

Additionally, two Habitat Conservation Plans cover the Santa Ana River. Habitat Conservation Plans (“HCPs”) are federal planning documents that guide development on lands with federally threatened and endangered species to ensure compliance with the Section 10 of the federal Endangered Species Act. The plans require conservation measures that avoid a net adverse impact on covered species. The first HCP, the Wash Plan, is improving habitat in the wash. The second one, the Upper Santa Ana River Plan, is in development to further improve conditions along the river and its tributaries.

A high flow study has identified areas where channel modification would improve spread of flows onto the floodplain in the wash, reconnecting the floodplain to the river. Future efforts will ideally prioritize these channel modifications, improving habitat for the threatened and endangered species discussed above. Additionally, studies of optimal flows for San Bernardino kangaroo rat and Santa Ana River woolly star are ongoing and will inform future restoration efforts.

These new and ongoing efforts to restore the Santa Ana River after the construction of Seven Oaks Dam are laudable, and are important steps toward a more balanced and sustainable water management system. The Center will continue to explore opportunities for additional restoration efforts that benefit people and wildlife. We support modifications of dam operations to restore the floodplain, including timing and release of outflows, which remains an avenue with great potential that should be studied in the upper Santa Ana River.

Importantly, restoring the Santa Ana River floodplain would have important co-benefits for people. Several groundwater basins lie within the Santa Ana River watershed, including the Bunker Hill, Colton, Riverside, and Orange County groundwater basins. By the 1940s, most of the river's natural surface flow had dried up due to agricultural and municipal water demands, and rates of groundwater extraction were overtaking rates of recharge (Orange County Water District, n.d.; Santa Ana Regional Water Quality Control Board, 2025). The Santa Ana River is a fully adjudicated river, most recently revised in 2002. Because there is no "unused water" in the Santa Ana River, restoration efforts will continue to use the river as a conduit for moving water to users, while supporting the ecology and function of the river for the numerous endangered species.  Downstream of the Seven Oaks Dam, the Santa Ana River Enhanced Recharge Project provides some percolation into the aquifer through spreading basins. However, due to the lack of flows and channelization of the river, overall groundwater recharge along the Santa Ana has been altered compared to historic pre-development levels. Floodplains facilitate groundwater recharge (Cartwright et al., 2019; Schulz et al., 2024), so restoring this historical floodplain could help return more ecologically functional processes that aid groundwater recharge, ultimately improving water availability for human uses.

## Conclusion

Water management infrastructure can have severe impacts on aquatic and terrestrial wildlife and connectivity, but those impacts aren't necessarily permanent. Collaborative efforts between agencies and stakeholders can minimize or even reverse the harms of infrastructure while improving water storage, flood control and availability for human uses**.**

In the Santa Ana River, managers are working to restore connectivity between the river and its historical floodplain. The river will never return to its pre-development state, but restoration efforts focused on ecosystem function and biodiversity will prevent the extinction of numerous species, support ecosystem resilience, and provide water storage benefits. While progress has been made, the Center will continue to explore additional opportunities to improve the health of the river. Floodplain restoration is a particularly promising avenue.

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