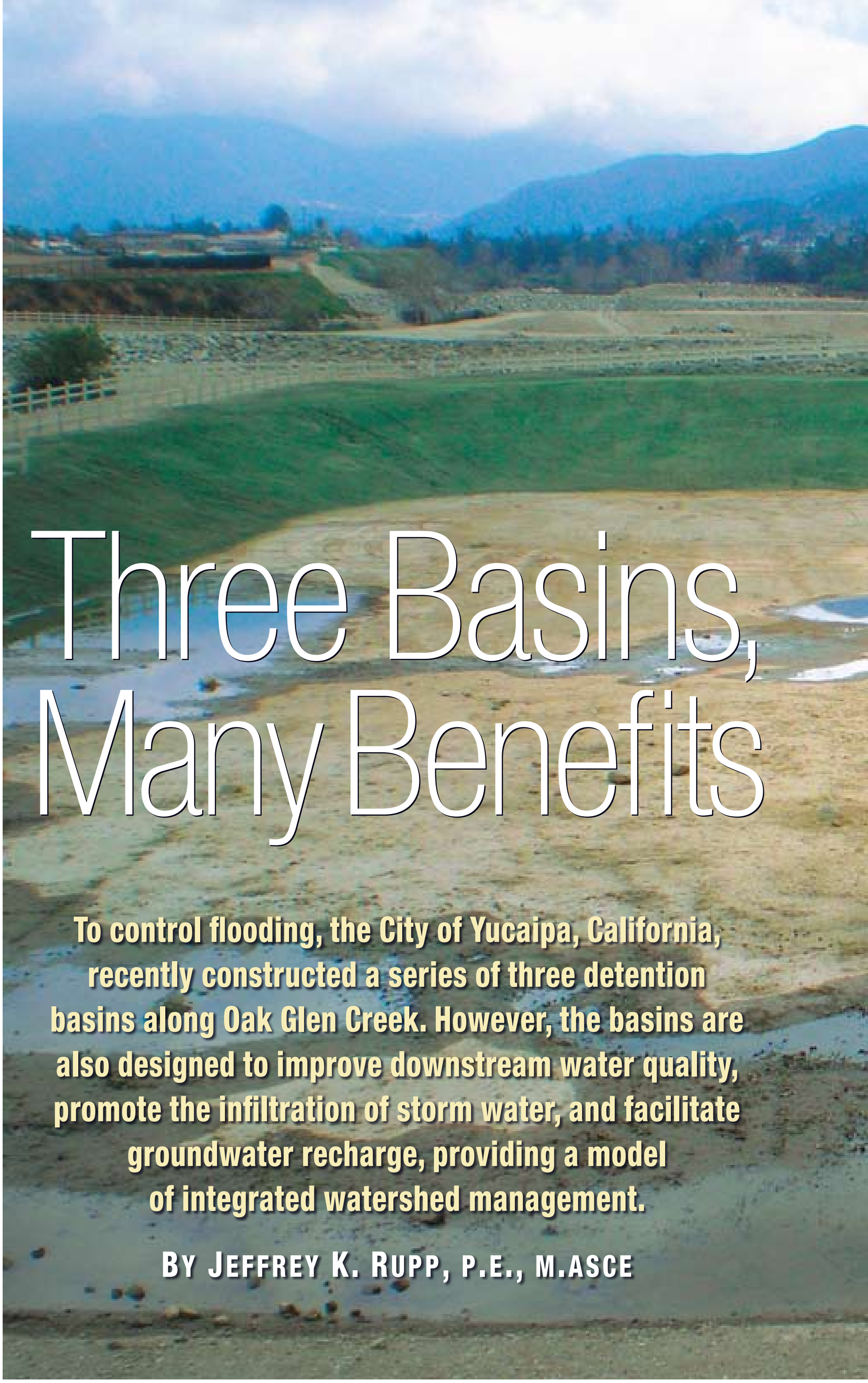


Three Basins, Many Benefits

To control flooding, the City of Yucaipa, California, recently constructed a series of three detention basins along Oak Glen Creek. However, the basins are also designed to improve downstream water quality, promote the infiltration of storm water, and facilitate groundwater recharge, providing a model of integrated watershed management.

By Jeffrey K. Rupp, P.E., M.ASCE

CALIFORNIA is in the grip of a water crisis. The state, like the rest of the southwestern United States, has had to cope with numerous challenges in recent years, including a nearly decade-long drought on the Colorado River, snowpacks that are below normal, and court-mandated reductions in the amount of water available for delivery by the State Water Project, the massive system of reservoirs, aqueducts, pipelines, and pumping stations that conveys water to 29 water suppliers throughout California. Meanwhile, such factors as climate change, population growth, and the increasing instability of the water supplies in the delta formed by the confluence of the Sacramento and San Joaquin rivers threaten to exacerbate the crisis.

To help address these problems, civil engineers and others involved in the field of water resources must evaluate individual water projects to determine how they might affect the larger watersheds to which they belong. In other words, an integrated approach to watershed management is needed. Placing more concrete and building larger conveyance systems will not solve the problems. Instead, growth and development should be guided by what are referred to as the Ahwahnee principles, a set of guidelines to help foster sustainable and livable communities that was developed in 1991 by a group of architects brought together by the Local Government Commission, a Sacramento-based nonprofit organization that assists local governments in creating healthy, pedestrian-friendly communities that use resources efficiently and judiciously. With respect to water resources, the Ahwahnee principles encourage practices that promote water conservation, groundwater recharge, low-impact development, flood protection, and improvements in water quality.

A project that will soon be completed by the City of Yucaipa, California, was developed with these principles in mind. The undertaking is being carried out in partnership with the San Bernardino County Flood Control District, of San Bernardino, California; the Yucaipa Valley Water District, of Yucaipa; the Inland Empire Resource Conservation District, of Redlands, California; California's State Water Resources Control Board; and the U.S. Environmental Protection Agency. A model of integrated watershed management, the Oak Glen Creek Detention Basins Project aims to control flooding, improve water quality, promote the infiltration of storm water, recharge groundwater supplies, create wildlife habitat, and educate the public about the water cycle and ways to improve the environment. If California is to begin tackling its water crisis, it will need more projects like Yucaipa's.

Yucaipa is nestled in the foothills of the San Bernardino

0885-7024-/09-0005-0074/$25.00 PER ARTICLE

JOHN LAROSE, CONSTRUCTION ENGINEER, CITY OF YUCAIPA

Located just to the east of Bryant Street, the 45 acre-ft (55,500 m^3) basin 1 uses the roadway as its levee.

Mountains in Southern California. The valley in which it is located is bounded by the San Bernardino National Forest to the north and east, by low-lying hills to the south, and by the Crafton Hills to the northwest. The valley opens to the west into a canyon leading to the city of Redlands. The foothills that surround the valley range in elevation from about 2,200 ft (670 m) above mean sea level in the west to more than 8,300 ft (2,530 m) above mean sea level in the east.

Yucaipa encompasses approximately 27.75 sq mi (72 km^2), or 17,763 acres (7,189 ha), of the valley just south of the San Bernardino Mountains. It is bounded by the city of Calimesa, in Riverside County, to the south, by the city of Redlands to the west, by unincorporated lands to the northwest and east in San Bernardino County, and by the San Bernardino National Forest to the north. According to California's Department of Finance, the population of Yucaipa grew by 27 percent between 1990 and 2000—from 32,400 to 41,207. In 2005 the city's population was estimated to be 49,388.

Yucaipa consists mainly of residential developments, and the city's housing stock comprises 18,290 units. Residential developments include mobile home parks, older single-family homes on narrow lots, multifamily residences, residences on large lots, and new residential tract developments. The city's commercial and industrial establishments are mainly concentrated in strip developments along major roadways.

Once a rural community, Yucaipa has experienced rapid development, and city officials now attach great importance to flood control. In February 1969 Yucaipa saw extensive flooding that caused millions of dollars' worth of property damage. In recent years it has experienced damage to its streets, parks, and private property.

Research has shown that the world is probably experiencing climate change. Average temperatures during the past 30 years have increased by approximately 1°F (0.56°C). This rise in temperature has caused the snowpack in the Sierra Nevada to melt earlier, and this heavier runoff in spring can mean that less surface water and groundwater is available in the summer.

The U.S. Department of Homeland Security's Federal Emergency Management Agency has prepared flood insurance rate maps for most areas within Yucaipa. The maps issued in 1996 indicated that an area of the city encompassing more than 1,450 acres (587 ha) was located within a 100-year floodplain, and since then Yucaipa has grown. Although new development is not allowed within the floodplain unless improvements are made to mitigate flood hazards, older developments along local waterways are exposed to such hazards. Built before the efforts to map floodplains, these developments include residences

Continued growth and development in Yucaipa mean that the expanse of pervious areas is diminishing, increasing the potential for flooding.

on large lots, an elementary school, and scattered commercial establishments.

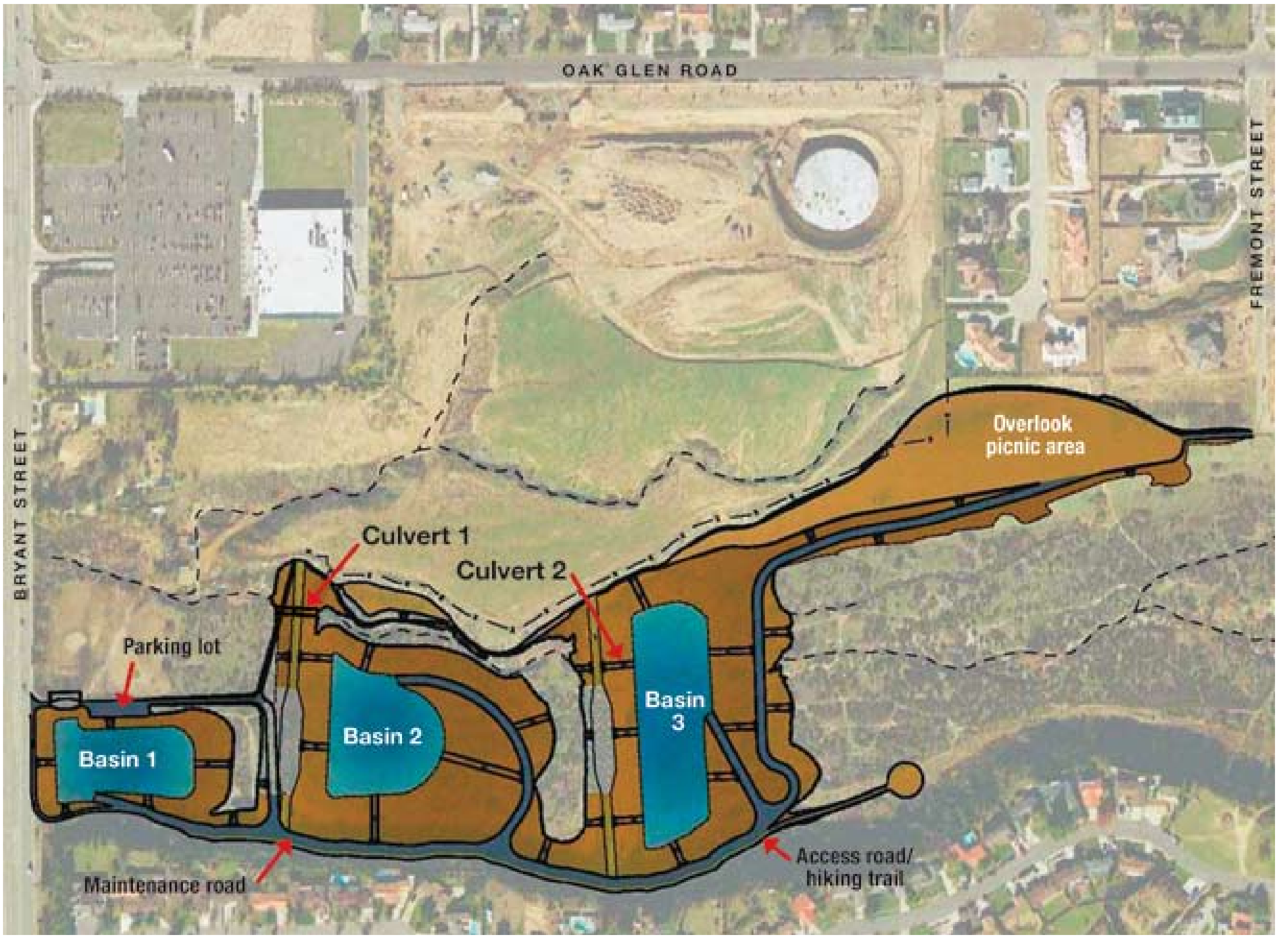
Continued growth and development in Yucaipa mean that the expanse of pervious areas is diminishing, increasing the potential for flooding. Such flooding primarily occurs along Wilson Creek, which runs through the center of town. Yucaipa decided it needed to implement additional measures, in particular, regional drainage facilities, to protect itself from flooding.

A tributary of Wilson Creek, Oak Glen Creek is a natural channel that drains a watershed of approximately 4,450 acres (1,800 ha). It enters Wilson Creek before the latter traverses the center of the city, flowing for the most part from northeast to southwest. The waterway then joins San Timoteo Creek, itself a tributary to the Santa Ana River. The areas along Oak Glen Creek consist primarily of natural foothill terrain with low-lying sagebrush ground cover. Within Yucaipa, Oak Glen Creek passes beneath Bryant Street, a four-lane arterial highway, by means of a 10 by 10 ft (3 by 3 m) reinforced-concrete box culvert. However, Bryant Street acts as a barrier during large storm events, forcing Oak Glen Creek to back up east of the road. During larger storms, the Bryant Street embankment may be overtopped, aggravating downstream flooding.

In 1993 Yucaipa completed and adopted a master drainage plan that specified approximately $90 million worth of improvements to its storm-water facilities. The plan included several spillover detention and desilting basins that would provide short-term and long-term flood protection and remove silt and debris from creeks in the city. The watersheds of Oak Glen Creek and Wilson Creek were viewed as forming a primary system for conveying storm water in Yucaipa to San Timoteo Creek.

In 2003 the city proceeded with the conceptual design phase for the detention and desilting basins for Oak Glen Creek and Wilson Creek. David Evans and Associates, Inc., which has its headquarters in Portland, Oregon, helped Yucaipa develop the concept. In 2006 the city hired the firm to design the basins, conduct environmental planning, obtain the necessary permits, and carry out the landscape architecture for the project. Although the primary purpose of the Oak Glen Creek Detention Basins Project was to control flooding and protect downstream areas of the city, the design team soon realized that many other goals and objectives could be achieved as well.

PLAN VIEW OF PROJECT



DAVID EVANS AND ASSOCIATES, INC.

Ultimately, the project was designed to accomplish the following primary goals:

1) Reduce flooding along Oak Glen Creek downstream of Bryant Street;

2) Collect debris and sediment in basins to improve water quality downstream and reduce the potential for flooding caused by clogged storm drains and culverts;

3) Provide groundwater recharge not only by allowing storm water to infiltrate into the ground rather than flow wastefully downstream but also by facilitating active recharge efforts through the infiltration of nonpotable water;

4) Provide open space and habitat for wildlife and native plants;

5) Provide opportunities to educate the public about the water cycle and the importance of water conservation and groundwater recharge.

The 11 by 11 ft (3.4 by 3.4 m) box culvert in basin 3 was designed to return flows to the main channel, helping to reduce high flows and minimize overtopping of levees.

JEFF RUPP

The design team evaluated various concepts and design features for the project, all of which attempted to minimize the disturbance to the natural channel while conferring flood control benefits. As part of this process, some of the initial concepts and configurations, which called for five separate basins, were reevaluated and refined until a layout for the Oak Glen Creek basins was selected. The preferred alternative featured a series of three interconnected basins east of Bryant Street, each having approximately 45 to 49 acre-ft (55,500 to 60,400 m^3) of storage capacity. By creating a series of engineered detention basins, the project was designed to detain peak storm flows and reduce the risk of downstream flooding.

In evaluating the various concepts, the project team first prepared a hydrologic analysis to determine the Oak Glen Creek flow hydrographs and peak flows for the 2-, 5-, 10-, 25-, and 100-year storm events. (Known as clear-water hydrographs, the measurements did not include a bulking factor to account for the likelihood of debris entering the runoff as a result of fires in the nearby mountains.) The hydrographs were developed using CivilCadd and CivilDesign, software for respectively site design and hydraulic modeling developed by CivilDesign Corporation, a subsidiary of the civil engineering firm Joseph E. Bonadiman and Associates, Inc., of San Bernardino, California. The accompanying table summarizes the peak discharges for the analyzed storm events (assuming a 24-hour storm duration that results in the highest peaks). The clear-water hydrographs were then used to develop inflow hydrographs that included bulking factors in the unsteady hydraulic model.

A qualitative assessment of sediment yield was performed for the Oak Glen Creek watershed. Of the many methods available to estimate sediment production, some give average annual sediment yield, while others provide estimates of sediment yield for a given storm hydrograph. On the recommendation of the San Bernardino County Flood Control District, the project team decided to use the method for estimating sediment yield developed by the U.S. Army Corps of Engineers' district headquartered in Los Angeles. The Corps developed this approach to estimate unit debris yield values for the design and analysis of debris-catching structures in Southern California watersheds.

The San Bernardino County Flood Control District will operate and maintain the basin facilities once they are completed, while the city will oversee other joint aspects of the site, including multipurpose trails, educational signage, and landscaped areas. During the design process, the district requested that the potential sediment yield for the Oak Glen Creek watershed be estimated for two flooding scenarios: a 100-year flood occurring four years after a fire and a 10-year flood occurring one year after a fire. The second scenario yielded the highest design sediment load, 460 acre-ft (567,400 m^3). Unfortunately, the proposed project could not feasibly provide enough basins to capture this design yield. Therefore, a bulking factor needed to be considered in the design. A factor of 1.33 increased the 100-year clear peak of 7,038 cfs (199 m^3/s) to a bulked 100-year peak flow of 9,374 cfs (265 m^3/s).

The Hydrologic Engineering Center's River Analysis System (HEC-RAS), also developed by the Corps, was used to construct an unsteady hydraulic model for the series of

Peak Discharges for Analyzed Storm Events

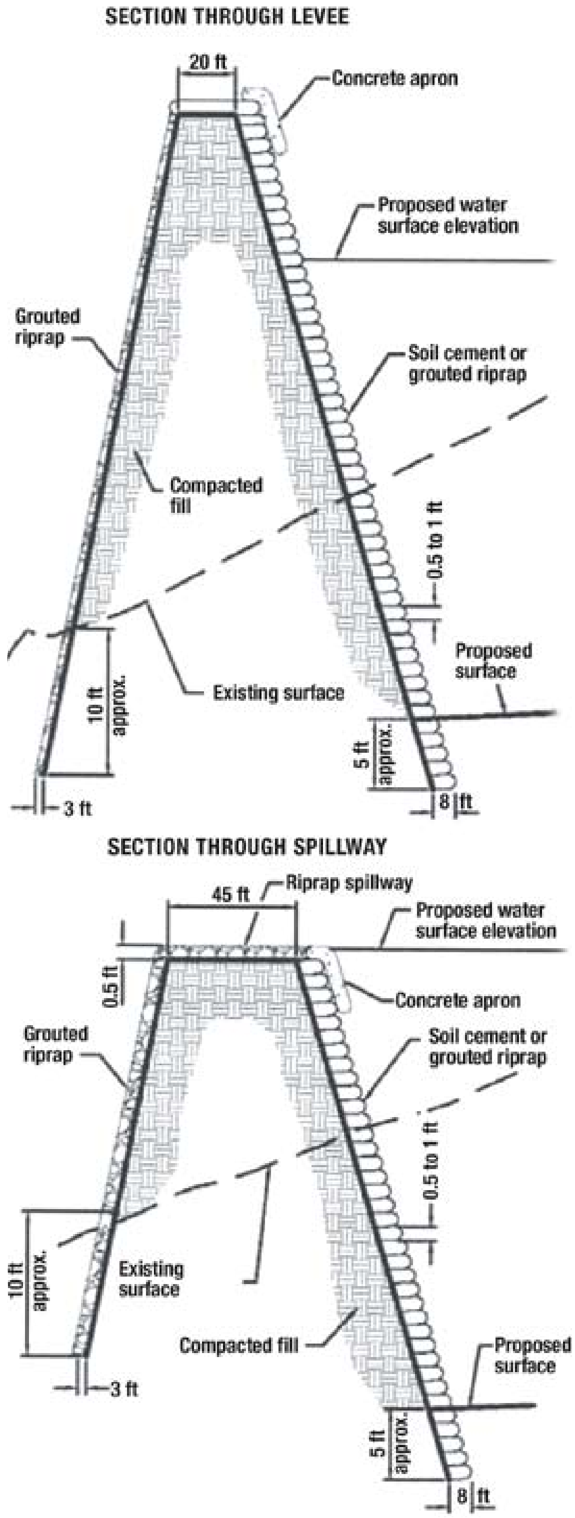
Event	2-year	5-year	10-year	25-year	100-year
Peak flows	2,825 cfs (80 m^3/s)	3,817 cfs (108 m^3/s)	4,564 cfs (129 m^3/s)	5,549 cfs (157 m^3/s)	7,038 cfs (199 m^3/s)

detention basins along Oak Glen Creek. The study reach extended 3,000 ft (914 m) upstream, or east, of Bryant Street (to Fremont Street) and 300 ft (91 m) downstream of Bryant Street. The hydraulic analysis was performed to optimize the type and size of the culverts to be located in the main channel between the basins. The design intent was to reduce high flows and minimize the overtopping of levees.

Nine alternatives were investigated, and the results were compared and summarized. The selected alternative featured three basins connected by 36 in. (900 mm) diameter storm drains having control valves, along with two 11 by 11 ft (3.4 by 3.4 m) box culverts to convey overflows past the basins and under Bryant Street. This option would provide relatively high flow reduction (19 percent for the 100-year storm and 12 percent for the 25-year storm event), the lowest velocities within culverts 1 and 2 between the basins, minimum water surface elevations in basins 2 and 3, and the least amount of scour downstream of the spillways. (See the figure on page 76.)

An initial study was prepared to define the potential adverse environmental effects from the proposed Oak Glen Creek detention basins. The effort included the following biological studies and surveys: habitat assessment and analysis of environmental factors; delineation of waters subject to the jurisdiction of the Clean Water Act; surveys of the least Bell's vireo, southwestern willow flycatcher, and yellow-billed cuckoo; a trapping survey of the San Bernardino kangaroo rat; and surveys of burrowing owls and other endangered species. Archaeological and paleontological survey reports also were prepared. On the basis of the findings of the initial study, a document referred to as a mitigated negative declaration, which detailed the mitigation and monitoring measures to be implemented as part of the project, was prepared in accordance with the California Environmental Quality Act.

The David Evans and Associates team of civil engineers, environmental planners, and landscape architects designed a series of three basins varying in size from 45 to 50 acre-ft (55,500 to 61,675 m^3) to contain peak storm-water flows and reduce flooding downstream within Oak Glen Creek and Wilson Creek. The basins would be created by the construction of levees at two locations along the creek channel, while Bryant Street would be modified to serve as the levee for the third basin. Overlook and rest areas would be provided, and defined hiking trails would be designated to replace existing informal trails. The team designed the project to preserve some existing oak trees at the site, while areas that were graded or otherwise disturbed were subsequently planted with native materials.



Basins 1, 2, and 3 are numbered according to their locations along Oak Glen Creek, which flows westward, basin 1 being farthest downstream, at Bryant Street, and basin 3 being farthest upstream. Basin 3 has been designed to capture storm-water sediment and debris from Oak Glen Creek, improving water quality downstream and decreasing the likelihood of clogging in downstream storm drain pipes and culverts. This desilting basin has the capacity to store approximately 47 acre-ft (57,970 m^3) of silt and water. Flows entering the basin will pass over waterfalls constructed at its eastern edge. The waterfalls include decorative boulders and native plantings along the slope. Placed in the path of the original creek, the waterfalls will also recreate the existing creek alignment as flows enter the basin.

A levee constructed at the western end of the basin spans the basin's width. Approximately 24 ft (7.3 m) high, the levee has a spillway at the center that is roughly 5 ft (1.5 m) lower than the top of the levee. The levee is approximately 20 ft (6.1 m) wide, except for the spillway, which is about 45 ft (13.7 m) wide and is designed to accommodate flows from a five-year storm event. The upstream bank of the levee is covered with soil-cement and has a concrete anchor at the eastern edge. Concrete was provided on top of the levee and on the downstream bank of the spillway, while riprap was used on the downstream bank of the levee.

DAVID EVANS AND ASSOCIATES, INC.

Although basins for detaining debris and storm water have been constructed in California for decades, these features have rarely been used to facilitate infiltration and groundwater recharge.

To enable runoff to pass through the levee during low-flow events, the desilting basin at its northwestern edge has a low-flow box with an inlet following the natural flow of the creek. This box directs flows to an outlet at the existing creek channel just west of the basin. A 36 in. (900 mm) diameter storm drain pipe inlet with a control valve that flows into the second basin just downstream was constructed at the southwestern section of the basin.

Located south of the creek, basin 2 has a storage volume of approximately 45 acre-ft (55,500 m^3). As with the desilting basin, the levee for this detention basin was constructed at the western end and is approximately 24 ft (7.3 m) high, a spillway being located at the southern section of the levee. Spanning the entire basin, the levee is approximately 20 ft (6.1 m) wide, although the spillway is roughly 45 ft (13.7 m) wide and about 5 ft (1.5 m) lower than the top of the levee. As with the first levee, the upstream bank of the second levee is covered with soil-cement and has a concrete anchor at the eastern edge. Concrete was used on the top of the levee and on the upstream bank of the spillway, while riprap was provided on the downstream bank of the levee.

At the northern end of the levee, a concrete culvert was constructed along the alignment of the existing creek to minimize disturbance to the creek channel. To accommodate low flows, a 36 in. (900 mm) diameter storm drain pipe inlet with a control valve was constructed at the southwestern section of the basin to direct flows into the third basin.

Located just east of Bryant Street, basin 1 also acts as a detention basin, providing a storage capacity of roughly 45 acre-ft (55,500 m^3). Bryant Street serves as the levee for this basin, and storm water in Oak Glen Creek continues to flow through the existing reinforced-concrete box located under Bryant Street.

Bryant Street is approximately 15 to 20 ft (4.6 to 6.1 m) higher than the bottom of basin 1. To prevent erosion of Bryant Street during heavy rains, the eastern edge of the roadway was fortified with a concrete cutoff wall that includes a concrete apron near the top to prevent floodwaters from undermining the asphalt pavement. A smaller spillway located at the northwestern corner of this basin enables high flows to exit the basin and move north toward Oak Glen Creek. A 36 in. (900 mm) diameter pipe installed just west of the spillway directs low flows from the basin north toward the creek.

Although basins for detaining debris and storm water have been constructed in California for decades, these features have rarely been used to facilitate infiltration and groundwater recharge. However, the Oak Glen Creek Detention Basins Project aims to do just that. The three basins are designed to capture storm water during large and small events and to facilitate infiltration into the groundwater basin, recharging the groundwater table.

Because the flow of runoff can be controlled between the basins by means of the drains equipped with control valves, the basins can also be used for groundwater storage. For example, the drains may be closed during smaller storm events, enabling storm water to collect in the basins and percolate into the ground. As it happens, the Yucaipa Valley Water Distinct, which provides services related to water, wastewater, and reclaimed water to customers in the valley in which Yucaipa is located, recently completed a water filtration plant with water storage tanks just north of the detention basins. This proximity afforded an opportunity for the district to use the basins at certain times to percolate water into the groundwater basin for later use.

To this end, the project included the

Because outlet gates in the basins will be underwater during storm events, catwalks will provide access to the outlet control gate valves. From the top of such catwalks in basin 2, *below,* the operator can turn a valve to open or close a gate.

JEFF RUPP

Serving as a rest stop for hikers, equestrian enthusiasts, and bicyclists, the area includes trees, shrubs, benches, decorative boulders, and an information kiosk.

construction of a 42 in. (1,050 mm) diameter pipeline from the district's facilities to the basin located farthest upstream. In addition to a mix of groundwater and surface water supplies, the district obtains water from a California Department of Water Resources pipeline that connects directly to the filtration plant. During dry periods, the district may choose to purchase low-cost nonpotable water when it is available and store it belowground by means of infiltration through the detention basins. The district would then be able to withdraw the water later from its wells.

For operation and maintenance purposes, access roads are provided around and into all of the basins. The roads extend into the bottoms of each of the basins so that sediment and debris can be removed from the basin bottoms and other maintenance activities can be carried out. Near the spillways, the access road is concrete pavement. Elsewhere, however, it is of natural material compacted to 90 percent. The road, which complies with the requirements of the Americans with Disabilities Act, also serves as a hiking trail that constitutes an important segment of the trail system outlined in the city's master plan, a segment that links a state park to the rest of the community trails. Split-rail-type fencing has been placed around all of the basins, and a 10-space paved parking lot has been provided off Bryant Street for those using the trails.

Also at the site are designated trails from the entry point at Bryant Street that connect to an overlook and rest area. Located on the northeastern portion of the project site, this area is approximately 30 ft (9.1 m) above the creek. Serving as a rest stop for hikers, equestrian enthusiasts, and bicyclists, the area includes trees, shrubs, benches, decorative boulders, and an information kiosk. In the event that debris must be removed from the basins after a storm, maintenance crews will temporarily store the material in the eastern section of this area.

The site includes two other rest areas—one at the southeastern section, the other at the northwestern section. The southeastern rest area includes equestrian hitching posts and informational signs. The northwestern picnic area includes decorative boulders and informational signs. Trees, shrubs, and other native and drought-tolerant plants have been planted at the overlook and rest areas along the northern perimeter of the site and along the eastern slope of the first basin. The slopes of the basins will be revegetated with a mix of native and drought-tolerant plants, the seeds of which will be mixed with water and fertilizer and spread by means of a sprayer. The use of native materials is expected to help minimize maintenance requirements and increase wildlife habitat.

Educational signs are located strategically along the site paths. The signs will convey

Located the farthest upstream of the three basins, basin 3 has been designed to capture stormwater sediment and debris from Oak Glen Creek, improving water quality downstream and decreasing the likelihood of clogging within the downstream storm drain pipes and culverts.

Oak Glen Creek drains a watershed of approximately 4,450 acres (1,800 ha). Though dry condtions make it hard to believe, the creek has contributed to flooding in Yucaipa, California.

JEFF RUPP, BOTH

information to the public about aspects of the water cycle within the context of the site itself and in the broader watershed. As people travel along the paths, a story will unfold before them and they will also learn about jurisdictional waters, watersheds, the hydrologic cycle, flooding, natural processes, groundwater recharge, sediment transport, desilting basins, ecosystems, and local flora and fauna. The signs are arranged hierarchically, the primary signs detailing the "Journey of Water" and the secondary ones providing the supporting information. Educational kiosks also provide information on the water cycle, helping people understand the importance of water and how they can conserve and recycle it.

Construction of the $6.1-million project began in June 2008. KEC Engineering, of Corona, California, constructed the basins. Construction proceeded smoothly, and this component of the project was completed in March 2009, as planned. During basin construction, much larger quantities of rock and boulders were encountered than had been anticipated. Fortunately, nearly all of the rock could be incorporated into the project, obviating the need to haul in rock from outside sources. The grading operation involved moving more than 200,000 cu yd (153,000 m^3) of material, including boulders that weighed as much as 50 tons (45 metric tons). The overall project is expected to be completed next month.

The Oak Glen Creek Detention Basins Project embodies an integrated approach to watershed management. By capturing storm water and facilitating groundwater infiltration, it reduces downstream flooding, improves water quality, recharges the groundwater supply, and provides open space for wildlife and plant life. Public access to the facility affords opportunities to educate visitors on the importance of the water cycle and the need to set aside open space for drainage facilities in lieu of more concrete channels. **CE**

Jeffrey K. Rupp, P.E., M.ASCE, is a vice president in the Ontario, California, office of David Evans and Associates, Inc., which has its headquarters in Portland, Oregon. This article is adapted from a paper delivered at the World Environmental and Water Resources Congress 2008, which was sponsored by ASCE and its Environmental and Water Resources Institute and held in Honolulu.

PROJECT CREDITS **Owner:** City of Yucaipa, California **Designer:** David Evans and Associates, Inc., Portland, Oregon **Contractor:** KEC Engineering, Corona, California **Construction management:** Vali Cooper and Associates, Inc., Richmond, California **Geotechnical engineering:** Converse Consultants, Monrovia, California **Biological assessment:** L and L Environmental, Inc., Corona, California **Sediment transport analysis:** West Consultants, Inc., San Diego **Financial contributors:** San Bernardino County Flood Control District, San Bernardino, California; Yucaipa Valley Water District, Yucaipa, California; Inland Empire Resource Conservation District, Redlands, California; California State Water Resources Control Board; and the U.S. Environmental Protection Agency