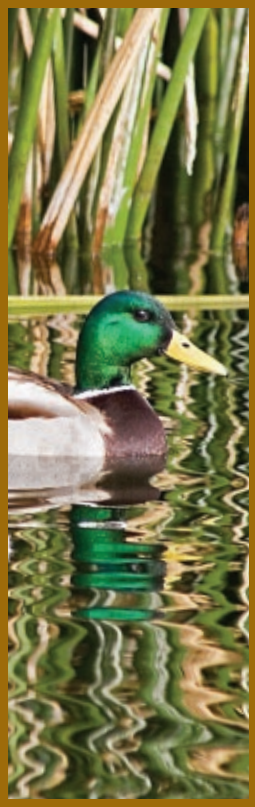
a living river

CHARTING WETLAND CONDITIONS OF THE LOWER SANTA CRUZ RIVER

2015 Water Year



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25 SONORAN INSTITUTE

PIMA COUNTY

Velvet mesquite (*Prosopis velutina*)

Huachuca water umbel (*Liaeopsis schaffneriana*) with damselfly

Willow flycatcher (*Empidonax traillii*)

2015 NOTABLE FINDINGS

- Water quality and clarity improved
- Several new fish species appeared
- Flow extent shortened with higher infiltration rates
- Wetland plant cover reduced in the river's drying sections
- Very little odor crossed the reclamation facility boundary

Learn about the past seven years of ***Living River*** data for the Upper Santa Cruz River (learn more at **www.tiny.cc/uscr7**).

THE LOWER SANTA CRUZ RIVER
A LIVING ECOSYSTEM

Although the Santa Cruz River has undergone dramatic changes since its waters provided a cool and shady retreat to early inhabitants over 12,000 years ago, the river endures and continues to benefit the wildlife and communities of southern Arizona. The river has never flowed continuously from start to finish, but where and how much it flows has changed. Today, some flowing stretches have gone dry, but others have taken their place. Indeed the Santa Cruz remains a living river.

The Lower Santa Cruz River offers a great example of how this river continues to evolve. Today, thanks to the release of effluent—or highly treated wastewater—into the river, this section flows year-round. The use of effluent is re-creating our flowing-river heritage, supporting rare wildlife habitat, and building a valued community amenity. For decades, much of this stretch of river was hidden from view behind industrial neighborhoods along the freeway. As effluent created a thriving river ecosystem, the community responded by building river parks and The Loop recreational trail to provide easier access to this river bounty.

Effluent in the Lower Santa Cruz River is not new; two wastewater treatment plants, or "water reclamation facilities," have been operating here since the 1970s. What has changed is the quality of the effluent being released. In its largest public works project ever, Pima County invested more than $600 million to upgrade the facilities. Completed in 2013, this project significantly improved the quality of water released into the river, a key ingredient for a healthier river.

To gauge conditions of this valuable ecosystem and track the impacts of our community investment, Pima County and the Sonoran Institute developed a *Living River* series for the Lower Santa Cruz River. Modeled on the Sonoran Institute's *Living River* report for the Upper Santa Cruz River, this report documents annual change along the Lower Santa Cruz River to gain insight into the river's health. Beginning with a baseline in 2013 (prior to reclamation facility upgrades), the *Living River* series is an assessment of the wetland conditions created and affected by the effluent.

This third report examines changes in indicators of river health along a 23-mile stretch of the river during the 2015 water year (October 1, 2014–September 30, 2015). Facility upgrades were completed in December 2013, thus this report captures conditions during the first full water year after project completion.

All *Living River* reports for the Lower Santa Cruz River are available for download at **www.sonoraninstitute.org**.

PINAL COUNTY

PIMA COUNTY

Pinal Air Park Road

Marana Rd

Trico Rd

Silverbell Rd

Tangerine Farms Rd

Avra Valley Rd

Sanders Rd

Sandario Rd

Twin Peaks Rd

Cortaro Rd

Ina Rd

Camino Del Cerro

MARANA

ORO VALLEY

TRES RIOS

AGUA NUEVA

TUCSON

CAÑADA DEL ORO WASH

RILLITO RIVER

SANTA CRUZ RIVER

10

19

THE SANTA CRUZ RIVER WATERSHED

REACHES OF THE RIVER

- Marana Flats
- Cortaro Narrows
- Three Rivers
- River reaches with seasonal flows
- River reaches dominated by effluent
- Direction of river flow
- Water reclamation facility (treatment plant)

0 1 2 miles

north

WATER SOURCES

In urban areas, water is often pumped or diverted from one location, used by people, treated in a reclamation facility, and released as effluent (highly treated wastewater) in a new location. Most of the water flowing in the Lower Santa Cruz River comes from effluent continuously released by the Agua Nueva Water Reclamation Facility (Agua Nueva) and Tres Rios Water Reclamation Facility (Tres Rios). Effluent is also frequently used in reclaimed water systems that irrigate landscaping.

Additional water in the Lower Santa Cruz River comes from precipitation in the surrounding watershed. When it rains or snows, water that doesn't evaporate, percolate into the soil, or get absorbed by plant roots, becomes stormwater that eventually flows into a wash and down to the river. The Santa Cruz River Watershed includes all of the land whose stormwater flows toward the river. Along with stormwater from Tucson, Marana, Oro Valley, and Green Valley, irrigation runoff from farmland in Marana flows toward the river and provides additional streamflow.

American coot (Fulica americana)

Raccoon (Procyon lotor)

The Ribbon of Green

Sections of the Santa Cruz that are dependent entirely on stormwater tend to have vegetation that is adapted to drier conditions. Add effluent to the river and suddenly we see a vivid ribbon of green snaking its way downstream (notice the green start near the Agua Nueva outfall). This green ribbon includes native willows and other wetland plants that need more water. Though these ribbons of green represent a small fraction of the landscape in the desert Southwest, they provide vital habitat for wildlife in the region. They also create a vibrant, cooling corridor for people to enjoy as they visit river parks and travel The Loop recreational path.

Sweetwater Wetlands

A portion of effluent from Agua Nueva is reused to create the Sweetwater Wetlands and supply adjacent recharge ponds where the treated water percolates down through soil and replenishes the local aquifer. This water is then pumped and distributed by the reclaimed water system for reuse at golf courses, parks, and other large turf-irrigation areas. In addition to these human benefits, the wetlands are a water-rich environment providing urban wildlife habitat for many native species.

ASSESSING CONDITIONS

The *Living River* report evaluates conditions of the Lower Santa Cruz River using indicators (see table below) organized into six categories that represent a breadth of biological, chemical, physical, and social properties of the river. The indicators relate to conditions in the river channel and in riparian areas, the areas next to and affected by the river. Other characteristics monitored informally and discussed throughout the report include birds, amphibians, reptiles, and recreation.

The purpose of the *Living River* series is to monitor and report on wetland and riparian conditions at various intervals downstream of the effluent discharge points. As effluent flows downstream, it impacts and is impacted by the natural conditions of soils, vegetation, and the surrounding ecosystem. For the purposes of this study, the 23-mile stretch of river is divided into three sections, or reaches: Three Rivers, Cortaro Narrows, and Marana Flats. Reaches were delineated by their differing hydrology, geology, and adjacent land use.

The following pages compare the data collected in the 2015 water year (October 1, 2014–September 30, 2015) to the baseline conditions observed in the 2013 water year. To review data and additional charts from the 2013, 2014, and 2015 water years, please download a supplementary report from the Sonoran Institute website that is available at **www.tiny.cc/lr15**.

CATEGORY	PURPOSE	INDICATORS
FLOW EXTENT	Water flowing in and out of the system determines available aquatic habitat.	• Miles of flow in each reach • Number of “dry days” at Trico Road
WATER CLARITY	Solid particles in the water and on the riverbed can impact habitat and conditions for aquatic life.	• Total suspended solids • Turbidity • Percent fines on riverbed
WATER QUALITY	Specific chemical conditions are necessary to sustain the river’s animal and plant communities.	• Total dissolved solids • Ammonia • Dissolved oxygen • Biochemical oxygen demand • Metals
AQUATIC WILDLIFE	Wildlife in the river integrate and reflect conditions of many factors of the surrounding environment.	• Fish • Aquatic invertebrates
RIPARIAN VEGETATION	Plant communities reflect changes in water quantity and quality.	• Wetland indicator status • Nitrogen affinity score • Riparian tree cover
SOCIAL IMPACTS	Aesthetic factors directly impact people living or recreating along the river.	• Odor at reclamation facilities

1

2

3

4

1. Where the river flows start and stop has varied through time. Long before releases of effluent created the Lower Santa Cruz, the river flowed in a narrow channel right through downtown Tucson as seen here at the Congress Street Bridge in 1907.
2. Before the facility upgrades, the river was flowing to the end of the study area as seen here near Trico Marana Road, May 2013.
3. At the downstream end of the study area, increasingly dry conditions from reductions in flow extent caused a decline in riparian tree cover as seen near Trico Marana Road, June 2015.
4. Water is critical for many insects because life starts in the river with a larval stage before they live outside of the water as adults like this adult damselfly.

STREAMFLOW, RAINFALL, AND WATER BUDGET

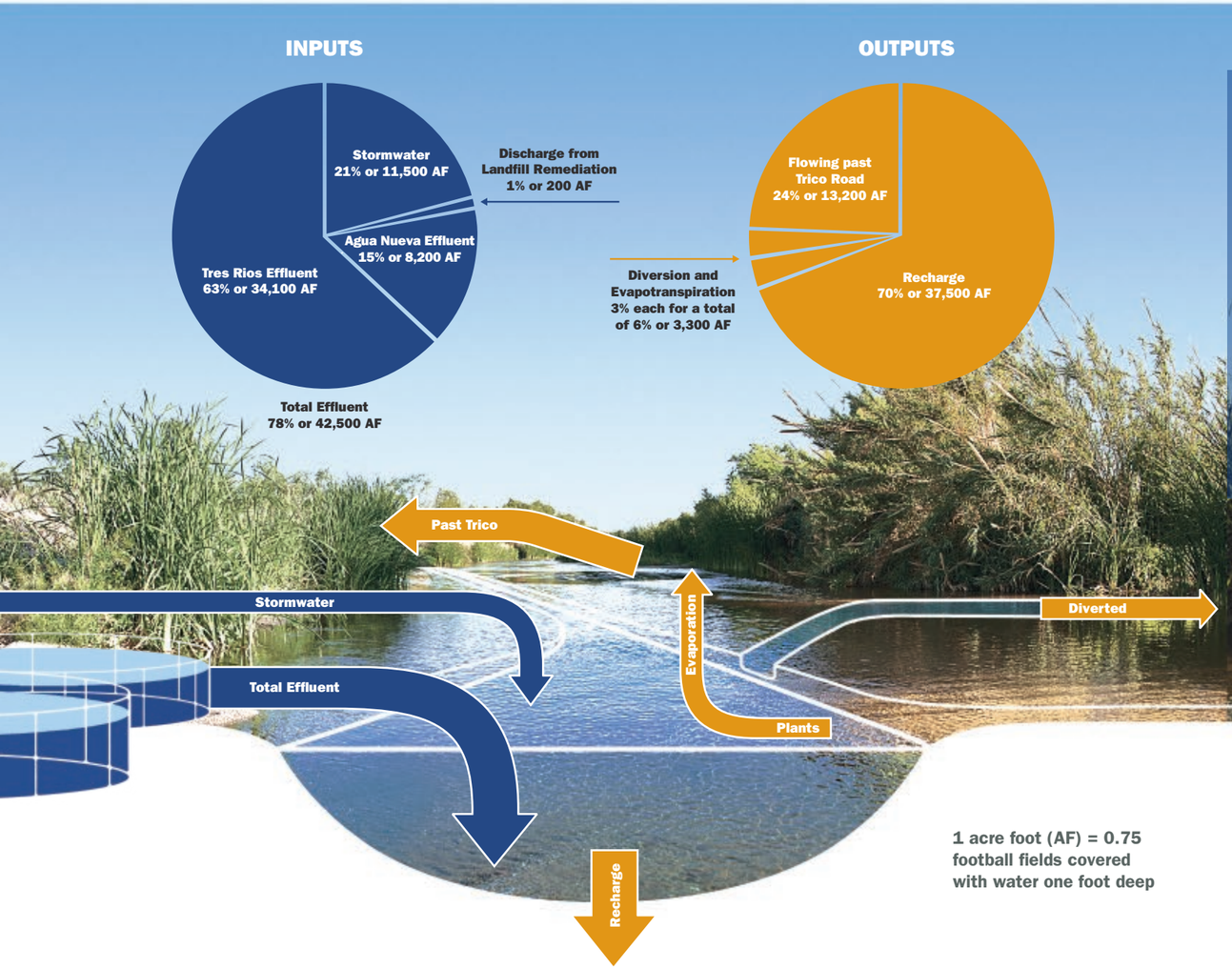
The amount of water flowing in the river provides an important context for the indicator results. Rainfall influences the amount of stormwater contributing to streamflow and flooding. Floods can scour the riverbed, recharge aquifers, disperse seeds, induce seed germination, and clear natural debris.

A water budget for the Lower Santa Cruz River estimates the water inputs and outputs. Inputs are effluent and stormwater (2015 also included a small input from the remediation of a landfill along the river). Outputs describe where the water went and includes water that either flows past Trico Road (see map on page 2), evaporates or is used by wetland vegetation (a process called evapotranspiration), is diverted for agricultural use, or sinks into the riverbed to recharge the local aquifer. Input and output volumes are totaled in acre-feet (AF). An acre-foot is the amount of water needed to cover an acre with water one foot deep. Learn more about streamflow, rainfall, and the water budget, and view data from 2013–2015 at **www.tiny.cc/lr15**.

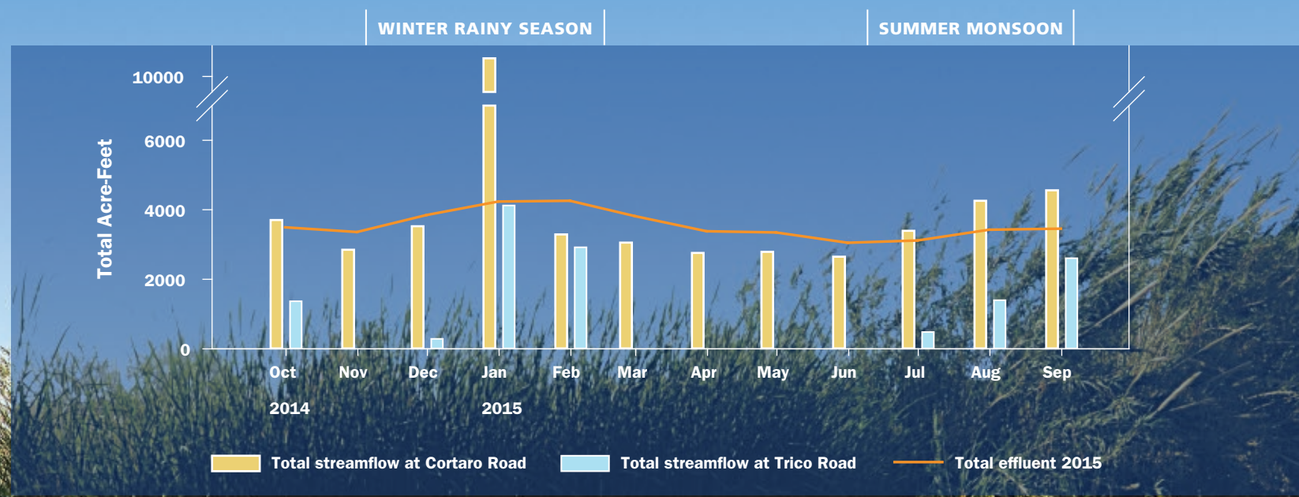
2015 WATER BUDGET

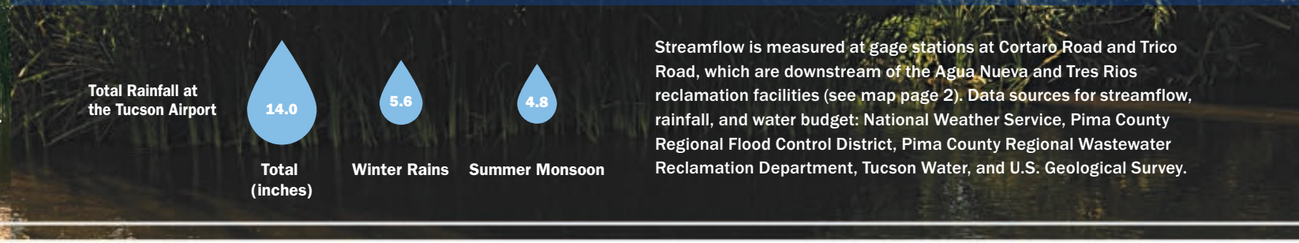
Total inputs of water to the Lower Santa Cruz were 5% higher than the 2013 baseline. This increase is due to greater stormwater flows, which contributed 21% of the inputs in 2015 compared to only 8% in 2013. Effluent was still the primary source of water, with a total of 42,500 AF released into the river. This represented a 10% reduction from the 47,000 AF released in 2013, largely because more effluent was diverted to supply nearby basins with water to recharge local aquifers.

The largest output in 2015 shifted from flow passing Trico Road to recharge. The 13,200 AF flowing past Trico Road in 2015 was considerably lower than the 31,000 AF in 2013. This is likely from increased rates of infiltration resulting in part from improved water quality and scouring floods in September 2014 and January 2015 which reduced the "clogging layer" in the riverbed (see page 14). The fact that 2015 had the highest calculation of recharge in the river in the past three years, with 20,500 AF more recharge in 2015 than in 2013, demonstrates this increased infiltration.



1 acre foot (AF) = 0.75 football fields covered with water one foot deep





Streamflow is measured at gage stations at Cortaro Road and Trico Road, which are downstream of the Agua Nueva and Tres Rios reclamation facilities (see map page 2). Data sources for streamflow, rainfall, and water budget: National Weather Service, Pima County Regional Flood Control District, Pima County Regional Wastewater Reclamation Department, Tucson Water, and U.S. Geological Survey.

2015 RAINFALL AND STREAMFLOW

There was more rain in 2015 compared to 2013, and 25% more rain than the 11.2-inch historical average. Increased flow from stormwater was most notable in January and from July through September, when the total volume of streamflow at Cortaro Road was significantly greater than the effluent released into the river upstream. Overall, volume of streamflow at Cortaro Road was generally similar to 2013. However, at Trico Road, streamflow was lower in 2015, with no flow recorded in March through June, the driest time of year.

SUMMARY OF 2015 CONDITIONS

This report compares indicators in the 2015 water year to 2013 baseline conditions. Data from 2014 can be found online in the supplementary report at **www.tiny.cc/lr15**.

As anticipated, water quality improved following the completion of the upgrades to the reclamation facilities. All water quality measures were better or similar to the 2013 baseline. Most notably, ammonia levels were significantly reduced, improving conditions for fish and aquatic life. Although surveys found no native fish, four fish species were now present in the river. Furthermore, reductions in ammonia likely allowed fish to expand upstream to Three Rivers, where fish were absent in 2013.

Reduced nutrient levels may have diminished the "clogging" layer in the riverbed, which increased infiltration and percolation of river water through the sediment in the riverbed. This effect likely contributed to the drying of sections of Three Rivers and Marana Flats. Although shorter flow extent suggests decreased availability of habitat for aquatic wildlife, increased infiltration of water recharges local aquifers.

Sediment and other particles carried in the water decreased, resulting in clear river water on normal non-flooding days. The percentage of the fine materials covering the riverbed was reduced compared to the 2013 baseline. Fine materials can smother habitat and suppress life on the riverbed if too abundant. Therefore, in addition to improved water quality, the decrease in fine materials may have contributed to improvements in the aquatic invertebrate community.

While pollution-tolerant invertebrates are still the most common, community diversity improved and the abundance of species sensitive to pollution increased. However, the invertebrate community still reflects impaired river conditions compared to warm-water streams in Arizona that are not dominated by effluent. More time may be needed for the invertebrate community to attain the diversity and abundance found in other streams.

Release of effluent supports wetland species and mature trees that are abundant downstream of the reclamation facilities.

However, in river sections that are drying, there may be a shift from wetland plants to more upland plants. In 2015 there was a decrease in native willow trees, a species with shallow roots that is sensitive to changes in soil moisture.

As discussed in the 2013 baseline report, both the extent and intensity of odor emanating from the reclamation facilities has diminished significantly with the upgrade process. An extensive system monitors odor at the facility and along the fenceline. Levels of hydrogen sulfide, the cause of the "rotten egg" odor, were far below the levels required by facility permits. Furthermore, anecdotal observations from people recreating in the area indicate that odors are either gone or hardly noticeable compared to past conditions.

CATEGORY	2013 CONDITIONS	2015 CONDITIONS
FLOW EXTENT	Water was always flowing through all three reaches.	Flow extent decreased in both Three Rivers and Marana Flats (p. 12).
WATER CLARITY	High amount of particles in the water column during normal, non-flooding conditions. Materials in the water increased as the river flowed downstream.	Water clarity improved with reduced particles in the water column during normal, non-flooding conditions (p. 13).
WATER QUALITY	High levels of ammonia posed a health risk to aquatic life. Other measures met standards or provided a baseline for comparison in future assessments.	All water quality measures improved or remained similar to 2013. Most important were significant reductions in ammonia, improving conditions for aquatic wildlife (pp. 14–15).
AQUATIC WILDLIFE	No fish in Three Rivers, but Western Mosquitofish present in Cortaro Narrows and Marana Flats. Aquatic invertebrate communities in all three reaches suggest the river is impaired or under environmental stress.	Four fish species found and at least one fish species observed in all reaches. Aquatic invertebrate communities showed some signs of improvement (pp. 16–17).
RIPARIAN VEGETATION	Wetland and nitrogen-tolerant plants increased immediately downstream of the reclamation facilities. With the exception of Marana Flats, riparian trees generally declined as the river flowed downstream.	Effluent supports wetland and nitrogen-tolerant plants as well as mature trees downstream of the reclamation facilities. Decrease in willows suggests shift to upland plants in drying areas of Three Rivers and Marana Flats (p. 18).
SOCIAL IMPACTS	New odor data unavailable at press; past efforts to reduce odor impact have resulted in significant reductions in odor levels.	Odor levels far below levels required by facility permits, and anecdotal observations of odor as hardly noticeable near the facility boundaries (p. 20).

Over 100 dragonfly species, including this Flame skimmer, thrive in Arizona's warm climate.

Common carp *(Cyprinus carpio)*

Black bullhead *(Ameiurus melas)*

Green sunfish *(Lepomis cyanellus)*

The fall 2015 fish survey found three additional non-native fish in the river.

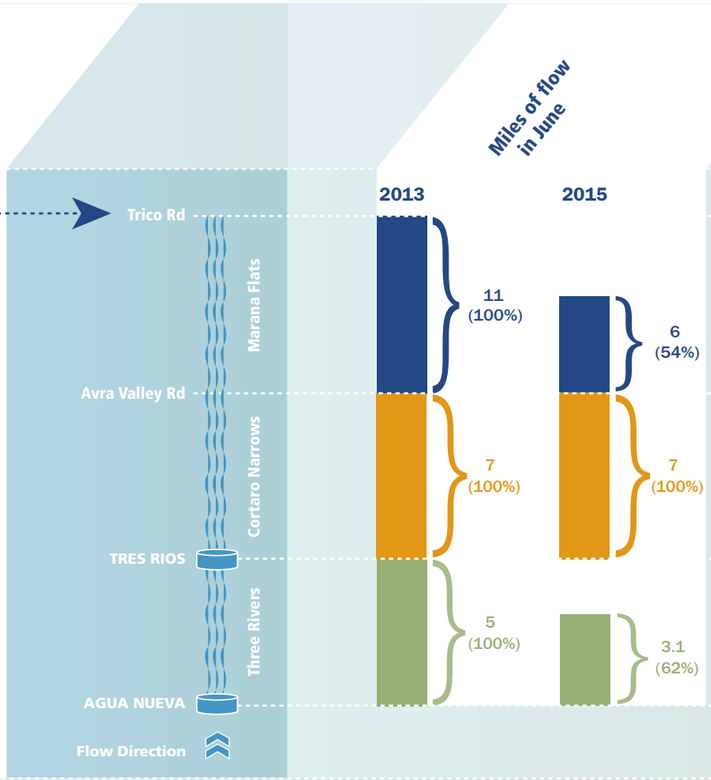
INDICATOR RESULTS

FLOW EXTENT

Measuring flow extent, or the distance the river has visible water flowing, provides a general measure of changes to the river's water budget and the length of available aquatic habitat. Full flow extent suggests high availability of habitat for aquatic life or low infiltration of water into the riverbed. Decreased flow extent could result from low water input or high infiltration of water into the riverbed.

2015 RESULTS:
Flowing stretch of river is shorter

Flow extent decreased considerably in 2015. When measured as miles of flow in June, prior to the start of the monsoons, only Cortaro Narrows maintained flow through the entire reach. When looking at daily flow at Trico Road, the end of the study area, there were 244 days when the river was dry and did not flow. In 2013 the river flowed every day past Trico Road. Overall, decreased flow extent is likely due to increased infiltration (see water budget page 8). Reductions in effluent released from Agua Nueva also contributed to changes observed in the Three Rivers reach. Some wastewater was redirected to Tres Rios and thus released further downstream, and more effluent was used to supply recharge basins near Agua Nueva. Learn more about changes in flow extent and view data from 2013–2015 at **www.tiny.cc/lr15**.



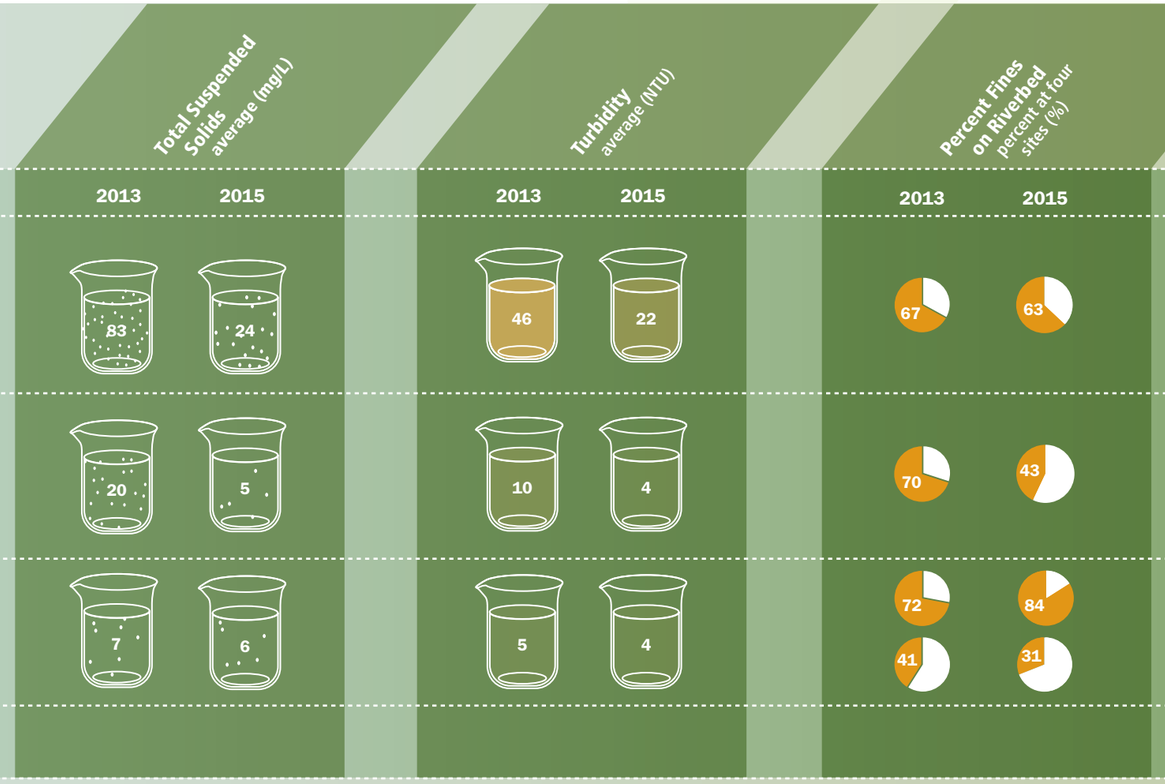
Data source: Pima County Regional Flood Control District and U.S. Geological Survey

WATER CLARITY

Rivers naturally move sediments and other particles downstream. As these materials are swept away, others are conveyed from upstream, bringing an influx of nutrients, organic matter, and sediments to the river ecosystem. Measuring the concentration of the materials in the water provides an estimate of the suspended particles or "cloudy" conditions in the water. Murky water and the associated fine materials that settle on the riverbed can harm aquatic life and degrade river aesthetics.

2015 RESULTS:
Water clarity improved

Water clarity was measured throughout the year at several locations when the river was not flooding (murky conditions are normal during storm flows). Suspended solids in the water declined in 2015. Turbidity evaluates the ease of seeing through the water, with high scores representing cloudier water. Average turbidity was lower in 2015, indicating improved water clarity. The percent fines that settle out of the water onto the riverbed was reduced at two sites in the spring of 2015, suggesting improved conditions for aquatic life on the riverbed. Similar, or increased, levels of fine materials are found in areas experiencing reduced flows. Slow flows allow particles to easily settle onto the riverbed. Learn more about changes in water clarity and view data from 2013–2015 at **www.tiny.cc/lr15**.



Data source: Pima County Regional Wastewater Reclamation Department, Harris Environmental Group, Inc.

WATER QUALITY

Aquatic ecosystems, such as streams, depend on particular water-quality conditions (chemical, physical, and biological properties) to sustain plant and animal communities. There are many typical measures that help track changes in water quality in the river, including the amounts of total dissolved solids, ammonia, dissolved oxygen, biochemical oxygen demand, and metals.

Nitrogen and other nutrients enter the river from air pollution, fertilizer, surface runoff, and release of effluent. While elevated nutrient levels can benefit growth of riparian plants, they can also lead to poor conditions for aquatic wildlife. High nutrient levels can also encourage an overabundance of organisms that live in the spaces between the sand and gravel in the streambed. These organisms can explode in number and are one of the factors that create a “clogging layer” that reduces the ability of water to soak into the riverbed and recharge local aquifers.

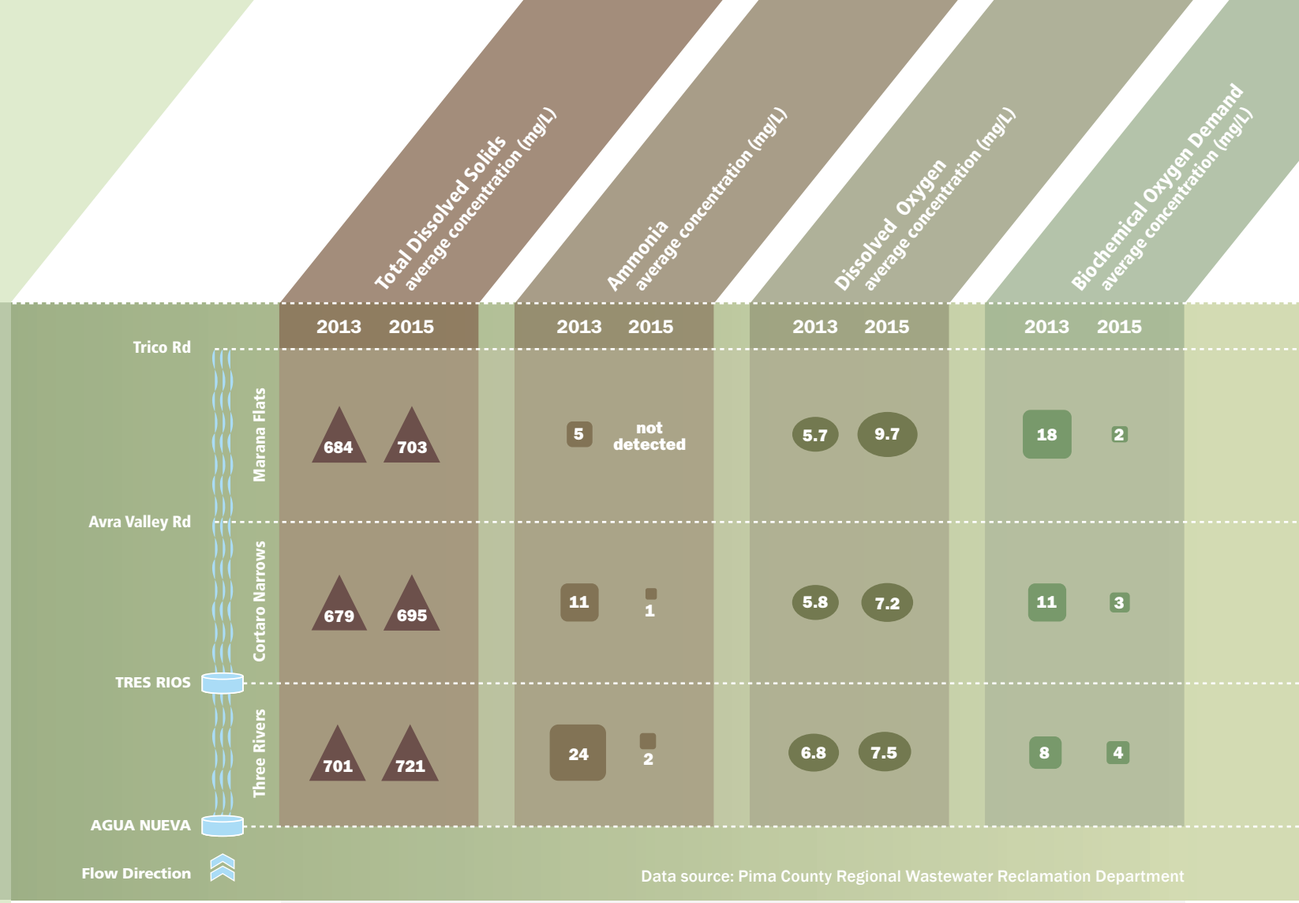
Desert Sucker
(*Catostomus clarki*)

Sonora Sucker
(*Catostomus insignis*)

Gila Topminnow
(*Poeciliopsis occidentalis*)

Longfin Dace
(*Agosia chrysogaster*)

Gila Chub
(*Gila intermedia*)



Data source: Pima County Regional Wastewater Reclamation Department

Sonora mud turtle (*Kinosternon sonoriense*)

Amphibians, Reptiles, and Fish

Riparian areas are critical habitat for numerous amphibian, reptile, and fish species. The effluent stretch of the Lower Santa Cruz River provides some of the only flowing water habitat for these species in the Tucson area. Historically, the Santa Cruz River was home to a community of amphibians and reptiles commonly found along rivers and desert washes in southeastern Arizona. Though no formal surveys were conducted, Sonora mud turtles have been observed in the river. American bullfrogs and spiny softshell turtles are two non-native species that are present and breeding in the river.

The Santa Cruz River historically supported several native fish species in the Tucson area. These species included Gila Topminnow, Gila Chub, Desert Sucker, Sonora Sucker, Longfin Dace, and a pupfish species that went extinct when the river ceased to flow year-round. Several groups survey fish annually. See results on page 16.

2015 RESULTS: Improved water quality with reduced nitrogen and more oxygen

Measures of water quality were taken at several locations throughout the year. The upgraded wastewater treatment process improved the water quality in the river. Ammonia (NH_3) is one form of nitrogen that can be toxic to fish and is more common in rivers dominated by effluent. Average concentrations of ammonia significantly declined in 2015. Lower concentrations of ammonia and other nutrients are likely a major factor in reducing the clogging layer in the riverbed. Reduced clogging has, in turn, resulted in increased recharge (page 8) and reduced flow extent (page 12).

Fish and other aquatic animals need dissolved oxygen to survive. Levels of dissolved oxygen remained high enough for fish and were notably higher in Marana Flats as compared to 2013. Biochemical oxygen demand estimates the amount of dissolved oxygen used to break down organic matter. If organics are abundant, microorganisms breaking them down use up oxygen in the water and leave little for other aquatic life. Compared to 2013, biochemical oxygen demand declined along the river, suggesting lower organic pollutant levels.

Other measures of water quality remain similar to the 2013 baseline. Measuring total dissolved solids is a common way to test for salts in the water. Total dissolved solids have been higher with the community’s rising use of water from the Colorado River. However, the range of observed values did not change much compared to 2013. Metals in high concentrations can endanger wildlife in aquatic ecosystems. As in 2013, all the samples tested for arsenic, cadmium, chromium, copper, lead, mercury, selenium, and zinc were low enough to protect conditions for aquatic wildlife in the river.

Learn more about changes in water quality and view data from 2013-2015 at **www.tiny.cc/lr15**.

AQUATIC WILDLIFE

Water is essential for aquatic wildlife to survive in our arid landscape. With naturally occurring waters becoming increasingly rare throughout the Southwest, release of effluent into the Lower Santa Cruz River provides critical habitat for aquatic wildlife in the Tucson region. Furthermore, wildlife can be good indicators of river health because they integrate and reflect conditions of multiple factors in the surrounding environment, including water quality and availability of habitat.

Mexican amberwing (*Perithemis intensa*)

Aquatic Invertebrates

Dragonflies (adult pictured here) start life in the water and, like mayflies, are sensitive to pollution. Though surveys found only a few, dragonfly larvae in the river provide further evidence of improved water quality.

Birds

The Lower Santa Cruz River is an excellent destination for birdwatching. Between 2013 and 2015, 787 volunteers collected over 80,000 bird observations along the river as part of a citizen-science program managed by Cornell Lab of Ornithology, www.ebird.org. Overall, there were 240 unique species observed along the Lower Santa Cruz, including several wading birds like great blue herons, killdeer, and black-necked stilts.

Data source: eBird Basic Dataset. Versions: EBD_relFeb2014, EBD_relNov-2014, and EBD_relFeb-2016. Cornell Lab of Ornithology, Ithaca, New York.

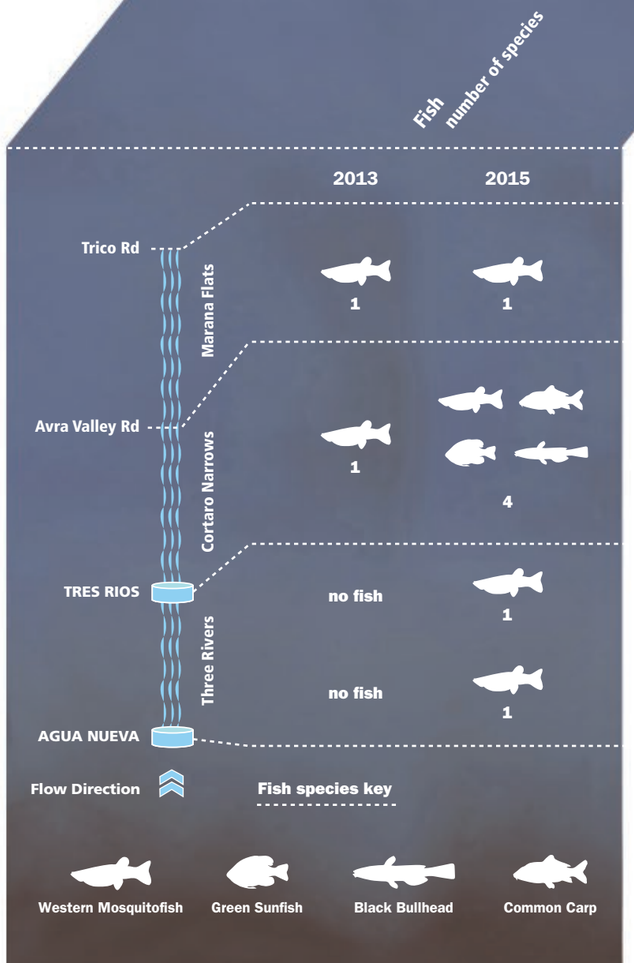
Great blue heron (*Ardea herodias*)

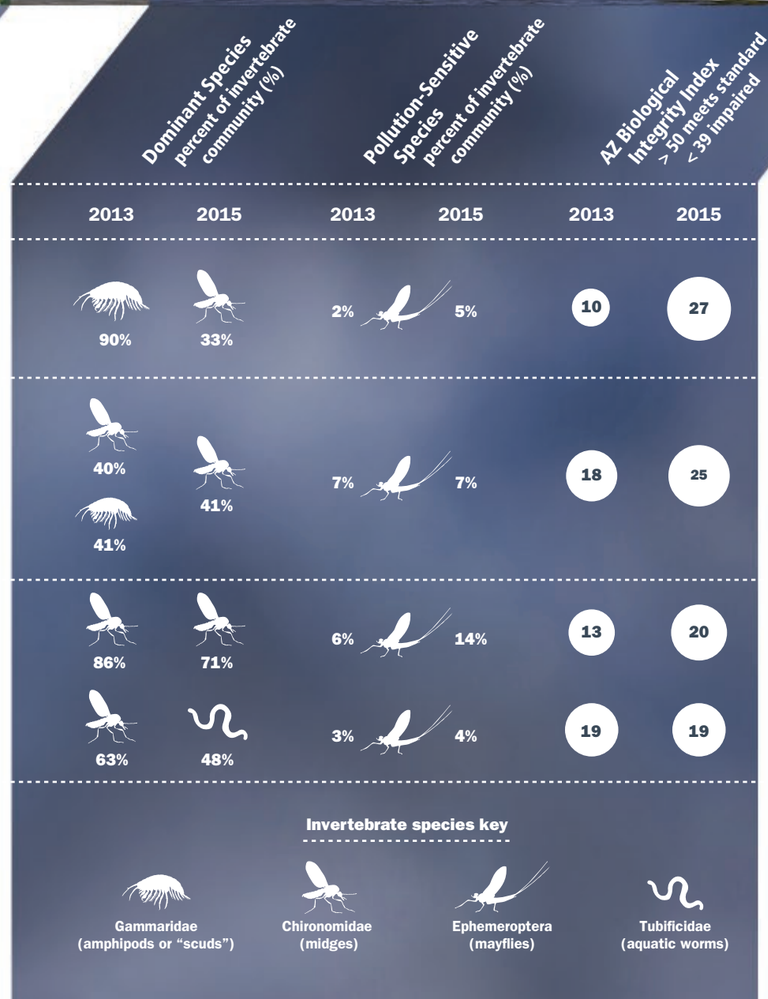
2015 RESULTS: Aquatic wildlife show some improvement

A fall 2015 fish survey was conducted at four locations along the river to detect fish species. Improvements in water quality have allowed fish to thrive again. Three additional non-native species were caught in Cortaro Narrows, including Common Carp, Green Sunfish, and Black Bullhead. Fish presence has also expanded upstream to Three Rivers, though only Western Mosquitofish were found in that reach. Flows are often very shallow in Three Rivers and may not provide habitat for the other larger species. In time, large floods may bring back native species, since the Longfin Dace and Gila Topminnow are found in the Upper Santa Cruz in Santa Cruz County (see map inset page 2).

A spring 2015 survey of the aquatic invertebrate community was conducted at the same four locations. Overall, there were signs of improvement. The pollution-tolerant midges (Chironomidae) were still the most common insect. However, diversity is likely higher because at three sites the dominant species made up a smaller percentage of the community. If the dominant species is more than 50% of the community, river life is thought to be impaired. There were also small increases in the percent of pollution-sensitive mayflies (Ephemeroptera). While this increased diversity is supported by an increase in the biological index scores, the scores remain below 39. Scores below 39 suggest that river life is impaired. Continued monitoring will determine the level of improvements.

Learn more about aquatic wildlife and view data from 2013-2015 at **www.tiny.cc/lr15**.



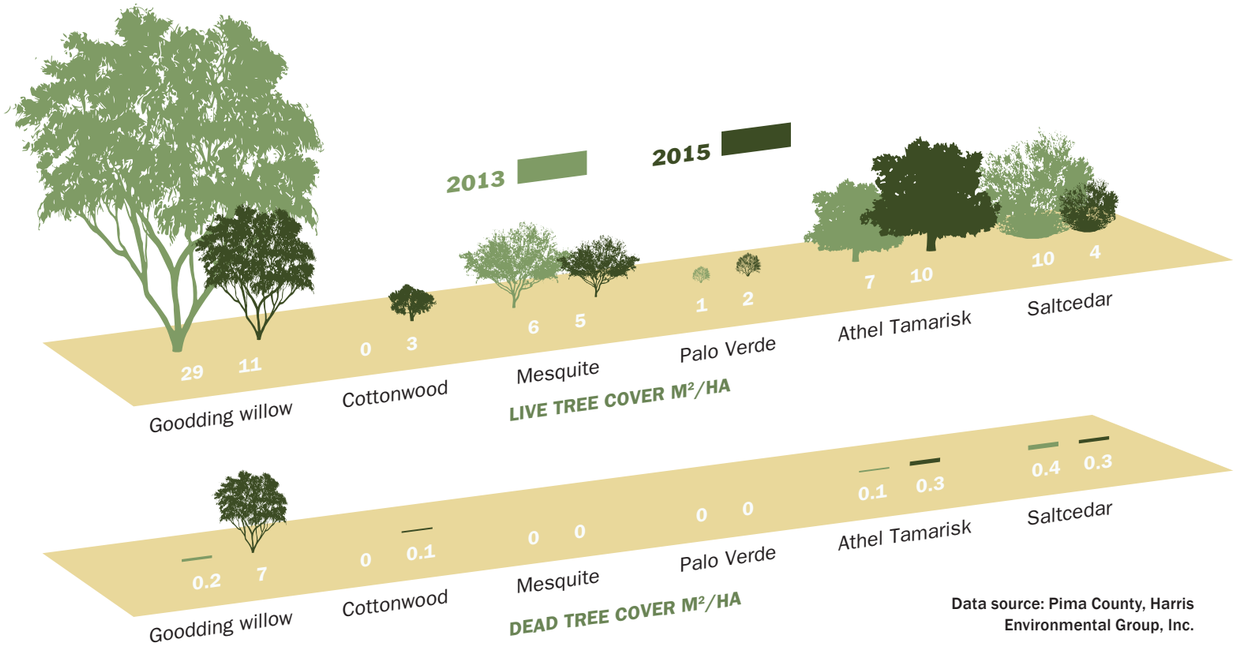


Data source: Arizona Game and Fish Department, Harris Environmental Group, Inc., Pima County, Sonoran Institute, University of Arizona, U.S. Fish and Wildlife Service

RIPARIAN VEGETATION

Just as water is essential for aquatic wildlife, many plants grow only in areas with more water, such as wetlands and riparian areas next to rivers and desert washes. Thus, effluent released into the river is also supporting numerous plants that add to the ecosystem diversity along the Lower Santa Cruz River.

Although riparian vegetation represents only a small percentage of the land cover in the Santa Cruz River Watershed, it provides important benefits to the region, such as slowing flood flows, increasing groundwater recharge, reducing erosion potential along stream banks, maintaining habitat for wildlife, and providing recreational and spiritual enjoyment.



Data source: Pima County, Harris Environmental Group, Inc.

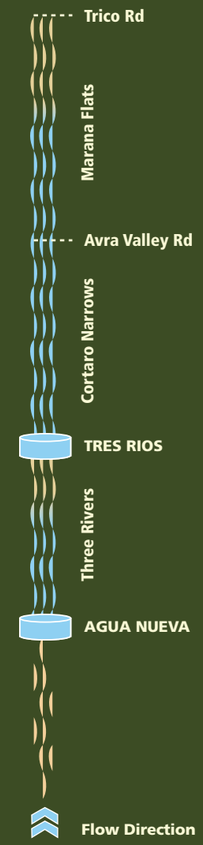
2015 RESULTS: Effluent supports wetland species; decreased willow cover in drying areas

In the spring of 2015, measurements of riparian vegetation were taken at seven sites along the river and at one site in a dry area of the river upstream of Agua Nueva. The release of effluent supports wetland species and mature trees that are most abundant downstream of the reclamation facilities. The changes in vegetation observed since 2013 were at the downstream ends of Three Rivers and Marana Flats, where increasingly dry conditions exist because of reductions in flow extent. While there were still wetland plants in these areas, the plant community may be shifting to plants that grow well in drier, low-nitrogen environments like those found upstream of the Agua Nueva outfall. Decreased flow resulted in reduced cover of mature riparian trees in these areas. Riparian tree cover indicates presence of sufficient soil moisture and is measured as the area covered by tree stems in square meters per hectare (M^2/HA). Cover of live Goodding willow notably decreased between 2013 and 2015, while cover of dead Goodding willow increased. This native species has shallow roots and is more sensitive to reductions in soil moisture. The willow decline suggests a shift to more deep-rooted trees and upland plants in drying areas. Learn more about riparian vegetation and view data from 2013–2015 at **www.tiny.cc/lr15**.

The areas with increasingly dry conditions had a decrease in willows, and vegetation may be shifting to upland plants

Downstream of Agua Nueva and Tres Rios had wetland plants and those growing well with high nitrogen

The dry area upstream of Agua Nueva had upland plants and those growing well with low nitrogen



Effluent flows support wetland vegetation and tree cover

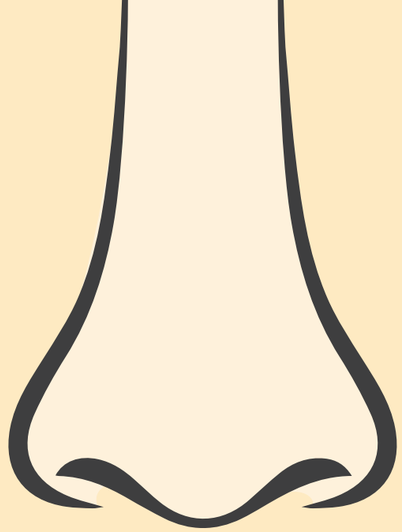
Recreation

The Lower Santa Cruz River is a popular destination for birding and other recreation. There are several parks with access to the river and numerous bridge crossings where you can get a bird's-eye view of this wetland amenity.

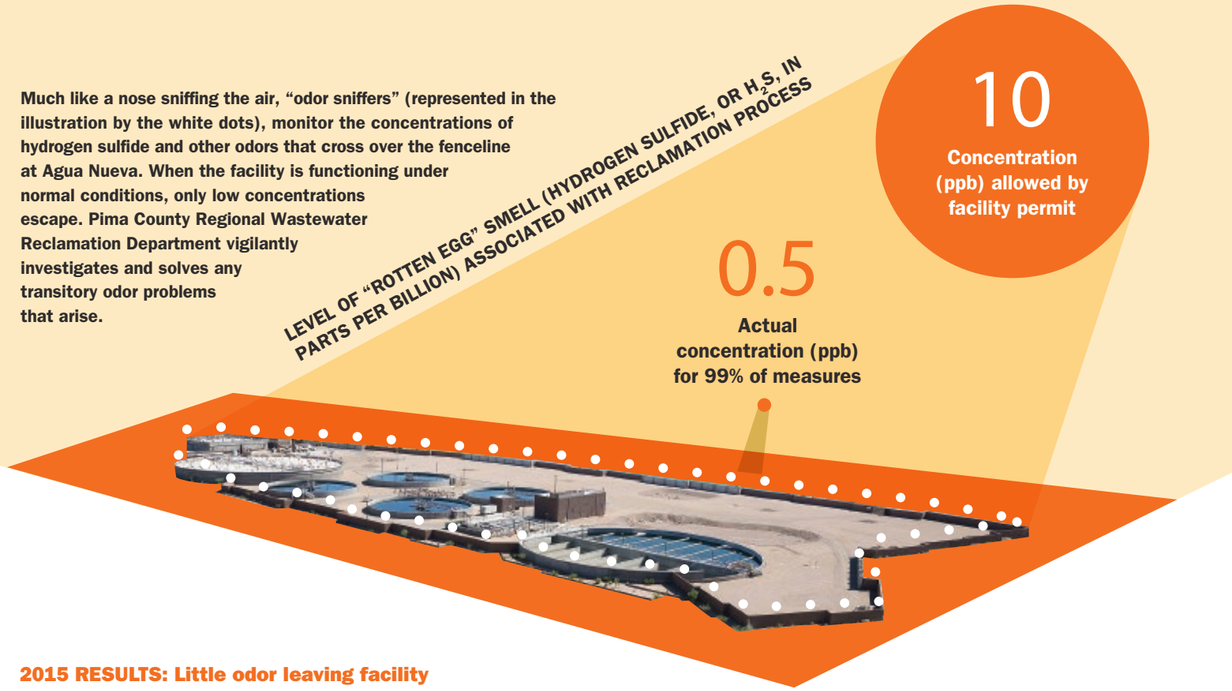
While conducting traffic counts on two days in October 2015, volunteers working with Pima Association of Governments counted more than 300 bicyclists and pedestrians along the The Loop recreational path from the Sweetwater Wetlands to the junction of the river with the Cañada del Oro. Go to www.pima.gov/TheLoop to find a detailed map and plan your visit.

SOCIAL IMPACTS

With the release of effluent into the river, reclamation facilities are supporting important wetland habitats and heightening the recreation experience for those enjoying our river parks or walking and biking along The Loop trail adjacent to the river. Even so, unpleasant odors often associated with the reclamation process can lead to negative perceptions of the river. The most common offender is hydrogen sulfide (H_2S), which causes the "rotten egg" smell. Minimizing both the extent and intensity of disagreeable odors coming from the facilities was one of the goals of the reclamation facility upgrades.



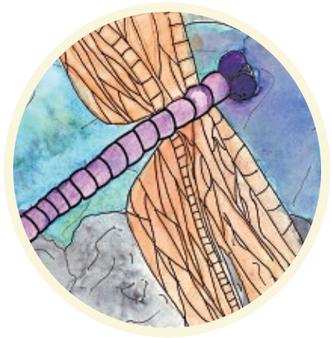
Much like a nose sniffing the air, "odor sniffers" (represented in the illustration by the white dots), monitor the concentrations of hydrogen sulfide and other odors that cross over the fenceline at Agua Nueva. When the facility is functioning under normal conditions, only low concentrations escape. Pima County Regional Wastewater Reclamation Department vigilantly investigates and solves any transitory odor problems that arise.



2015 RESULTS: Little odor leaving facility

As part of the upgrades, odor is monitored continuously at the facilities and at numerous points along the surrounding fencelines. At Agua Nueva, 55 of the 60 monitoring points are on the fenceline. Levels of H_2S at Agua Nueva were very low in 2015, with 99% of the measures taken throughout the year being less than 0.5 parts per billion (ppb). This concentration is far less than the 10 ppb allowed by the facility permit.

Detailed odor data of this kind is not available for years prior to the upgrades, thus comparisons to previous H_2S levels are not possible. Similar data will be available at Tres Rios when that monitoring system is fully installed. Progress was made with the installation of 43 monitoring points in December 2015. Anecdotal observations from people living or recreating in the area indicate that odors are either gone or hardly noticeable compared to past conditions. Learn more about odor at **www.tiny.cc/lr15**.



LIVING RIVER OF WORDS YOUTH POETRY AND ART CONTEST

The Living River of Words offers local schools the opportunity to participate in a program that encourages young people to explore how water moves through the landscape and the connections that plants, animals, and people have to water.

The *Living River* reports help guide the science-based classroom activities and field trips to the river. These field trips often represent the first opportunity for many students to experience and visit a flowing river. Students then work with local artists to take what they have learned and create poetry or art entries for the contest. The contest is open to all youth 5–19 years old.

The 2016 Living River of Words Youth Poetry and Art contest received 950 submissions. Included here, and on other pages, are some of the final poetry and art selections featured in the traveling exhibit. Learn more about the program at **www.pima.gov/nrpr**.

Lucia Meinig-Reeves, age 11 | Paulo Freire Freedom School, Ms. Mohr-Felsen

THE WHISPERING WIND

I hear the wind whispering,
to the willow trees,
telling them the stories,
of everything she's seen.
I hear the wind whispering,
to the river reeds,
bragging about every city she's seen.
If you look closely at the water's edge,
the midges are squirming and butting heads.
Why can't we just open our eyes a little longer?

Madilyn Hanna, age 11
DeGrazia Elementary School, Mr. Mayer

Hannah Bae, age 14 | Basis Oro Valley, Ms. Yom

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The Sonoran Institute convened a Living River Technical Committee of ecology, hydrology, and wildlife experts to bring the best available science to bear on the development of the *Living River* wetland health assessments. The Technical Committee provided guidance by selecting and aggregating indicators of river health, identifying reference values or standards for evaluating and tracking changes in river conditions, and reviewing this report. The information presented in this report grew out of discussions involving these experts and represents the product of a collective effort; it does not reflect the opinions or viewpoints of any individual member of the technical team. The viewpoints and opinions expressed in the discussions of the group and captured in this report also do not reflect the opinions or viewpoints of the agencies, institutions, or organizations with whom the technical team members and external reviewers are associated or employed. Any errors or omissions contained herein are solely those of the Sonoran Institute.

Raine Ugstad, age 11 | Paulo Freire Freedom School, Ms. Mohr-Felsen

SPARKLING WATER

Drifting through our world
During the rise of day and the show of night
Through cracks of our dry desert land
To care for every living creature

Alexie Gonzalez, age 10
Mesquite Elementary School, Ms. Collins

THE RIVER

The river sounds
Like a bird tweeting
It smells like mint
The air blooms into
The flowers. The flowers
are blooming and floating

Giselle Cardenas, age 8
Borton Magnet School, Mrs. Cavazos

Lucas Knoll, age 8 | Presidio School, Ms. Cohn

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Anmalina Whillock, age 6 | Roadrunner Elementary, Ms. Carroll

Daniel Yom, age 7 | Manzanita Elementary, Ms. Green

SONORAN INSTITUTE

The Sonoran Institute's mission is to connect people and communities with the natural resources that nourish and sustain them. We work at the nexus of commerce, community, and conservation to help people in the North American West build the communities they want to live in while preserving the values which brought them here. We envision a West where civil dialogue and collaboration are hallmarks of decision making, where people and wildlife live in harmony, and where clean water, air, and energy are assured.

The Sonoran Institute is a nonprofit organization with offices in Tucson and Phoenix, Arizona; and Mexicali, Baja California, Mexico. Visit our website to learn more www.sonoraninstitute.org.

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GET INVOLVED

- **Have your child enter the 2017 Living River of Words Youth Poetry and Art Contest. Sign up at www.pima.gov/nrpr.**
- **Take a water harvesting class. Water harvesting is a great way to improve the resilience of our community by using water more efficiently. Learn how with Watershed Management Group www.watershedmg.org.**
- **Save water, save rivers, and build community by joining Tucson's Conserve 2 Enhance (C2E) program. C2E connects conservation with community action. Learn more at www.conserve2enhance.org/Tucson.**
- **Visit the river for yourself! One easy entrance point is from the Crossroads and Silverbell District Park in Marana. You can walk out to The Loop and easily watch the river flow by. If you're lucky you might see a Great Blue Heron fishing for his dinner!**

PIMA COUNTY

Pima County Regional Flood Control District
www.pima.gov/floodcontrol

Pima County Wastewater Reclamation Department
www.pima.gov/wastewaterreclamation

Pima County Office of Sustainability and Conservation
www.pima.gov/government/sustainability_and_conservation

www.pima.gov

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