

ECOLOGICAL OPPORTUNITIES IN THE LOWER SANTA CRUZ VALLEY

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ECOLOGICAL OPPORTUNITIES IN THE LOWER SANTA CRUZ VALLEY OF AVRA VALLEY AND THE SANTA CRUZ FLATS

WITH A FOCUS ON RECONNAISSANCE OF PIMA COUNTY FLOOD CONTROL DISTRICT PROPERTIES

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EXECUTIVE SUMMARY

- 1) Report Objectives: evaluate conservation significance of county-owned properties in Avra Valley, specifically with regard to Priority Vulnerable Species (PVS) and the Sonoran Desert Conservation Plan (SDCP).
- 2) The ecological trajectory in Avra Valley is severely compromised: a piecemeal, parcel-by-parcel approach has limited utility. I therefore present a broad perspective, followed by specific recommendations for individual parcels. The question I focus on is, “How do we create habitat and sustain wildlife by managing water?”
- 3) The SDCP is *de facto* focused on desert and semi-desert environments, although many of the PVS depend on lowland riparian and aquatic environments. Originally among the richest in North America, these wettest regional environments are severely degraded, and remain directly in the sights of poorly planned urbanization. To save them we will have to rework the environmental chaos of the past century or so, and avoid creating more of the same.
- 4) The SDCP is likely to result in significant “quality of life” improvements for metropolitan Tucson, translating also to lasting economic benefits. Similar benefits will only accrue to the inner city with city center revitalization – which is being implemented under Rio Nuevo Project – and with urban riparian corridor revitalization – which is scarcely even on the radar for mainstream politicians. Harmonizing the built and natural environments is the keystone.
- 5) Resolving these paradoxes requires a **reconciliation ecology model** for urbanization and ecology. For the Santa Cruz River, this means reconciling urban design with hydrological, ecological, and recreational functions along the riparian corridors.

- 6) For the purposes of ecological reconciliation, the river has 3 distinct sectors in the Tucson metropolitan region, each with different potentials for restoration (Figure 1):
- a) First is the Urban Core Reach, from Irvington Road to the Continental Ranch housing tract (short of the north end of Tucson mountains). Appropriate reconciled approaches for this reach are:
 - i) Maintained, mixed-use urban river parks.
 - ii) Sustaining existing open space and utilization of effluent water.
 - iii) Development of long-term concepts for re-shaping the central city revitalization, including aspects of the Rio Nuevo project, around natural and cultural resources of the Santa Cruz River corridor.
 - b) The San Xavier Reach is from Santa Cruz County line to Valencia Road in southern Tucson. Appropriate reconciled approaches for this reach are:
 - i) Regulation of urbanization patterns in the Green Valley region to utilize the floodplain for natural parks and recreation, rather than for infrastructure and housing.
 - ii) Elimination of groundwater drawdown, and aquifer recharge.
 - c) The Lower Santa Cruz Valley Reach, extending from the north part of Tucson Mountains out into the Santa Cruz Flats, is the primary focus of this report. Two major options could contribute to ecological restoration and reconciliation in this sector:
 - i) Regulation of urbanization and levee construction patterns to maintain or restore the river's access to its broad floodplain.
 - ii) Management of effluent water to combine with natural storm runoff to create and maintain aquatic, riparian, and bottomland communities for ecological and recreational purposes.
- 7) There is a set of unmet problems in the area of political agenda and social vision:
- a) The Lower Santa Cruz is at its critical alternative futures point. Long-term future costs and options for ecologically reconciled urban design will be determined by present development patterns, and could be foreclosed by those that are current.

Similarly, alternatives for the Urban Core Reach's future may be foreclosed by new infrastructure and building in open space areas that are still suitable for a linear park and wildlife corridor.

Similar concerns apply to the San Xavier Reach, where developments could preempt natural floodplain function and groundwater table recovery. Tucson is rapidly expanding, and we are increasingly capable of modifying the natural environment. These two dynamics, working together, imply that today's actions will have large and long future effects.

- b) Impending failures to reconcile urban and ecological values for the river reflect a lack of regional vision and planning on the part of government, private capitalists, and the environmental community.
 - c) Cohesive regional plans to restore and preserve these key environments are stalled, even as urbanization and habitat destruction accelerate. Clear vision is needed for a renewal of urban design for Tucson.
 - d) The vision motivating this document is a metropolitan city is built around the floodplains, rather than on them, with key natural values integrated into the city's infrastructure, landscape, and cultural and economic life.
- 8) Five outstanding and difficult functional hydrological and ecological problems should be addressed:
- a) The more the river is constrained within a narrow floodway, the greater its scouring force. This **intensified scour** periodically rips out the riparian vegetation, selecting for a weedy, low-diversity biotic community.
 - b) The normally functioning floodplain would absorb water in a process of **natural flood irrigation** important for bosque formation and growth.
 - c) **Water quality** must be improved so that aquatic species of the desert valleys (especially fish and frogs) can be recovered and can eliminate mosquito problems that are endemic in fishless waters.
 - d) Continuous **water delivery**, perennial spring flow, or at least perennial holding basins, must be ensured to successfully manage for fish and other aquatic species.
 - e) Provision should be made to maintain strong management options for **removal of harmful exotic fishes** by establishing the ability to divert water and dry the river reach-by-reach when necessary.
- 9) Existing local examples demonstrate that such functional problems can feasibly be managed, yielding remarkably high-quality wildlife habitat, with high bird diversity, substantial tree diversity, high vegetation density, and still higher potential for additional biodiversity. Two example are of special significance:
- a) High Plains Recharge Project (near Sanders Road in Marana)
 - b) The bosque that developed at La Osa Ranch in adjoining southern Pinal County

These examples show the relative ease with which ecological restoration can be achieved given adequate space for the river and its bottomland.

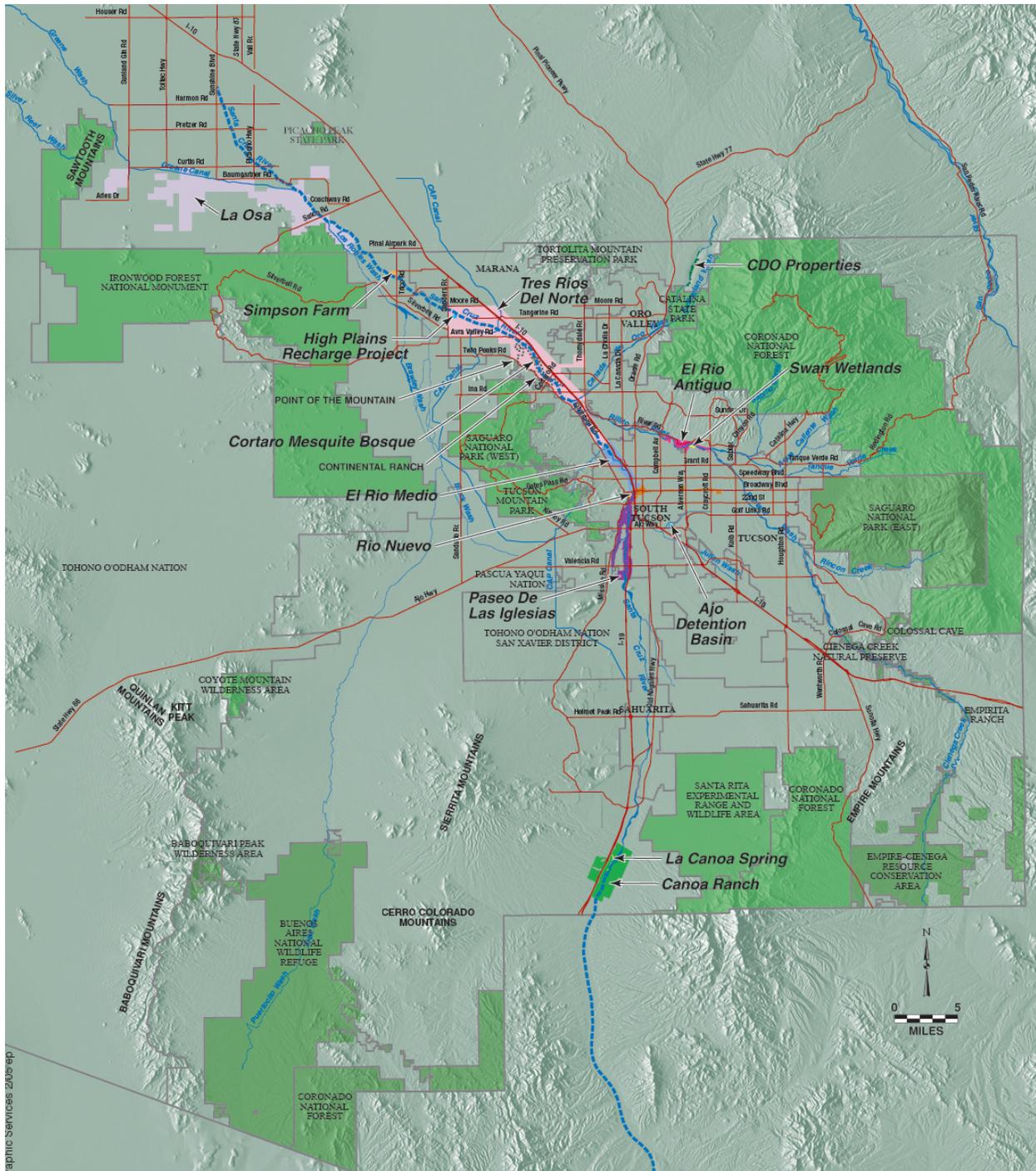


Figure 1. The middle and lower Santa Cruz River Valley showing the distribution of ecological restoration studies and projects in Pima County (large italic font), along with other features referred to in the text. The effluent reach of the Santa Cruz River, which flows into Greene Wash, is highlighted.

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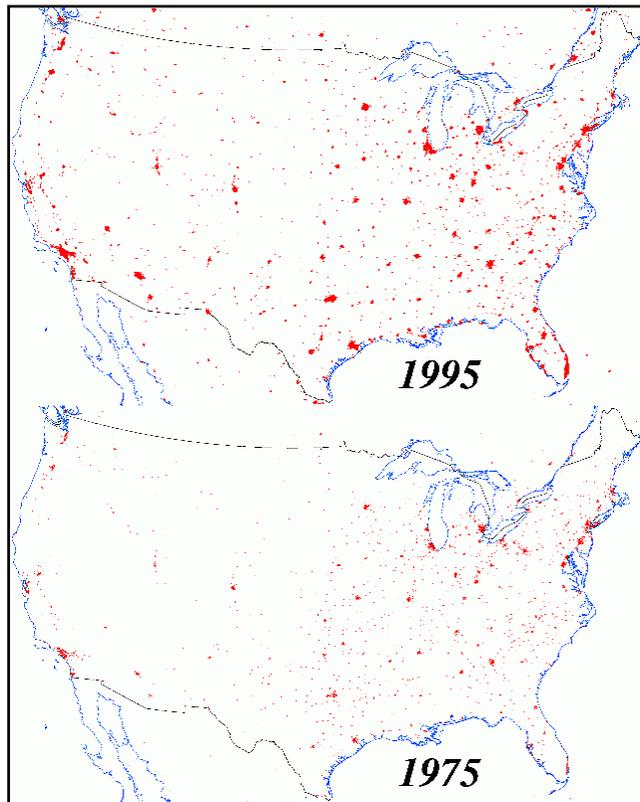
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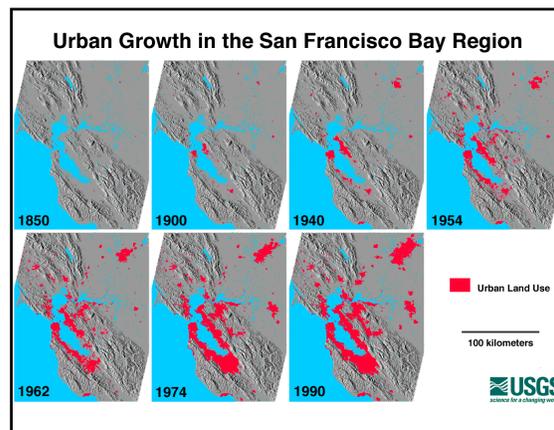
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INTRODUCTION – THE URBAN PLANET



Earth is becoming increasingly urbanized. Low biodiversity urban ecosystems occupy a steadily increasing share of the total land surface, and impact wider areas still. A small host of species (Figs. 4, 5) lives with us in our unplanned cities, such as starlings, pigeons, rats and mice. Our simplified ecosystems have unique attributes, but not very desirable ones. In addition to simplifying the animal life (reducing faunal diversity), we add plant species *ad infinitum* (increasing floristic diversity). However, exotic plants produce invasive species on a global scale, displacing unique local species, and yielding poor animal habitat. Our ever-expanding cities are zones of abundance for a few animal species, and a cacophony of introduced plants, contributing to biogeographic homogenization of the continents. Both sides of this equation translate to global biodiversity loss. And this ugly bio-simplification is worst in the very places we spend most of our lives.

The classic response to this problem, which has been to set aside land in reserves, has two principal limitations. First, our cities tend to occupy the richest and most important regional habitat areas. Tucson is a classic example. Second, as urban and agricultural landscapes assume overwhelming preponderance, their biotas will enter the mainstream of evolutionary races between diseases and resistances, predators and prey, among competitors, and with changing environments. Populous species hold the evolutionary advantage. Thus, not only do cities preempt the rich sites they occupy, and impact surrounding areas with pollution, they also contain the seeds of long-term, evolutionary damage to pristine reserves. Preservationist approaches, pursued alone, would create museum-like reserves surrounded by the real action in the places we live and work. If our cities are not harmonized with biodiversity, preserves will slowly – perhaps almost imperceptibly – wither and be lost much as a preserved museum specimen will, eventually, decay.



Such a bleak finality is not the inevitable outcome of our ascendance over non-human nature, but it is the predictable outcome under “business-as-usual”. Urbanizing areas like Marana and Tucson cannot mitigate urban development by preserving a handful of struggling species in small or outlying areas. Assuming that Avra Valley in Marana will become urban, the ecological issue becomes, “What will be the nature of the new urban biota?” The planning issue becomes, “What kind of harmony can be produced between the new urban setting and the native biological diversity of the region?” The answers are to be found in a new discipline called **reconciliation ecology** (see Rosenzweig 2003). The challenge is to create the ecological city.



Figure 4. The ubiquitous pigeon, or European rock dove.

This brief report addresses the central role the Santa Cruz River – including its perennial flow, stormwater flow, flood processes, and floodplain – could play in the altered life of the Avra Valley and adjoining Santa Cruz Flats. It focuses on the dynamic connections between the river and biodiversity that may, or ought to be built into the new urban zone. Reconciliation ecology is feasible for the Santa Cruz, but if it is not adopted now, regional biodiversity will be severely impacted in the immediate and distant future.

This report offers specific as well general ideas, including on a parcel basis.



Figure 5. The European starling and the house sparrow – globally widespread, in cities.

OVERVIEW OF THE SANTA CRUZ IN THE TUCSON REGION

For the purposes of ecological reconciliation, the river has 3 distinct sectors in the Tucson metropolitan region, each with different potentials for restoration.

Urban Core Reach

The Urban Core Reach (Fig. 6) runs from about Irvington Road (north of the open country near the San Xavier del Bac) to the Continental Ranch housing tract (just short of the north end of Tucson mountains). Most of this area already has massive infrastructure on the floodplain preempting re-establishment the key natural floodplain function of widespread, shallow flood irrigation during stormflow events. The floodplain also contains numerous historic dumps (“landfills”) that preclude the early re-establishment of groundwater and natural perennial surface flow. Thus, the river is constrained to function as a usually dry storm drain for the city in this reach, at least for the near future. Appropriate reconciled approaches are:

- i) Maintained, mixed-use urban river parks.
- ii) Sustaining existing open space and utilization of effluent water.
- iii) Development of long-term concepts for re-shaping the central city revitalization, including Rio Nuevo and other projects, around reconciled natural and cultural resources of the Santa Cruz River corridor.

The first (i) is partly in process, partly in planning, yet inadequately institutionalized and perhaps undervalued. The second (ii) is being violated by developments and by plans for toilet-to-tap effluent use. The third (iii) reflects the request of the present document. It calls for large thinking: structuring inner-city quality-of-life enhancements around a river corridor with open space and parks; integrating neighborhood ecological and cultural involvement with the linear park; and engineering a long-term vision for solving the river’s problems of aquifer depletion, hydrological function, and garbage dump pollution. This calls us to reverse the ongoing degradation of the river corridor’s natural values and open space possibilities.



Figure 6. Effluent reach and dry reach of the Santa Cruz River, both in the urban core of Tucson.

San Xavier Reach

This runs north from the Santa Cruz County line to around Valencia Road, and includes Canoa Ranch, the Green Valley area, and the San Xavier District of the Tohono O’odham Nation. The natural ecology of this area has been severely degraded by removal of groundwater in the upstream areas. However, the limited extant infrastructure on the floodplain would permit ecological restoration of natural riverine functions, including flooding on the floodplain surface and recharge of the aquifer to re-establish springs and streamflow. There are two major options that could contribute to this:

- i. Regulation of urbanization patterns in the Green Valley/Sahuarita region to utilize the floodplain for natural parks and recreation, rather than for infrastructure and buildings that cannot coexist with shallow flooding.
- ii. Elimination of groundwater drawdown, via substitution of CAP water, and limits to additional withdrawals.

Implementation of (ii), especially, would contribute to a rising groundwater table on the San Xavier District of Tohono O’odham Nation. It is assumed that Black Mountain and Martinez Hill (“Sahuarita Butte”) are connected by an underground rock dike that would force groundwater upward, reproduce the original shallow groundwater table, and reactivate the springs near Martinez Hill and south of San Xavier Mission. This would provide multiple benefits for the tribe and Tucson.

Lower Santa Cruz Valley Reach

This reach of the river extends from near the north tip of Tucson Mountains out into the Santa Cruz Flats. There, the river more or less disappears, with most flow currently going into Greene Reservoir Wash, which extends the main flow path through Greene Reservoir (near Sawtooth Mountains south of Casa Grande). Most of this is in Avra Valley, and includes Marana, unincorporated Pima County, and Pinal County. Sediments are deep, so creating a natural water table is implausible, except perhaps at the point of the Tucson Mountains. However, the floodplain is largely unconstrained by levees, allowing floodwater irrigation, and over 50,000 acre-feet/yr of effluent water is discharged from sewage treatment plants at Roger and Ina roads flows into Avra Valley.

The Lower Santa Cruz is the primary focus of the present report. Two major options could contribute to ecological reconciliation and restoration in this sector:

- i. Redesign of urbanization and levee construction patterns to maintain or restore access of the river to its broad floodplain.
- ii. Management of effluent water to combine with natural storm runoff to create and maintain aquatic, riparian, and bottomland communities for ecological and recreational purposes.

The Lower Santa Cruz is at its critical point for alternative futures. Cost estimates for restoration within the already urbanized Urban Core Reach demonstrate that tremendous savings would be realized by planning ahead now. This requires a new urbanization pattern - in which new cityscapes are built around the floodplain, rather than on it, and key natural values are integrated into the infrastructure, landscape, and cultural and economic life of the city.

OPTIONS FOR LARGE-SCALE SANTA CRUZ VALLEY ECOLOGICAL RESTORATION

The Santa Cruz River was the mesic core of the high Sonoran Desert of eastern Pima County and adjacent areas (Fig. 7). It supported high, tropical levels of biodiversity, and had major forests that were used recreationally by Tucsonans much as the Catalina Mountain canyons are today. Today, this core is in a degraded condition, although some biodiversity and productivity have survived, and are being rejuvenated by sewage plant effluent in the Nogales region. In the Tucson region, little high biodiversity habitat currently exists, although many unusual species are hanging on. Pumping has lowered the water table, which was originally at the surface, to around 200 feet deep in Tucson.

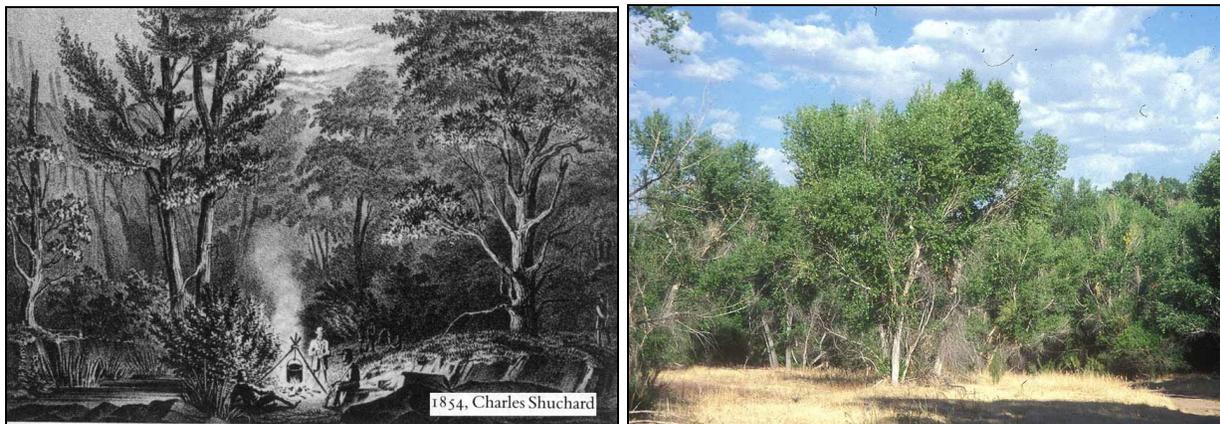


Figure 7. Historic (1854) and current (2000) conditions along Santa Cruz River near Tumacacori.

Massive groundwater pumping still continues in Tucson and upstream of the San Xavier District of Tohono O’odham Nation, preventing natural recovery of the aquifer and the re-establishment of high-quality riparian conditions. Although ecological restoration would appear plausible at San Xavier, it does not appear to have been seriously proposed. Political and engineering issues beyond the scope of this report are probably involved.

Currently, about 60,000 acre-feet/yr of effluent flows in the river channel from sewage treatment plants at Roger and Ina roads. This exceeds the roughly 15,000 a-f/yr estimated for surface flow in the 19th century (Logan 2002). Today, the flow creates a rich line of willow-dominated forest, set within a relatively arid floodplain for a length of well over 20 miles. Along with irrigation from storm flows, this effluent also created a huge mesquite bosque, with marshy ground and ponds, and a central riparian corridor and stream at La Osa Ranch, where Avra Valley opens into the Santa Cruz Flats near the Pinal County line. The amount of effluent water

available, and in some areas the available space for natural floodplain function, are potentially key assets for ecological planning.

In the city, the floodplain is mostly too narrow to retain a smooth, level surface like the one that existed prior to the river's degradation. Flood scour is severe, except near West Branch, and thus the original high biodiversity cannot be sustained by natural processes (i.e., without artificially irrigating the now-stranded floodplain surface above the river's arroyo walls) in most areas. Possible exceptions are reaches south of Valencia Road and north of Ajo Way, where the arroyo may be wide enough to sustain flood-resistant trees if they are established on a reliable water source, such as an aquifer.

At the present time, new housing developments, shopping centers, and other infrastructure are still being approved for placement on the floodplain in the city. This trend tends to restrict the options for a river corridor in the urban core, and makes it difficult to conceptualize restoring natural hydrological processes to the Urban Core Reach. Until urban design for Tucson is re-thought, the options for the river are strongly limited and grow more so with each new degrading step.

For this reason, although ecological reconciliation is possible within the city, the most feasible ecological restoration – using natural hydrological process and large available water supplies – should focus at or above San Xavier, or in Avra Valley and Santa Cruz Flats.

SIGNIFICANCE OF THE LOWER SANTA CRUZ FOR ECOLOGICAL RESTORATION

The Lower Santa Cruz currently supports the most mesic riparian forests and the most nearly functional natural floodplain of the Santa Cruz River in the Tucson region. It receives over 50,000 acre-feet/year of effluent water, plus somewhere around 30,000 acre-feet/year of storm runoff. The perennial flow of the Santa Cruz River near Tucson was something like 12,000 – 18,000 acre-feet/year (Logan 2002, p. 155, and recalculated) for the dry season, and thus was likely less than or equal to the current effluent discharge. Although the current discharge is not supported by the critical underlying aquifer, it nonetheless offers the potential to support many fine examples of the original lowland biota (see Figs. 8-10, 14, 15). The original hydrology supported perhaps the richest biodiversity in Arizona:

South of Tucson, along the banks of the Santa Cruz River lies a region offering the greatest inducements to the ornithologist... The river ... rises to the surface ... and the bottom lands on either side are covered, miles in extent, with a thick growth of giant mesquite trees, literally giants, ... many of them sixty feet tall and over – Swarth (1905)

The mesquite trees are wonders of their kind. There were some whose trunks ... scaled four feet in diameter The undergrowth is a thick mass of hackberry, etc., with various thorny bushes growing close to the ground. Meandering wood roads lead in every direction ... into this tangled wildwood we drove some four miles from the village [San Xavier del Bac]. – Frank Willard (1912, Condor)

The first three days we devoted to exploring the mesquite forest, with most gratifying results ... the medley of bird songs was absolutely confusing, and the numbers of individuals of the many species ... was far beyond what is usually the case – ornithologist Swarth (1905, Condor)

There is apparently enough water available now – as effluent plus storm runoff – to effect the restoration of a viable riverine ecology. The question is: how would we apply this water?



Figure 8. Water distributed broadly across the Santa Cruz River floodplain at La Osa Ranch between the Pima County line and Sasco Road, 19 January 2005. This natural floodplain process produced the excellent bosque habitat shown in Figs. 14 and 15, which was destroyed in 2003, revealing this underlying “distributary floodplain” pattern. This image looks west toward Ragged Top in Ironwood Forest National Monument. A marginal relict patch of the recently destroyed bosque is visible left of center.

The U.S. Army Corps of Engineers has estimated \$39,000 – \$257,000/acre for partial restoration of 4 miles of the Rillito River (Rio Antiguo Restoration Study), with little or no live surface water and considerable ongoing maintenance costs. For the “Swan Wetlands” project (now renamed to avoid the connotation that actual open surface water would be created) has also been proposed for part of the Rillito restoration study area, and although its price tag is less astronomical, its scope is also quite limited. Within the city, ecological restoration is important, but it is both expensive and controversial, and for the time being, limited in scope. Political will for ecological issues could be improved within the city government; and the public has conflicting and often misinformed concerns about ecological restoration in their neighborhoods.

In the Lower Santa Cruz, restoration and maintenance costs would be much lower, as are land values. However, political will is also an issue there in most jurisdictions: landscape analysis and planning to reconcile ecology and urbanization have been circumscribed, both in vision and in practice. Within just the past half decade, levees further constraining the Santa Cruz River have been extending deep into Avra Valley, plans have been made to urbanize the river’s floodplain in Marana, and to create a major airport adjoining outstanding bird habitat existing along the Santa Cruz River. In Pinal County, a housing developer secretly bulldozed most of the La Osa bosque and, apparently, channelized the river, perhaps in an attempt to keep

the bosque from re-forming. Although Pinal County authorities halted that debacle for the time being, overall it is clear that poorly coordinated urbanization processes are rushing forward in the Lower Santa Cruz. Ecological restoration and reconciliation opportunities must be taken up now, before it is entirely too late.

The Lower Santa Cruz currently retains an auspicious combination of characteristics making it suitable for both riverine restoration and reconciliation ecology. It has (1) actually and potentially functioning natural floodplains without excessive infrastructure and urban development, (2) existing high quality habitat, (3) large, available, free or inexpensive effluent and storm water supplies, and (4) protected surrounding mountain-centered parks with ecologically critical connections to the productive valley floor. The Lower Santa Cruz is available for large-scale ecological restoration without necessarily obstructing urbanization. However, planning must be initiated now to permit this.

STATUS OF ECOLOGY AND PLANNING IN THE LOWER SANTA CRUZ

I can find no published evidence – nor evidence in the behavior of local political and business leaders – that planning efforts for the Santa Cruz River have included an integrated vision of existing and potential, human-created biodiversity values. Reconciliation ecology, which is the obvious choice for combining urban development or revitalization with desirable natural functions, remains largely off-screen for decision-makers.



Figure 9. Gila topminnow.

For example, in the Lower Santa Cruz, Marana's infrastructure and development plans show little specific planning to preserve or enhance habitat quality or biodiversity. Marana's focus on only 4 relatively rare species (the Ground Snake, Tucson Shovel-nosed Snake, Cactus Ferruginous Pygmy Owl, and Burrowing Owl)



Figure 10. Yellow-billed cuckoo

reflects a vision limited to avoiding regulatory action under the federal Endangered Species Act. Abundant species in Avra Valley include Priority Vulnerable Species (e.g., Bell's Vireo and Abert's Towhee), and potentially restorable Priority Vulnerable Species (such as fishes, Lowland Leopard Frog, and Mexican Garter Snake), along with a host of other riparian dependant species, but these have not been integrated in Marana's planning for Avra Valley. Planners have not approached the problem from the perspective of reconciliation ecology, but rather from a conventional, developer-driven perspective of maximizing convenience and profit over shorter time scales than those used for reconciliation.

Although U.S. Army Corps of Engineers is involved in studying restoration ecology potential for Santa Cruz River from Prince Road in Tucson to Sanders Road in central Marana

(the Tres Rios del Norte study), published evidence of thoughtful regional ecosystem planning for this region can scarcely be found outside of Fonseca's (1998) work. The Army Corps study suffers from at least one fatal flaw: its study area ends in the middle of the functional landscape. This is underscored by the bulldozing of thousands of acres of bosque and wetland at La Osa Ranch, the significance of which was obscure for officials whose planning area was too narrowly defined.

Yet there are bright spots in the ecology of the Lower Santa Cruz. At La Osa, the damaged habitat still has not been urbanized, and such an environment is capable of relatively rapid recovery (compared to upland desert environments). In Marana, closer to Tucson, there are places where riparian ecology has accidentally flourished. As described below, riparian tree diversity may total eight or more species (e.g., cottonwood, willow, tamarisk, mesquite, elderberry, blue paloverde, catclaw acacia, tree tobacco), and vegetation achieves regional maxima in riparian density and structural diversity. In places, the large, old trees indicate a long-term ability to survive the inherent disturbance regimes, especially the scouring floods. This is permitted by the broad floodplain width (Fig. 11).

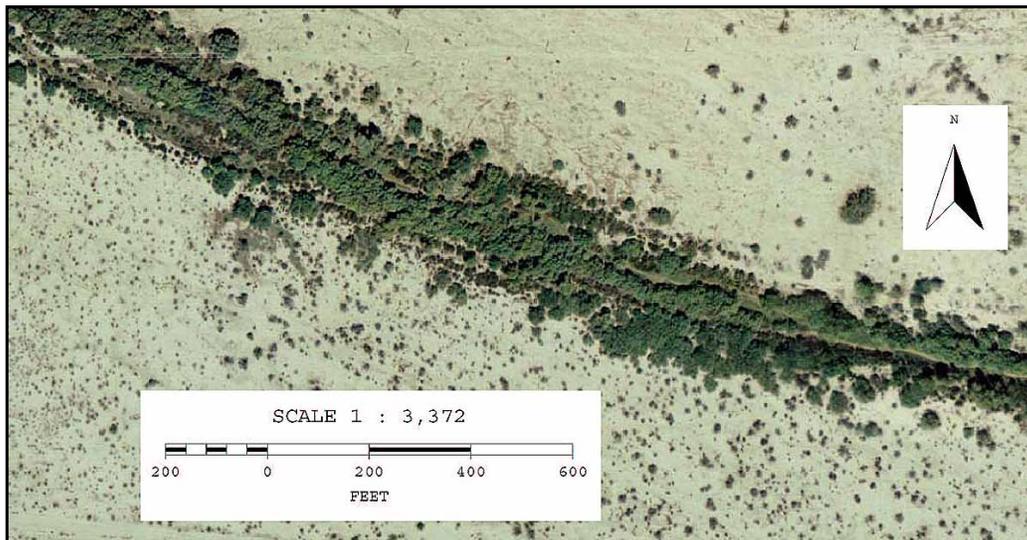


Figure 11. Aerial image of the mature willow forest and mesquite bosque along Santa Cruz River in Avra Valley, at High Plains recharge site near Sander Road, 2002.

There are other bright spots. A number of animal species with limited distributions in Pima County are very abundant (SWCA 2000) along the Lower Santa Cruz, including Lucy's Warbler, Abert's Towhee, Bell's Vireo, Common Yellowthroat, Yellow-rumped Warbler, and a variety of other migratory, wetland, and riparian birds (Fig. 12). I found turtles, snakes, and lizards to be abundant in certain areas, and a diversity of summer breeding amphibians associated with the major floodplains survives even in parts of Tucson. Other Priority Vulnerable Species, including 6 fishes, 3 aquatic amphibians and reptiles, and 1 riparian lizard, could be included in ecological planning for the Lower Santa Cruz River. Endangered species such as the Southwestern Willow Flycatcher and Yellow-billed Cuckoo (see Sage Landscape A&E, Inc. 2003) may also find habitat there. All these species could live within the context of planned

urban development, but it appears that so far none of this has been incorporated into development plans in Avra Valley.



Figure 12. Bell's vireo and common yellowthroat – native birds on the Lower Santa Cruz.

Although concepts for Santa Cruz River ecology have previously been given (Fonseca 1998), current planning remains vague or unspecific on key issues and concepts (Marana 2002). Meanwhile, as stated above, levees, concrete “bank protection”, and conversion to housing are proceeding rapidly, threatening to foreclose planning options before they have been seriously considered. The planned Marana airport expansion places most of Marana’s Avra Valley river corridor under restrictions against water fowl and other large wetland birds, and slates adjoining lands for unregulated conversion from native vegetation to commercial and industrial landscapes. All of this tends to foreclose riparian ecology options in critical ways. Another glaring failure of existing planning for the valley center is lack of concern for exotic and invasive plant problems.

Reconciliation ecology is not yet within the conceptual vocabulary of planning in the Lower Santa Cruz Valley. Biodiversity considerations appear to be low priority addenda to the “real work” of landscape conversion from natural and rural to urban. The existing Habitat Conservation Plan process envisions protecting four species for which it can do little. Marana’s role in the Sonoran Desert Conservation Plan’s regional planning could be re-focused in far more productive ways. Much or all of this critique may apply to the City of Tucson’s planning.

FUNCTIONAL CONCEPTS AND EXAMPLES FOR RIVER CORRIDOR ECOLOGY

There are key functional issues that will determine whether the river in Avra Valley will be a biodiversity center, or a depauperate drainage channel: (1) water quality for aquatic wildlife; (2) floodplain width; (3) water rights; (4) an ecologically based hydrological budget; (5) integration of water distribution for desired vegetation; and (6) habitat connectivity and stability.

Point (1), water quality, will not be a major focus in this report, but it must be recognized that current water quality is marginal or inadequate for fishes or aquatic frogs. This limits the conservation potential and creates potential health hazards by preventing fish populations from eliminating mosquito hazards. Water rights, Point (3), also will not be a focus herein, but it should be emphasized that prominent regional water planners envision increasing effluent quality but then re-routing all of it to drinking water and golf courses. Current planning is largely disconnected from the value of the river. If there is no change in these water plans, the discussion I am presenting in this paper is largely moot.

I will provide details related to Points (2), floodplain width, and (6), connectivity, here and touch on (1), water quality, and (5), sustained water delivery, with regard to potential fish restoration. The primary objective of my discussion is to motivate developing an ecologically based water budget. However, the details of such a budget itself are technical in detail, and require much more in-depth data and analysis than I will present here.

Floodplain Breadth and Reconciled Landscapes

Ecologically, the most non-obvious requirements for sustaining high native biodiversity involve efficiently delivering water to the river and its floodplain and, most notably, creating stable conditions that are rarely destroyed by flood scour. The following examples demonstrate that ecological function can be created and sustained on the lower Santa Cruz River.

Example 1. The High Plains Riparian Gallery

Southeast of Sanders Road bridge and near the High Plains Recharge Project, a rancher has been diverting a portion of river flow for some decades, creating a rich and stable riparian forest and narrow bosque, referred to here as the “High Plains Riparian Gallery Forest” (Fig. 13). This is done by the simple expedient of maintaining a small levee in the riverbed to divert part of the effluent water into a channel along the southwest margin of the interior river bottom floodplain. Using a bulldozer, and the natural layout of the river’s inner floodplain, or first terrace, a stable forest has persisted despite historically major flood episodes, 1983-1993.



Figure 13. The High Plains Riparian Gallery Forest, formed by a diversion of water south from the main river channel to irrigate pastures visible at upper left-center. The mature aspect of the gallery (at left) contrasts markedly with the scoured aspect of the main channel (center of image), 19 January 2005.

The environment is dominated by large trees such as Goodding's Willows, many of which are clearly several decades old and have survived 50-year and 100-year floods in 1983 and 1993. At the diversion point, there are populations of American Bullfrogs and Sonoran Mud Turtles in the river. (I don't know if there is any successful breeding in the river water by the bullfrogs, which could have arrived by dispersal from other sites.) Large populations of Bell's Vireo, Abert's Towhee, Lucy's Warbler, Common Yellowthroat, Yellow-rumped Warbler, and a variety of other abundant songbirds and wading birds were found at this site in spring 2004.

Although Pima County (T12S R11E section 3) and the Arizona State Land Trust own much of this land, and could theoretically protect it, a big levee was recently installed (ca. 1999-2000) on the opposite side of the riverbed. Confinement of large flood flows may render this current channel configuration unstable, leading to new channel widening. This in turn may prevent maintenance of the diversion, jeopardizing both the riparian habitat and the associated High Plains groundwater recharge project. Thus, we may have a living example of how to reconcile human-dominated environments with riverine function, but one that may soon be destroyed.

Example 2. The High Plains Pasture

The High Plains diversion is designed to flood-irrigate cattle pastures immediately southeast and northwest of Sanders Road. These pastures are on the river bottom flats, only slightly elevated above the riverbed and low-flow channel. A pond at the terminus of the pasture system supports dense riparian forest, as well as a huge number of adult American Bullfrogs (again, successful breeding has not been confirmed at this site). The floodplain retains enough breadth to prevent excessive flood scour. It is therefore possible to sustain grassland, for cattle or not, or to allow a natural or managed transition to mesquite bosque at modest cost.



Figure 14. Mesquite bosque, with riparian forest at its center along the Santa Cruz River at La Osa Ranch in southernmost Pinal County. The photo is taken near the boundary of Ironwood Forest National Monument; Picacho Peak State Park appears beyond the wooded bottomland.

Example 3. La Osa Ranch

The flood irrigation method in Example 2 could be adapted to creating and sustaining mesquite bosque at that site or at other sites. La Osa Ranch on the Santa Cruz River bottom

exemplified the rich habitat that could be re-created using effluent and storm flow. There were several square miles of bosque (Figs. 14, 15) that mingled with stream, marsh, ponds, and floodplain desertscrub. This mosaic apparently developed without much intentional design, and without great cost. Although the bosque was bulldozed, setting back the ecosystem by some decades, the potential for restoration remains. A bosque could be re-created, diversity of its regenerating flora could be enhanced, and high quality grasslands and carefully managed aquatic environments could be incorporated into the regeneration process, probably with limited cost.

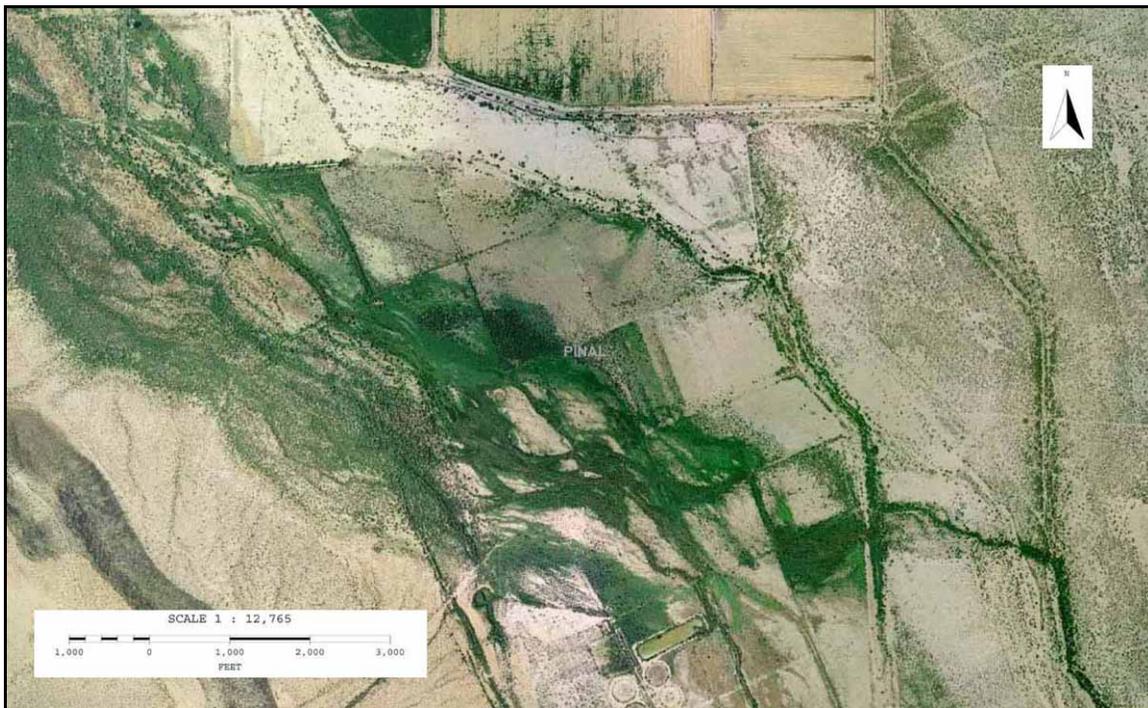


Figure 15. Aerial overview of the wooded La Osa bottomland, 2002, showing distributary behavior of the river floodplain, and the rich mix of environments that resulted.

I see no major obstacle to creating or recreating habitat at La Osa and elsewhere in the Lower Santa Cruz Valley, assuming planners decide to do it. It is worth emphasizing, however, that the La Osa urbanization plan, which placed most of its infrastructure and building on the floodplain, would foreclose reconciliation ecology options in much of the Santa Cruz Flats, and could require upstream infrastructure that could also foreclose the options for Avra Valley.

Example 4. Trico-Marana Farms

The sparsely vegetated Santa Cruz River floodplain in the area of FCD and City of Tucson properties at T11S R10E sections 14 and 24 are near active, inactive, and abandoned farm fields. These environments are open and productive enough to support Burrowing Owls and other open-country species. As with the preceding examples, these habitat qualities could be sustained in some areas by the natural aridity and scour of the Santa Cruz River floodplain, and by reconciling ongoing agricultural operations with species' habitat needs. The river may maintain suitable habitat with little management, and the fields – both fallow and active, may provide foraging habitat for birds, including Burrowing Owls.

This example suggests that a mixed management strategy creating both mesic riparian environments (through controlled irrigation and natural flooding) and arid, open environments (with heavier scour and/or less water delivered to the floodplain) could maximize habitat diversity and native biodiversity in a reconciled landscape. Species that could thrive in the more arid parts of the landscape include Desert Iguana, Desert Horned Lizard, Kit Fox, and numerous other arid-adapted, open-country species.

Problems of Population Colonization and Persistence on the Floodplain

Ecologically functional floodplains in Avra Valley would require (1) active establishment or re-establishment of desirable species that cannot readily reach the area by dispersal, and (2) provisions for flood refugia for non-flying species. First, most animals (and some plants) disperse slowly, unlike birds, so habitat creation or restoration does not ensure that desirable species will arrive. For example, my surveys of the Santa Cruz River show that riparian reptile and amphibian species that were present from San Xavier to Tucson (e.g., Clark's Spiny Lizard, Eastern Fence Lizard, Giant Spotted Whiptail, Sonoran Spotted Whiptail) have not recolonized the river edge forests anywhere, although habitat and elevation appear good for some or all of them. An active program involving translocation would be needed for many kinds of native plants or animals in order to best achieve a restoration of biodiversity.

Second, once populations are established on a floodplain – especially animal populations – they may be subject to destruction during floods. Surrounding uplands or levees (or levees added as upland islands within the floodplain) would likely suffice as flood refugia. In some cases, relatively small parcels owned by FCD could be utilized for this purpose, if they were allocated to open space conservation.

Problems of Water Quality and Distribution

Two aspects of water quality are critical for restoration of the aquatic ecosystem of the Santa Cruz River in effluent-dominated reaches: (1) water chemistry (i.e., treatment level of sewage effluent), and (2) water persistence (which is a problem because the surface flow – effluent – is disconnected from the groundwater table).

The issue of water quality could be fixed – and likely will be – via improvement of the effluent water treatment processes and facilities over time.

The second problem is less tractable. As of now, the perennial water flows over deep, dry sediments and thus cannot re-connect to groundwater in most areas. After large flood flows, the riverbed's microbial seal is scoured off, and the flow sinks rapidly into the riverbed sand. Perennial flow can be reduced from 20-40 miles in length to 5 miles or less. How can aquatic animals like fish and frogs survive? There is no mechanism in place to deal with this problem.

Although mosquitofish have been collected (in the late 1990's) from the area of the High Plains Riparian Gallery, and I saw fish, possibly African cichlids, in the river at La Osa Ranch at that time, generally there are few or no fish in the Santa Cruz River effluent. Given the numerous ways fish are likely to be arriving at the effluent stream, it is likely that water quality is grossly

insufficient for fish. Similarly, although I have seen adult bullfrogs in large pools connected to the river near Orange Grove Road for over a decade, and found adult bullfrog populations (see above) in the High Plains area, and have heard breeding choruses, no tadpoles or juveniles have been found, and abundances have remained unexpectedly low. In spring of 2004, I was besieged by mosquitoes along the river in Marana, and during summer 2004 cases of West Nile Fever, transmitted by mosquitoes, were reported nearby. If fish – including native Longfin Dace, Gila Topminnows, Desert Pupfish, and Gila Chubs – could thrive in the river, there would likely be no successful mosquito breeding there. Water quality in the river needs to be improved at least to the level of Phoenix, where discharges already sustain large fish populations.

The long flow paths from Roger Road and Ina Road Wastewater Treatment Facilities (WWTF) to downstream areas in Avra Valley and Santa Cruz Flats lead to periodic, short-duration drying of entire river reaches. The microbial seal allows water to flow for many tens of miles, reaching as far as Chui-Chu in the Casa Grande region in winter 2003-4 after the La Osa floodplain was bulldozed. However, after large floods and for a period of time thereafter, the dry riverbed would eliminate fish populations (assuming improvements in water chemistry had permitted them to flourish). Repopulation would take many months, during which time the river would be open to infestations by mosquitoes. At the same time, frogs would probably die, and populations of birds and snake dependant on the fish would suffer. In general, the fluctuation of the environment produced by this problem creates several undesirable consequences.

One solution to this problem may be release of treated effluent to the river at multiple points. This could be accomplished by placing WWTFs at various points, and/or by directing the effluent to the river by outflow pipes from a main pipe along the river. The release points could also be designed to provide fish with adequate refuges from the brunt of flood scour, and these refuges would help maintain adequate fish populations along the river's length.

VALLEY-CENTER HABITAT WITHIN THE CITY: URBAN LANDSCAPING

General Considerations

Although this report focuses on the river and its floodplain, ecological restoration and reconciliation must also consider the kinds of environments that will exist throughout the urban matrix. Will these environment support high or low biodiversity? Will the species be desirable ones? Such issues are currently relegated to back yard programs. They would be better served by beginning the urbanization process with institutionalized plans for the kinds of habitat that will come with the new urban setting. The costs associated with optimizing urban habitat conditions can be contained to whatever level is desired, as suggested by what follows.

Issues of urban native vegetation and riparian conservation converge in context of Marana's plans for the Santa Cruz bottomlands. Although Marana may be prepared to consider native vegetation ordinances for paloverde-ironwood-saguaro-dominated communities on the Tortolita Bajada (or "Fan"), there is no indication of an analogous approach for the formerly wooded lowlands (Marana means "thicket") associated with the river. Presumably, then, whatever urbanization plans exist involve the hyper-destructive "scrape and replace" with exotic plantings. Instead of using hardy, native, wildlife-friendly species that would extend river

riparian values into the newly urbanizing community, such plans invite the usual small host of urban core animals and the usual welter of potentially harmful exotic plants.

Urban landscaping has moved from high water-use lawns and temperate or tropical plantings to low water-use designs that, unfortunately, incorporate primarily exotic shrubs and trees. Both approaches are significantly harmful to biodiversity. To begin with, both approaches attract few and undesirable animals. High water use plants – especially exotic ones – attract non-native species of birds and other animals. The great majority of non-native plants that thrive do so by “escape” from their natural enemies, such as rusts, fungi and other diseases, and herbivores, such as insects. Until they re-accumulate such enemies, which may take decades or centuries, they produce poor food resources for animals, including desirable ones such as warblers, vireos, gnatcatchers, thrashers, flycatchers, lizards, and many other birds.

The shift to arid-adapted exotic plants in Southwestern landscaping is potentially worse than the use of water-hungry exotics. Desert-adapted exotics are far more likely than water-hungry exotics to invade natural environments, spreading their impacts on native plants and the animal food base beyond the city’s direct impact zones. Such invasions are expected to often occur decades after initial introductions and cultivation, so that the worst floristic and botanical impacts of recent and ongoing planned, scrape and replace development are likely to occur with increasing velocity over the next few decades. Already, the flora of washes in urban Tucson makes this emerging trend clear enough. As the West becomes more urban, thoughtless urbanization may replace poor ranching practices as the leading driver of the biodiversity crisis.

Urban landscaping currently fails as suitable habitat in two other critical ways: oversimplification of (1) surfaces and (2) vegetation structure. People have developed a virtual addiction to rectilinearity and order, and this is expressed in the seamlessness of infrastructure, building projects, and landscaping. To date, what biodiversity thrives with us does so in the cracks, crevices, and forgotten byways we inadvertently permit to develop or persist. Thus, the better we get at construction and maintenance, the more thoroughly we destroy habitat surfaces. Similarly, we often design landscaping in two predominant layers, lawn (or gravel) and umbrella-shaped trees. Few species successfully inhabit such landscapes, although the addition of flowerbeds and shrubs adds something. Key features for animals such as thickets, low shrub story vegetation, and dense vine tangles, are seldom incorporated in modern landscaping. Habitat has not been explicitly incorporated into landscape architecture, with predictable results.

It is remarkable that in the American West, urban landscapes – which are now sprawling across huge swaths of the total landscape – appear to be more damaging than urban landscapes in the eastern United States. There, natural processes and native species tend to persist or be re-established by succession. In the arid West, natural succession is slower, the landscape is less resilient under the destructive forces of non-reconciled urbanization, and the created urban environments are more different from what is natural. Remarkably, in the West, the “planned development” approach to urban expansion is actually far more damaging to the land surface and ecology than pell-mell wildcat development. This is a grim testimony to the extent of damage we in Tucson are facing if we fail to reconcile our urban existence to the native ecology.

Appropriate Local Approaches to Urban Landscape Planning

Remarkably, solutions to these problems facing the urbanizing planet are not all that difficult to find, and many are perfectly feasible and bear insignificant cost.

Solution 1. Use Only Regionally Native Species. By mandate, regional planners could require use of only native plants in and planned housing and commercial development for which governmental approvals are required. The result could involve savings on water and maintenance costs. It would help native species of plants, and the animals that use them, to flourish around residential communities and even big-box stores, office building, and industrial facilities.

The cost would likely be a compromise in reduced use of fast growing plant species that respond faster than native species to supplemental water. For example, exotic mesquite species are often favored over native mesquites because they grow faster, even though native mesquites may eventually be better. From an economic standpoint, however, if all developers faced the same mandate, none would suffer in sales, and cost would be trivial.

Solution 2. Develop Recommendations for Ecologically Desirable Vegetation Types and Vegetation Structures. Recommendations for urban habitat would provide information and concepts few landscapers, developers, or ordinary homeowners currently have. Without belaboring this here, I note that (1) the desire of people to live in water- and shade-enriched environments could be translated into the creation of desirable riparian habitat analogs; (2) shade and water runoff created by buildings, notably including large buildings, create opportunities for riparian-like native plant communities; and (3) lower, near-ground and at-ground vegetation structures are usually the most deficient aspects of habitat in landscaping, although more generally what is needed is a full spectrum of “foliage height diversity.”

A singularly important issue that is easily neglected is the use of truly native mesquite, which is the velvet mesquite, *Prosopis velutina*, in the Tucson Basin. Mesquite is the natural anchor for healthy desert riparian areas – well buffered against temporary drought, and providing excellent forage and microhabitat. Mesquites (genus *Prosopis*) are diverse on both regional and global levels. Non-native Southwestern mesquites (especially honey mesquite, *P. juliflora*, which may produce undesirable hybrids with velvet mesquite) as well as exotic mesquites (such as Chilean and other extraneous species, which appear to produce little in the way of forage for songbirds or lizards) are both widely used in Tucson. It would be a simple matter – again a matter of awareness and will – to correct this.

Solution 3. Minimize the Area Bulldozed or Dug by Heavy Machinery. The two foregoing solutions seem to me to lack appreciable cost beyond startup and education. A third desirable solution is to minimize the initial disturbance to the land surface during building projects by designating construction limits on plans and erecting temporary fencing to guide work crews. Even a quarter acre of natural vegetation within an urbanized matrix can serve as a base in which native species persist and from which they can colonize reconciled urban habitats.

Although this solution brings costs associated with foregoing building in some amount of natural habitat area, and in re-designing the industrial model of scrape and replace construction, these costs may not be so large that they cannot feasibly be borne in an urbanizing society. A reconciled landscape would pay significant future dividends in quality of life.

OTHER AVRA VALLEY LOWLANDS DESERVING CONSERVATION ATTENTION

A brief treatment of this large issue is given here, as two of the FCD properties I surveyed are in bottomlands of the two other major riparian corridors in Avra Valley – Blanco Wash and Brawley Wash. One of these FCD properties is at Blanco Wash not far north of Avra Valley Road, and the other impinges on the north margin of Brawley Wash not far southeast of Trico Road. Neither of these is in Marana’s current boundaries, but both are well within the de facto area of its suburban expansion.

Blanco Wash

Blanco Wash is the locus of the only known, remaining, viable Ground Snake (Fig. 16) population in eastern Pima County’s lowlands. It also supports mesquite bosque and thicket, perhaps much like that originally seen in Marana and elsewhere in Avra Valley, and hosts a variety of species in abundance. The environment is dependant upon sustaining some level of sheet flooding, and thus requires avoiding turning the wash into a trench that keeps floodwater off the floodplain.

Housing around its periphery, or more generally, designed not to require flood protection, may coexist with many of the natural values of this system. Two problems can be identified: (1) this wash, which supports a Ground Snake population at least from Avra Valley Road to Silverbell Road, is not yet included in the “biological core” of the Sonoran Desert Conservation Plan; and (2) as with any other floodplain, elevated terrain should be saved so terrestrial animal species can survive major flood events and reoccupy or repopulate the floodplain.



Figure 16. Ground snake (*Sonora semiannulata*), a species currently known in Avra Valley only from Blanco Wash. Photo by Young Cage.

Brawley Wash

Brawley Wash is among the most degraded lowlands in southern Arizona, retaining little of its original character. This character is nonetheless evident in the skeletal remains of bosques on now-baked adobe soils that exemplify degradation suffered by a delicate environment. This sort of degradation can also be observed southwest of Sells, where it surrounds impressive remnant bosques with mesquite, netleaf hackberry, and vine thickets growing on this soil type. I think the fundamental ecological problem is recent downcutting (entrenchment) and dewatering of broad (1-5 mile wide), very level floodplains. The soils are so dense that water must stand or drain off slowly so that it soaks in to support rich vegetation if it sits. Thus, shallow entrenchment in these environments can have outsized impact.

This kind and extent of devastation is evident adjoining the Pima County parcel at T11S R 10E section 35, and it is widespread on the floodplain throughout that section of Avra Valley.

To the south, similar degradation is observed in large patches over a wide area between Avra Valley Road and Manville Road. At least under drought conditions, these areas present the aspect of slowly dying, medium-stature mesquite woodland on a sterile soil on which nothing grows. Research is needed on (1) original conditions on these soils, especially based on past aerial and topographic map evidence for downcutting, vegetation change, and agriculture effects on the landscape, (2) potential future conditions that may be created, and (3) a regional “ecological runoff water budget” to determine where natural runoff can best be re-allocated to floodplains via ecological restoration.

PARCEL-SPECIFIC POTENTIAL FOR PIMA COUNTY FCD LANDS

A broad outline for conservation has been suggested in the preceding sections, and Pima County Flood Control District might play a role in implementing it. Specific parcel references will be given here. These come in two flavors, riverine restoration-dependent and -independent.

Restoration-Independent Recommendations for FCD Properties

The major properties discussed in this section (Fig. 17) are along the Santa Cruz River, and, along with Arizona State Trust Lands, would have important significance as anchors for a reconciliation ecology program for the Lower Santa Cruz. Although this document focuses on that broader issue, certain specific actions might be possible on a piecemeal basis within the context of individual FCD properties. These parcels are individually referenced and discussed in this section, going roughly downstream (southeast to northwest) along the Santa Cruz.

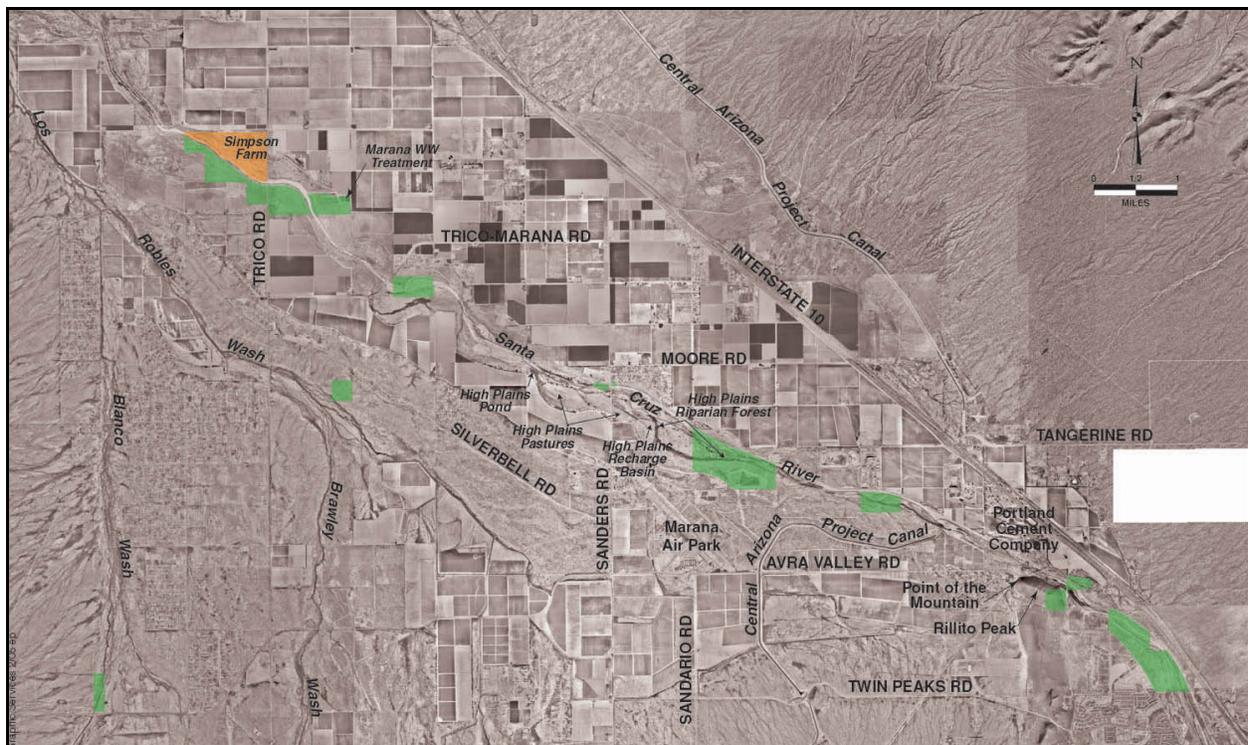


Figure 17. Pima County Flood Control District properties along the lower Santa Cruz River and in Avra Valley, and selected other features referred to in text.

Parcels 22607005J and 22608007L (Santa Cruz floodplain in Continental Ranch area). In the Continental Ranch reach, FCD properties (T12S R12E sections 16 and 17) could be slowly developed as a mix of created bosque (i.e., Cortaro Bosque) and arid-adapted desertscrub, especially saltbush-mesquite communities. The corridor between the inner, bank-protected riverbed, and the bank-protection at the Continental Ranch housing is wide enough, and may experience catastrophic flooding infrequently enough, to permit desert and bosque species populations to persist. High ground should be created or maintained within this zone to permit species survival during catastrophic flooding. Further, more intensive work in this area might be left until significant neighborhood support becomes evident.

Parcels 226010200 and adjoining lots (floodplain at north tip of Tucson Mountains). At and near FCD properties the tip of the Tucson Mountains (T12S R12E section 8), the river bottom forest is particularly rich, and its close association with rock slopes with paloverde-saguaro habitat may make the area especially suitable for species like the Pygmy Owl. I found a high diversity of reptiles in this area, including widespread desert species, a riparian Tucson species at the desert-ward margin of its distribution (the Southwestern Black-headed Snake), and two Lower Colorado Valley species at their extreme northeastern range edge (the Desert Iguana and Long-tailed Brush Lizard). The riparian forest is relatively species-rich at this site, and bird diversity was high. Minimization of shifts in the low-flow channel, so that gallery forest and marshland may persist, should be considered here.

If expensive or complicated projects to preserve riparian gallery forest during flooding were to be contemplated, this area would be the highest priority. If the groundwater table can be elevated in this area due to shallow bedrock, that too could be worth pursuing. On the northeast side of the new levee at this site, additional property purchases would help to conserve the unusual reptiles reported here, all of which were at or adjoining the county property there. If enough land can be obtained here to allow the river to broaden during flood (i.e., to permit abandonment of part of the new levee) and minimize scour, this area would benefit greatly.

Parcels 22614001E and 22614005B (Santa Cruz floodplain near cement plant). FCD properties west of the cement plant and just north of Avra Valley Road (T12S R12E section 7) were only briefly examined. They appear have little unique character. Unless there is a way to permit flooding to occur broadly, and to protect some uplands to avoid inundation (see Figure 18), it may be best for this reach to focus on maintaining a minimum of connectivity between upstream and downstream ecological and recreation functions.

Parcels 21503011A, 21750035A, and 21748001C (Santa Cruz floodplain terrace east of Sander Road). At the High Plains Riparian Gallery Forest area, FCD properties (T12S R11E section 3, T11S R10E section 32) may anchor an effort, which may prove temporary, to sustain that gallery forest, which is the densest, most mesic forest that currently exists on the floor of the Tucson Basin and in the lower Santa Cruz Valley. It is denser and more mesic than Sabino-Bear Confluence and upper Tanque Verde Wash, although it is set in an arid landscape. However, there is reason to suspect that this forest will not continue to survive scour events, now that it faces a narrowed channel with an opposing levee embankment. This needs further consideration, inasmuch as the existing habitat quality is so high.



Figure 18. Santa Cruz River corridor looking north from Tucson Mountains (2004), illustrating an important linkage for species populations. At upper left, beyond Avra Valley Road, is the large natural desert area at the High Plains riparian site, which then connects to greater natural open spaces further down the floodplain; at right is the Arizona-Portland Cement plant. Pima County Flood Control District owns numerous parcels of flood-prone land in this corridor, which could form an anchor for maintenance and restoration in the corridor. The floodplain at image center may offer the opportunity to create another High Plains-type flow diversion (see Figs. 11, 13).

For the time being, in cooperation with the local rancher, Town of Marana, and State Land Department, the existing habitat of gallery forest, flood-irrigated pasture, and forested pond should be maintained and studied as examples of how other areas of the river might be successfully managed for a combination of preservation, restoration, and enterprise.

The uplands owned by FCD and State Land Trust along the southwest side of the river here support one of the largest remaining patches of native desertscrub in the area of the central Avra Valley. This area may support a population of Tucson Shovel-nosed Snake, along with other habitat fragments near and along Avra Valley Road. At the least, careful survey for this species should be conducted here and in other areas for which intensive urban development is planned or proposed. Ecological work in this area may be constrained by airport expansion plans, or *vice versa*.

Parcels 208140270, 208140140, and 20812010B,C (river floodplain near Trico-Marana Road bridge and east of Trico Road). The pair of FCD property areas close to Trico-Marana Road and to Trico Road (T11S R10E sections 14 And 24) includes areas of open tamarisk-sand inner bottomland that may be open enough, and close enough to levee embankments to support Burrowing Owls, along with desert species such as the Desert Iguana. I found bird life to be diverse there, including Priority Vulnerable Species such as Bell's Vireo and Abert's Towhee, and many other species along the river, including an American Bittern. The lowermost of the two areas, southeast of Trico Road, includes the Marana Wastewater Treatment Facility, where there

may be opportunities to utilize a source of effluent not dependent on the long flow path from Roger Road and Ina Road WWTF.

Working with Tucson Audubon Society, private farm owners, the State Land Department, and City of Tucson, FCD could design river restoration projects at and near these properties that mimic those in the High Plains area. This area, including the river and floodplain down to the county line, would also, as described below, be the best area in Pima County for economically feasible restoration of natural Santa Cruz River floodplain function.

In 2004 a major open space bond was passed for Pima County. Purchase of the identified bond parcels in this area would greatly benefit the proposal advance here.

Parcel 208040040 (river floodplain and field at Pinal County line). The FCD parcel at the county line just east of the river (T11S R10E section 4) could be associated with the more involved restoration efforts suggested for the Trico-Marana and Trice road areas. It currently supports a small pond with American Bullfrogs and Mosquitofish, which are both widespread, along with other non-native fishes, in the farmland ponds at and south of the county line. It also supports a small, rich riparian area that has high bird diversity. Both of these features could be used for native fish and turtle propagation. Until bullfrog control is effected in this northern part of the county – not impossible but probably not soon foreseeable – restoration of leopard frogs and Mexican Garter Snakes is probably not possible under pond (non-stream) conditions.

Use of the open space bond funds here would be appropriate if the restoration approach I suggest is going to be implemented. Acquisition of parcel 202-07-0060, which is owned by the State of Arizona, and is on the Santa Cruz proper, would be essential for this purpose.

Other Parcels owned by FCD are near Brawley Wash (208230260, T11S R10E section 35) and Blanco Wash (208251020, T12S R10E section 17). These are small, and bring with them separate, complicated issues associated with those drainages. They have been briefly discussed above under a separate heading.

Restoration-Dependant Issues for FCD Properties

Continental Ranch to Sanders Road

Parcels upstream of Sanders Road generally present higher costs for major riparian restoration. Unfortunately, it appears the High Plains Riparian Gallery Forest is now vulnerable to scour effects intensified by the Army Corps levee installed in 1999 or 2000.

There are two principal constraints on restoration in this reach: (1) small shifts in the location of the low-flow channel result in the death of riparian trees, shrubs, and forbs, and (2) public acceptability of effluent and stormwater in proximity to residential areas, particularly near Continental Ranch.

While there may be an economically feasible engineering solution to the problem of shifting channels, it is not apparent to me. Raising the groundwater table close to the surface would help, but various old dumps, very deep water tables in this reach, contact between effluent and elevated groundwater, and legal difficulties inhering in Arizona water law make this problematical. Thus, it appears that in this reach, we must assume much vegetation will periodically be killed by shifting channels or stripped away by major scour events. Despite this,

bird life is diverse and abundant along the river and floodplain, and will continue to be as long as effluent is supplied.

Perhaps there is an engineering solution that would minimize the periodic shifts in position of the low-flow channels in the urban reach. I suspect that recent riparian forest death I observed on this survey (downstream of Ina Road on the Santa Cruz River) resulted from neglect, intentional re-routing of the low-flow channel, or both. It is possible that hydraulic engineers might devise a concrete-based system of baffles to direct the power of scouring events aside from desirable forested areas within the bank-protected confines of the riverbed. At least, care might be taken to avoid unduly shifting the low-flow channel.

Although existing effluent is not acceptable near residential areas, more highly treated effluent would be, and is planned for use in the Cortaro Bosque project. However, such projects are expensive, and even with clean water seem not universally well received in adjoining neighborhoods. Residents are afraid that homeless people will colonize dense riparian vegetation, threatening their comfort and security. The issue will remain until neighborhood organizations and the authorities make it clear they will implement readily available, viable resolutions of the problem.

Sanders Road to Santa Cruz Flats

Downstream from Sanders Road the floodplain may be wide enough to allow sustained riparian vegetation, as at the High Plains Riparian Gallery Forest. This might be possible on FCD properties, but planning for the whole corridor, with land exchanges and purchase, would better accomplish large-scale restoration.

It may be possible to achieve a more productive floodplain by restoring a meandering flow path. Much of the Santa Cruz River has been forcibly straightened. In places within the Right-of-Way owned or acquired over time by Pima County and other public owners, it may be possible to restore meanders that would reduce scour and better irrigate the floodplain surface. This approach is especially suitable for the lower Santa Cruz, in the neighborhood of Trico Road, but may also apply in the region of Continental Ranch.

Land holdings would have to be consolidated at the most upstream portion feasible, such that the river (along with the Brawley Wash system) can be allowed to irrigate areas 1-2 miles across, or wider, when in flood. This area might begin somewhere between Sanders and Trico Roads, perhaps in the vicinity of Trico-Marana Road. From here, the river could eventually be allowed to meander largely unhindered within its floodplain.

Channels like that near High Plains could be constructed and protected from excessive scour. Bosque, grassland, and pasture could be periodically irrigated in certain areas to create high-quality habitat; other areas could be allowed to retain the arid, open riverbed aspect to support open-country species of interest, such as the Burrowing Owl, Desert Iguana, and others. This natural floodplain environment could be narrowed to by-pass the Pinal Air Park or other infrastructure, and then broadened again with a focus on similar restoration and habitat creation on the river floodplain at La Osa Ranch.

La Osa Ranch is a key area for reconciliation as envisioned here. Application of Pima County open space bond funds to contribute to the purchase of La Osa Ranch in Pinal County should have, according to the concept laid out here, the highest priority – higher than the purchases recommended above of lands along the Santa Cruz in Pima County.



Figure 19. View across open space in central La Osa Ranch, in southern Pinal County, 19 January 2005.

The La Osa Ranch region is currently undeveloped, and remains an open space connection between major regional natural areas (Figs. 19-21). Its future should be of interest to a coalition of interested parties, including environmentalists, Pima County (via the connection to the Sonoran Desert Conservation Plan), the Bureau of Land Management (via the connection to Ironwood Forest National Monument), the State of Arizona (via a connection that may be established between the Monument and nearby Picacho Peak State Park), the Department of Defense (via its need for unoccupied, open land adjoining its stated billion dollar investment in the military helicopter training base), the Arizona Game and Fish Department and its hunter constituency (via their concern that the Monument's natural Bighorn Sheep herd would be threatened by adjacent urbanization), and the U.S. Fish and Wildlife Service, as well as Nongame Branch of Arizona Game and Fish Department (via the potentially high-quality habitat that could exist on the floodplain and Santa Cruz Flats for such species as the Yellow-billed Cuckoo, Southwestern Willow Flycatcher, Borrowing Owl, Pygmy Owl, Mesquite Mouse, Sonoran Pronghorn, various bats, the Mexican Garter Snake, Tucson Shovel-nosed Snake, leopard frogs, and desert fishes). This is a broad set of interests, some with enough money to purchase the needed property.

A restoration and reconciliation ecology project on the Lower Santa Cruz would contribute significantly to recovery of the most imperiled elements of the regional biota. With improving treatment of effluent, it would become an increasingly important regional attraction and recreational feature for the Tucson metropolitan area in both Pima and Pinal counties. Within the context of Marana's urbanization, a viable native ecological community could thrive within the context of the northward expansion of metropolitan Tucson.

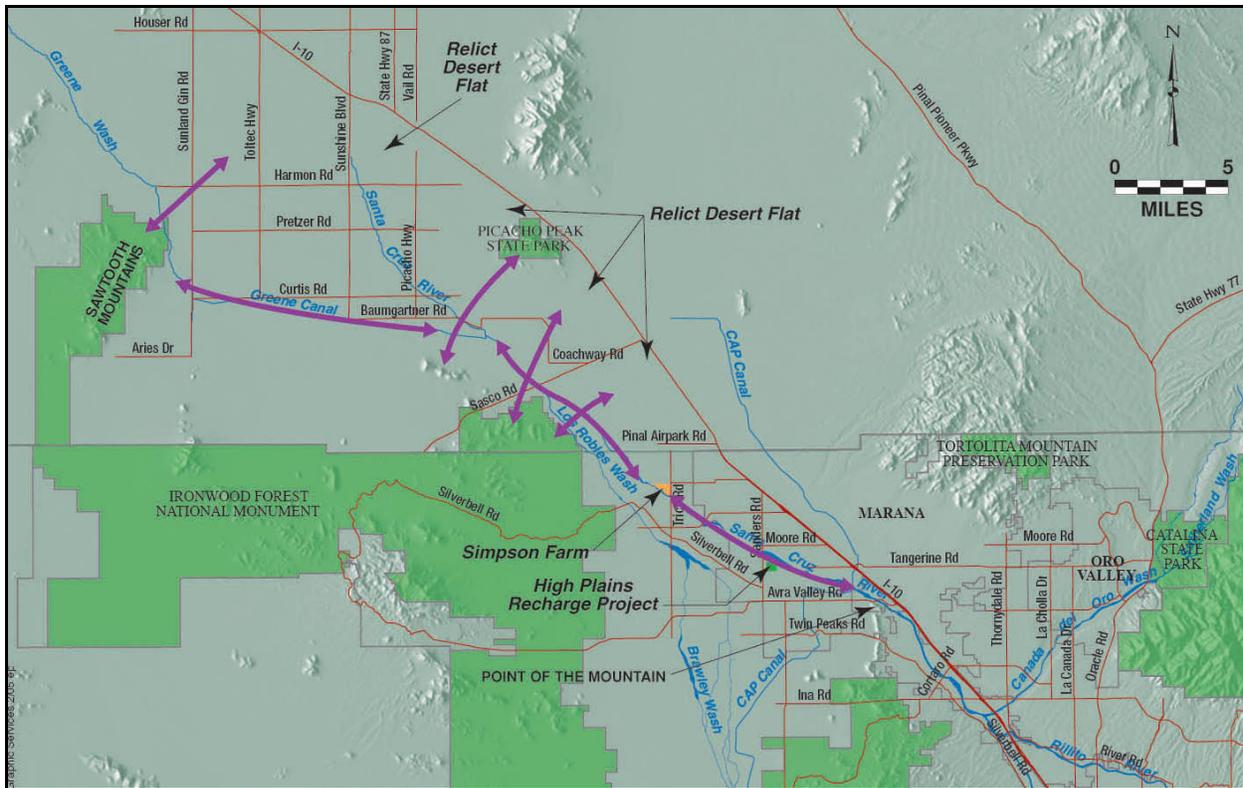


Figure 20. Critical landscape linkages for a reconciled metropolitan riparian design in the Lower Santa Cruz Valley and Santa Cruz Flats. Corridors are shown along the flow path of the Santa Cruz, including in Greene Wash, as well as across the lower valley from natural areas in Ironwood Forest National Monument to natural areas east of the river, at Picacho Peak State Park, and in the Santa Cruz Flats.



Figure 21. Connection from Ironwood Forest National Monument (foreground) to Picacho Peak State Park (upper left-center) across La Osa Ranch. This is a key corridor area, both south-to-north along the Santa Cruz River and west-to-east across Avra Valley.



Figure 22. An example of Santa Cruz River bosque – near Tumacacori, 2000.

RECOMMENDATIONS

I. Regional River Corridor Planning and Issues

- (1) **Establish a priority for conservation and restoration of the Lower Santa Cruz Valley**, including Avra Valley, La Osa Ranch, the Santa Cruz Flats, Ironwood Forest National Monument, and Picacho Peak State Park, based on existing and potential riparian and xeroriparian habitat, and including a claim on effluent and storm runoff.
- (2) **Establish a conservation and restoration plan**, complete with hydrologic budget, a landscape-level view of where major riverine and bottomland features will exist, a clear view of how the present habitat instability will be remedied, and a list of vegetation types, habitat types, and species that would be included.
- (3) **Operationalize** the plan and integrate it with urban development plans **before development plans further compromise options** for a functioning regional ecology.
- (4) **Use reconciliation ecology for urban development planning** for Tucson, Marana, and unincorporated Pima County in Avra Valley.
- (5) **Use ordinances and incentives to encourage the use of native plants and natural vegetation structure** in new urban landscaping as the Lower Santa Cruz Valley urbanizes.

- (6) **Restrict further construction of levees and bank protection** on the Santa Cruz until a hydrologically and ecologically sound regional plan for the river is established.
- (7) **Continue building public landholdings** on the river and its floodplain to simplify the social issues facing ambitious restoration plans.

II. Other Avra Valley Bottomlands

- (1) **Incorporate Blanco Wash into the biological core of the SDCP**, expanding upon existing Pima County FCD property holdings there.
- (2) **Establish a restoration ecology study for the Brawley Wash flats**, which are highly degraded.

III. Parcel-specific Potential for FCD Properties

- (1) Study methods of riparian and floodplain reconciliation ecology using the High Plains reach the Santa Cruz River (near Sanders Road) as an exemplary paradigm.
- (2) Evaluate engineering options for preserving and stabilizing forest, wetland, and bosque on Santa Cruz River at the north tip of Tucson Mountains.
- (3) Similarly, seek engineering options for river conservation near Continental Ranch, and in other effluent-dominated reaches of the Santa Cruz River.
- (4) Evaluate the potential to conserve Burrowing Owl populations on some of the disturbed, arid, open floodplains of the river near Trico-Marana Road and Trico Road.
- (5) At Trico-Marana and Trico properties, evaluate the potential to establish restoration projects using methods seen in the High Plains project example.
- (6) For each parcel, include at least a narrow, adequately protected corridor of suitable habitat for connectivity along the entire lower river corridor.
- (7) Add high ground to these corridors so that non-flying terrestrial species are not completely without refuge and totally eliminated during major flood events.
- (8) Construct small water features that can be used by native fishes (Gila Topminnows and Desert Pupfish) and Sonoran Mud Turtles at the county line FCD parcel near the river, and at the northern Marana WWTF facility.
- (9) Maintain the riparian area currently on FCD land near the county line, and manage the water more carefully to reduce the mosquito population there.
- (10) Catalog the bullfrog populations in the region, including those in the river southeast of Sanders Road, in a forested pond northwest of Sanders Road on the

floodplain, in a roadside pond on the county line property, in farm ponds, and elsewhere along the river. Observe where successful reproduction occurs (sources populations) and evaluate water quality in relation to breeding from a general amphibian perspective. Establish a conceptual plan for how bullfrogs might or might not be successfully removed from the Lower Santa Cruz Valley.

IV. Open Space Bonds

- (1) The highest or most immediate priority for open space bonds purchase activity identified in this report is acquisition of La Osa Ranch in southern Pinal County along the Santa Cruz River.
- (2) The highest priority for open space bonds purchase in Pima County identified in this report is acquisition of lands astride the Santa Cruz River downstream of Sanders Road in Avra Valley, especially in the area from Trico Road to the Pinal County line.
- (3) A third priority is for floodplain lands between Continental Ranch and Sanders Road.
- (4) The Blanco Wash represents a previously little-considered area of important floodplain riparian habitat where bond moneys could be utilized.

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