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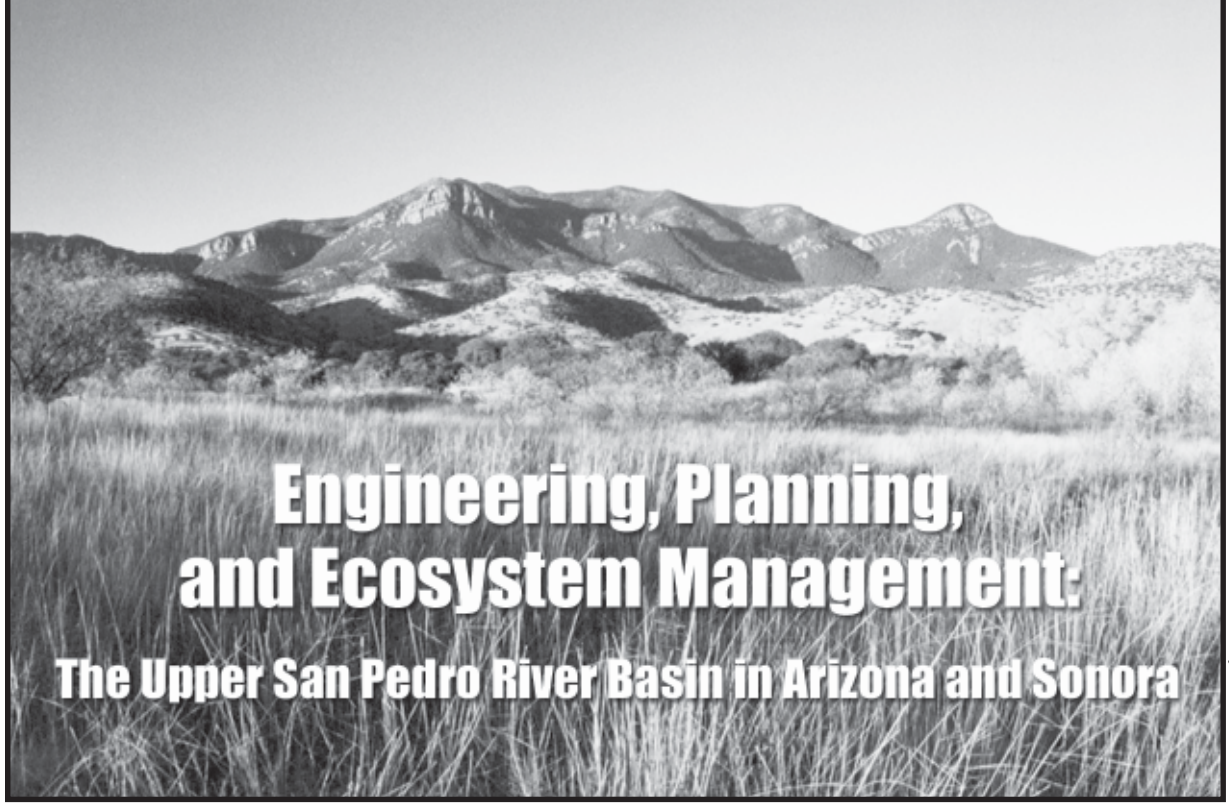

Engineering, Planning, and Ecosystem Management:

The Upper San Pedro River Basin in Arizona and Sonora

Photo by Robert L. Anderson

By Mr. Robert L. Anderson

The Upper San Pedro River Basin in southeastern Arizona is home to both Fort Huachuca—the Army's Intelligence Center and Electronic Proving Ground—and the growing city of Sierra Vista. The basin also contains some of the most diverse plant and animal life in North America. However, water use by Fort Huachuca, Sierra Vista, and agriculture in the basin threatens to lower the water table and dry the San Pedro River. This, in turn, could alter the vegetation in the basin and eliminate endangered species habitat in the nation's first federally protected riparian National Conservation Area. A team from the Harvard Design School; the University of Arizona; the Desert Research Institute; Headquarters, US Army Training and Doctrine Command; and the US Army Corps of Engineers determined the range of potential future growth patterns for the basin (Alternative Futures) and compared them for their relative impacts on a suite of environmental parameters, including hydrology, biodiversity, and landscape vegetation pattern.

Environmental Setting

Originating just south of the Mexican border, the San Pedro River flows northward, through the high desert of southeastern Arizona. Ecologists call the area a *transition zone*; it is an area with great biodiversity, where the species of four ecoregions overlap. From the north, the Rocky Mountains merge their Canadian and temperate character with the subtropical influences of the Sierra Madres. From the west, the Sonoran Desert, with its giant saguaro cactus, blends to the south and east with the Chihuahuan Desert, dominated by creosote bush. A multitude of ecological niches, created by variations in altitude and microclimates in the isolated mountains that rise like islands from a desert sea, expands the diversity.

Walking through the Huachuca Mountains on the fort at sunrise, one might spot a group of coatis, which resemble a hybrid between a raccoon and a monkey; piglike collared peccaries; a mountain lion; dozens of butterfly species; and scores of the nearly 400 bird species reported in the basin, including the quetzallike elegant trogon. Even jaguars have been reported near Fort Huachuca. The wildlife is similar to that found in a Central American forest.

The vegetation changes from high desert grassland and scattered mesquite near the valley floor to a Madrean montane conifer zone at the highest elevations, where Douglas and other species of firs, ponderosa pines, and aspens dominate. Nearly 1,000 plant species have been identified in the Huachuca Mountains alone.

The Problem

Environmental debate is a standard part of public discourse in the valley, which has been a center of controversy for well over a decade. Litigation and public debate have ensued over whether groundwater use from Fort Huachuca, an expanding Sierra Vista population, and valley agriculture will dry up the last free-flowing river of the southwestern deserts. A drive through Tucson or Phoenix reveals dry ghosts of former rivers, now containing water only during monsoon cloudbursts. Without concerted effort, the San Pedro River could suffer the same fate. The Sierra Vista newspaper, the *Herald,* has stated that the city looks to the Army for leadership in environmental issues.

Unfortunately, our ability to alter ecosystems far outpaces our ability to understand and manage them. The science of ecology, established in 1859, is a relatively young science, with no agreement on a standard approach to ecosystem management. However, it is evident that any such approach will need to center first on understanding and then compensating for how humans adversely impact the biological and chemical cycles that support the multiplicity of organisms—including people—in an ecosystem. Humans change the environment through land clearing, paving, development, agriculture, etc., in ways that can alter the ecosystem to a point where ecological sustainability is lost. Watersheds seem to be the best method of parsing an ecosystem into manageable units.

Engineering Solutions

Engineering efforts that have already been undertaken to conserve water at Fort Huachuca include closure/demolition of unused facilities, waterless urinals, low-flow fixtures, rainwater harvesting, leak detection, replacement of evaporative coolers with air-conditioning, xeric landscaping (use of native vegetation requiring little water), and irrigation with effluent. These efforts have resulted in reducing water use at the fort by nearly half since 1993—a remarkable accomplishment.

However, it is difficult to achieve equilibrium between groundwater pumping and recharge in arid environments. Although importing water is one option, a better option is to compensate for evaporative loss by supplementing effluent recharge with captured mountain-front runoff.

Stimulated by concern for the fort and the need for a regional, multidisciplinary approach, the Upper San Pedro Partnership (USPP)—a consortium of 21 state, federal, and local governments and private nonprofit and commercial members—was created in 1999. The goal of the USPP is to balance regional water use with recharge to sustain human needs, the river, and the National Conservation Area. As a member, the fort is working with the USPP to add 250 acre-feet of storm water to approximately 1,000 acre-feet of treated effluent recharge annually.

A New Challenge

Pursuant to a 2002 US Fish and Wildlife Service Biological Opinion issued under the Endangered Species Act, Fort Huachuca is obligated to balance its groundwater uptake with recharge by 2011. The Biological Opinion determined the Fort Huachuca responsibility to be 2,784 acre-feet per year, or 54 percent of the annual basin deficit (the difference between amounts pumped from and recharged to the aquifer) of 5,144 acre-feet. The city of Sierra Vista proposes to eventually recharge 3,600 acre-feet of treated effluent and storm water annually, allowing a cushion for fort mission expansion, if needed. The question is whether the region—not just the fort—can *reach* and *sustain* equilibrium between pumping and recharge while continuing to grow. This is as much an engineering challenge as an ecological one; therefore, civil engineers and hydrologists will play a major role.

Ecological Planning

It is often difficult for planners to foresee long-term, cumulative ecological impacts resulting from their decisions. This is due, in part, to the gradual nature of growth and the general inclination of planners to focus on parcels rather than on the entire regional landscape. The region's problems are indeed greater than the sum of its parcels.

Regarding these problems, the work of Carl Steinitz (the Alexander and Victoria Wiley Professor of Landscape Architecture and Planning at Harvard Design School) is impressive. He has developed a planning approach which he calls *Alternative Futures*. By surveying local stakeholders, his research team determines the range of potential growth patterns that might occur in an area over the next 20 years. The three initial alternatives considered include current growth plans; a constrained alternative, projecting less growth than anticipated; and an open alternative, projecting greater growth than anticipated. Each alternative is then analyzed by Geographic Information System models for its impacts on a range of environmental factors. In addition, the following questions are posed during the course of an Alternative Futures analysis:

- How should the landscape be described in content, space, and time?
- How does the landscape operate? What are the functional and structural relationships among its elements?
- Is the current landscape working well ecologically and culturally?
- How might the landscape change? By what policies and actions might it change? Where and when might it change?
- What differences will the changes cause?
- How *should* the landscape be changed?

Notice that if the questions are asked in reverse order, they provide a framework for evaluating whether pending planning decisions make sense. In the course of an Alternative Futures study, the questions are asked three times—each time reversing the previous order. Using this approach, planners have a much clearer vision of the potential for adverse environmental impacts in the future. It may even become apparent that some desirable future scenarios—such as maintaining river habitat—may not be attainable once certain thresholds—such as lowering the water table—are crossed.

The San Pedro Study

To represent the dynamic processes at work in the study area, a Geographic Information System was used to organize spatially explicit data for the region. The data was based on conditions in the study area during the period

from 1997 to 2000 (baseline 2000), which defines the reference period against which impacts of future changes were measured.

After questioning developers, a development model was derived to evaluate the attractiveness of available land for five kinds of development: commercial, urban, suburban, exurban (between suburban and rural), and rural housing. This model simulated the urbanization of the region under the three basic Alternative Futures scenarios. In addition, the study also examined two or three variations of each of the three basic scenarios in order to thoroughly investigate the full range of Alternative Futures the region might experience. To help generate the scenarios, questionnaires were developed for local citizens based on three issues that are central to public debate in the region: development, water use, and land management. The responses, interpreted into a set of assumptions and choices about policy, served as the basis for the range of future scenarios. All scenarios were projected to 2020 via the development model. One example of a scenario variable included maintaining the fort at current strength, expanding it, or closing it. However, none of the scenarios considered the impact of treated effluent and storm water recharge projects now proposed by the city and fort; follow-up evaluations will be needed once these projects have been finalized. Once the scenarios were developed, they were linked to a suite of process models to describe and evaluate how certain aspects of the landscape would be affected under each alternative.

The environmental factors analyzed in this study—each impacting subsequent factors in a cascading series—included hydrology, soil moisture, vegetation pattern, landscape ecological pattern, fire ecology, several endangered species habitats, and overall biodiversity. In addition, variations were analyzed in the view shed (scenic value) for each scenario. For example, a hydrological model evaluated how changes in groundwater storage affect surface flow in the river. A vegetation model indicated how changes in the hydrologic regime could subsequently impact fire and grazing management practices. Predictions of new vegetation patterns then formed the basis for a three-part assessment of regional biodiversity: a landscape ecological pattern model, an endangered species habitat model, and a vertebrate species richness model. The models were used to assess the potential impacts of each of the scenarios relative to the 2000 baseline conditions.

The San Pedro study occurred between 1997 and 2000 and is the first Alternative Futures study Steinitz has published as a book: *Alternative Futures for Changing Landscapes: The Upper San Pedro River Basin in Arizona and Sonora*: Island Press, 2003 (800.828.1302). This was also the first time an Alternative Futures study was conducted for an Army installation.

Results of the Study

The results of the study help determine how the region's activities can influence its natural resources and what can be done to mitigate negative impacts. For example, the study determined that basin agriculture was a major use of groundwater. To compensate for this, the fort, in cooperation with The Nature Conservancy, became the first installation to purchase off-post conservation easements for water rights from willing sellers near the river. This will eliminate 1,930 acre-feet per year of withdrawal near the river—a significant step toward sustainability.

The study seems to have ended the debate about whether the river is threatened. The baseflow of the river was lowered in all but the most conservative growth scenarios; again, proposed recharge was not evaluated. This stimulated the concerted regional effort of the USPP with its goals to protect human needs, the river, and the fort. However, Sierra Vista remains attractive to retirees and others seeking high desert scenery and escape from lower elevation heat. This is perhaps one of the best test cases in the nation for balancing growth and ecosystem sustainability.

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