BORDERLINK 2000 FINAL REPORT

## The Alamar River Corridor: An Urban River Park Oasis in Tijuana, Baja California, Mexico

Edited by

Suzanne Michel



Institute for Regional Studies of the Californias San Diego State University San Diego, California 92182-4403

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With the collaboration of

Paul Ganster, San Diego State University José Delgadillo, Universidad Autónoma de Baja California (Ensenada) José Guillermo Rodríguez, Universidad Autónoma de Baja California (Tijuana) Hugo René Aguilar, Universidad Autónoma de Baja California (Tijuana) Laura Musacchio, Arizona State University BorderLink 2000 student research team

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(see photographs on back cover)

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## Foreword

BorderLink is a cooperative applied summer research program involving advanced students from San Diego State University, the Universidad Autónoma de Baja California, and other universities. BorderLink 2000 was the fifth in the ongoing program that is coordinated by the Institute for Regional Studies of the Californias at SDSU. The five BorderLink projects are:

- 1993, The Wine and Tourist Industries of Baja California
- 1994, Economic Profile of the San Diego-Tijuana Region
- 1996, Border Waste Wi\$e: Analysis of the Management of Recyclable Solid Waste in the San Diego-Tijuana Region
- 1997, The Tijuana River Basin: Basic Environmental and Socioeconomic Data
- 2000, The Alamar River Corridor: An Urban River Park Oasis in Tijuana, Baja California, Mexico

The BorderLink projects are organized every one to three years, depending upon availability of funding, requests from agencies in the region, and availability of faculty leaders. Each of the projects is applied in nature and addresses specific issues or problems identified by organizations in the San Diego-Tijuana region. BorderLink 2000 examined the Alamar River Corridor in urban Tijuana at the request of Carlos Graizbord, Director of the Municipal Planning Institute (IMPlan) of the City of Tijuana. Faced with proposals to channelize the Alamar River to make more land available for urban development, planning authorities in the city wanted to examine the full range of options and asked the BorderLink project to explore alternative uses for this urban river. Suzanne Michel, Post-Doctoral Fellow at the Institute for Regional Studies of the California and an expert on urban watershed policy, was selected to lead the effort. She found willing collaborators in colleagues from the Universidad Autónoma de Baja California: José Delgadillo, director of the Herbarium at the Ensenada campus, and Hugo René Aguilar and José Guillermo Rodríguez of the Chemistry Department at the Tijuana campus.

In addition to promoting cooperative research involving faculty from Mexico and the United States, BorderLink also is designed to involve students from both countries and from a variety of academic disciplines. The 2000 project included students from business, economics, biology, chemistry, political science, landscape architecture, Latin American studies, and public administration. Along with the SDSU and UABC students, an exchange student from France and two graduate students from Arizona State University also participated. Through the intense applied research project, the students faced many challenges. Not only did they learn to work with peers from different academic disciplines, but they also learned how to work effectively in a different cultural context. BorderLink provides students with an opportunity to interact with policymakers from both countries and to participate in researching real-world issues of concern to stakeholders in the region. Students also gained important understanding of the similarities and differences in the two systems across the border, including higher education and public administration. BorderLink is truly a unique experience for participating students.

BorderLink 2000 included research and related activities in a number of different sites in the border region. The program began with a two-day workshop at San Diego State University's Field Station at the Santa Margarita Ecological Reserve in northern San Diego County and southern Riverside County. There, the BorderLink student researchers learned about issues related to the biodiversity and watershed management associated with the reserve. The program at the field station included presentations by experts on water law, herpetology, geomorphology, hydrology, land use planning, and plant ecology.

For two weeks, students conducted field research in the Alamar River and Tecate River corridors, focusing on three aspects of urban watershed management: water resources, riparian plant ecology, and land use planning. Besides field research, students toured the Tijuana River National Estuarine Research Reserve to better understand the problem of river sedimentation in the region. The Campo Environmental Protection Agency demonstrated its river restoration and groundwater recharge techniques. Students toured facilities associated with water reclamation (Santee Lakes, Santee, CA), river park planning (Mast Park and River Run, City of Santee), river ecosystem restoration (Mission Trails Regional Park), and river ecosystem education/visitors center (Mission Trails Regional Park Visitor's Center). Three BorderLink students attended a workshop on aquatic toxicity training sponsored by the Information Center for the Environment, University of California at Davis. BorderLink students also attended a presentation on water quality conditions in the Tijuana River watershed at UABC, Tijuana.

BorderLink 2000 students were exposed to different research methodologies and techniques, and were able to work at field stations, laboratories, facilities, and research sites on both sides of the border. The students worked with scientists and social scientists, and with practitioners that included agency personnel and urban planners. The theme of the project, suggested by Tijuana's planning agency, developed important information and analysis that supported sound public policy decisions.

BorderLink 2000 students presented initial results of the study to the Municipal Planning Institute of Tijuana (IMPlan) on July 14, 2000, for review and comments. The study was also the main topic of discussion at a public colloquium presented at IMPlan by the BorderLink faculty leader, Suzanne Michel, on August 21, 2000. The study and its results were designed to support efforts at Arizona State University to develop river restoration landscape design and the work of IMPlan to create a master plan for the Alamar River.

## **Executive Summary**

This report is the result of the BorderLink 2000 Program, an applied summer research project on the topic of Tijuana's Alamar River<sup>1</sup> and its potential as a site for an urban river park. The Alamar River is located in the northeast part of Tijuana, Baja California, and is a major tributary to the Tijuana River. Faculty and students of the Universidad Autónoma de Baja California (UABC, Ensenada and Tijuana campuses), San Diego State University (SDSU), and Arizona State University (ASU) conducted field research and participated in the writing of this study at the invitation of Tijuana's municipal planning agency.

## Assumptions

The primary assumptions of the study were as follows:

- Even though projects, such as channelizing the Tijuana River downstream from the Alamar River, have brought immediate economic and other benefits to the city and its residents, this economic development has occurred at the expense of the natural environment and has negative long-term impacts on Tijuana and downstream areas in the United States.
- The limiting factor to future economic development in the Alamar River region is the availability and functionality of *natural capital*, or life supporting services provided by the natural environment. These services are clean water, clean air, green spaces, groundwater recharge, flood control, soil erosion control, and so forth (Hawken, Lovins and Lovins 1999: 9).
- Many of the natural capital services performed by the rivers in Southern and Baja California, including the Alamar River, have been undervalued in terms of estimating the economic benefits these services provide to residents of Tijuana and the region.
- Population growth, poorly planned urban expansion, illegal discharges of pollutants, and trash are the primary causes of the loss of natural capital in the Alamar River Corridor. All must be addressed to assure a sustainable development for the Alamar River region and for Tijuana as a whole.
- The creation of an urban river park in the Alamar River Corridor will emphasize the economic, environmental, and social benefits of river restoration and, consequently, the natural capital services the river provides to the City of Tijuana. Restoration should provide for a sustainable balance between the needs of people and the natural environment.
- An urban river park will allow Tijuana residents to interact with and learn about the region's vast and varied biodiversity in river habitats. The park will be a source of city identity and pride, as seen in the cases of San Antonio, Texas; Denver, Colorado; and elsewhere around the world.

<sup>&</sup>lt;sup>1</sup> Within a geomorphology perspective the Alamar River would probably be labelled as a creek, not a river. Hence scientists often refer to the Alamar River as the *Arroyo Alamar* or the Alamar Creek. We have chosen to use the term river because the term "Alamar River" is the common name or title utilized by Tijuana's residents.

## Purpose

This document reports the activities and research findings of the BorderLink 2000 research program. The report endeavors to increase public awareness and understanding of the Alamar River, its natural resources, and the importance of stream restoration for Tijuana's development, the quality of life of its residents, conservation of its water resources, and preservation of natural habitat. This study will serve as the foundation for discussions with all stakeholders interested in developing a comprehensive management plan for the Alamar River and the Tijuana River watershed.

#### Key Findings and Opportunities for the Alamar River Corridor

Riparian habitats—the jungle-like vegetation that surrounds rivers, streams, and creeks—are a crucial part of life-sustaining ecosystems. The benefits of riparian areas for people, plants, and animals include providing basic necessities such as water and food. In addition, riparian wetlands are instrumental in flood control and groundwater recharge, and also aid in improving water quality. Although economic activity is usually considered to be centered in urban areas, such as the Zona Río in Tijuana, the trees, plants, and wildlife of the Alamar River Corridor impact the daily lives of Tijuana's residents and of downstream residents in the United States. With proper watershed management, the Alamar River can play an important role in the development of the region.

River restoration, or the creation of a river park in the Alamar River Corridor, along with appropriate urban development, would dramatically increase the amount of riparian habitat and green space in the City of Tijuana. Restoring the river to its natural state will provide the following benefits to Tijuana's residents and visitors (adopted from Dallman and Piechota 2000: 21):

**Local, cost-effective water supply.** Protecting and restoring riparian habitat fosters groundwater recharge. By enhancing and protecting the underground water supply, Tijuana conserves and enhances an economical, safe, and secure source to supplement the Colorado River water brought in by an aqueduct that is vulnerable to natural disasters and expensive due to high capital costs and energy requirements.

**Habitat.** In Southern and Baja California, a significant portion of riparian and wetland habitat has been destroyed, mainly due to urban development and water quality degradation. Preservation of local wetlands is essential not only to protect numerous native local species, but also to protect thousands of migratory avian species that use these wetlands for breeding, foraging, and nesting grounds.

**Need for open space and recreation.** Tijuana is one of the poorest cities in the world with regard to availability of parks. There are only 1.87 square meters of green spaces per resident for Tijuana's urban population (XVI Ayuntamiento de Tijuana 1999). In contrast, international standards recommend between 10 and 12 m<sup>2</sup> of green spaces per person (Ojeda 1991).

**Water quality.** By restoring riparian habitat and wetlands, water quality can be improved in rivers, creeks, groundwater basins, and in the ocean. The ability of wetlands and riparian areas to remove pollutants from water is well documented (Baker and Westerhoff 2000; Husted 1997).

**Restoration of natural hydrology.** Restoring natural stream functions and their habitat also helps to provide erosion control, reduce flood events, and manage sedimentation. Erosion and sedimentation are now severe problems in the Tijuana River watershed.

**Costs.** It is becoming increasingly costly to build artificial river channels or traditional concrete box channels in already developed areas. This is due not only because of direct costs, but also because of indirect negative impacts downstream, such as increased flooding, water pollution, and erosion. New approaches that reduce the volume and velocity of storm water, and improve water quality, are proving to be cost effective, especially when the multiple savings add up over long periods of time.

**Greening the urban landscape.** River restoration increases property values and can encourage upscale development nearby—especially for tourism and recreational purposes. In Denver, Colorado, river parks for the South Platte River and Cherry Creek are excellent examples of increasing property values that result from urban river restoration and green area development.

## Introduction

#### Tijuana from an Urban River Perspective

Tijuana is a city of paradox and contrast. The city is located in a semi-arid region facing the Pacific Ocean. Months of sun and dryness are alleviated by rainfall in the winter and early spring. The rainfall that enters the city's urban streams and upstream watershed provides potable water for its residents. It also nourishes wetland ecosystems that, in turn, support a wide variety of aquatic, terrestrial, and avian biodiversity. One such thriving wetland ecosystem exists in the Alamar River Corridor. However, population growth, urbanization, and industrial development threaten the city's urban rivers.

Tijuana is one of the most rapidly growing cities in Latin America, with an annual population growth rate of approximately 6 percent (Comisión Estatal del Agua 1999). By 2020, Tijuana's population will likely exceed 3.8 million (Peach and Williams 2000). One of the reasons for the city's rapid urban growth is the expansion of Tijuana's assembly and light manufacturing sector, the *maquiladora* industry. These mainly foreign-owned industries use low-cost Mexican labor for assembling components into final products (Carter 1999: 6). These plants dominate Tijuana's industrial and urban landscape. By late 2000, Tijuana had 810 plants that employed some 198,776 workers (INEGI 2000).

Urban residential, commercial, and industrial development has resulted in channelization and destruction of the natural hydrology and wetland habitat in the Tijuana River. When initially conceived and implemented in the early 1980s, the channelization project was seen as a great urban development program, providing for planned urbanization and controlled expansion of the city (see photograph 1, page 21). However, in Tijuana, as in many urban areas around the world, it is becoming clear that the long-term costs of such projects outweigh the short-term benefits.

Urban expansion deposits many contaminants into urban rivers. Eventually, many of these pollutants can enter the groundwater basins beneath the rivers. If too many toxic substances enter the groundwater basins, these aquifers will no longer serve as a source of potable water for Tijuana's residents. Given that potable water is a scarce and increasingly expensive resource in Tijuana, it would be unwise for the city to lose any of its groundwater resources.

The Alamar River is located in the northeast section of the City of Tijuana. As shown in Figure 1, the Alamar River is situated in the Tijuana River watershed with the Tijuana River downstream and the Tecate River upstream. The Alamar River discharges into the Tijuana River, flows through the city, eventually into the Tijuana River Estuary in the United States, and then into the Pacific Ocean. The Alamar riverbed is a vital recharge zone for a large aquifer that lies beneath the Alamar and Tijuana rivers. The Alamar River is not channelized and, consequently, it provides a riparian corridor linking Mesa de Otay to Tecate.





### The Problem and Approach

The City of Tijuana is facing an increasing population in need of a larger supply of potable water as well as more space for parks and open areas. With more people, more industry, and more urbanization in the region, increasing amounts of contaminants are deposited in Tijuana's urban rivers and aquifers. In the Alamar River Corridor, water pollution continues to affect groundwater quality, thus reducing supplies of potable water. In addition, the existing land use activities in the river floodplain, such as the irregular settlements and sand mining, are damaging the riparian habitat.

Riparian vegetation provides numerous benefits to Tijuana's residents. During rainfall and flood events, riparian vegetation slows and dissipates storm water flows (Dallman and Piechota 2000). This slowing of water first prevents erosion and sedimentation downstream. Second, it allows for the floodwater to percolate into the soil and eventually into the aquifer beneath the riverbed, providing an important source of potable water for urban residents (Campo EPA 1994). In addition, riparian vegetation in the Alamar River Corridor helps improve the water quality in streams, aquifers, and the coastal waters downstream (Husted 1997). The destruction of riparian vegetation results in the termination of the aforementioned benefits. Protecting and restoring the Alamar River will help address all the specific problems discussed below including water supply, water quality, biodiversity, and erosion problems.

The authors of this report advocate the use of a watershed approach for the protection and restoration of the Alamar River. The watershed approach incorporates strategies for not only the Alamar River region, but also upstream and downstream areas. By applying the watershed approach, the city's water resources requirements can be augmented by first capturing more water on site. Capturing water on site will increase groundwater recharge and, thus, enhance the city's drinking water supply (Dallman and Piechota 2000). Second, preserving and restoring wetlands and riparian habitat will reduce contaminants in the river and groundwater (Husted 1997). Third, the watershed approach, as opposed to conventional engineering methods of river concrete channelization, advocates the use of the riverbed and floodplain for green spaces and recreational areas for Tijuana's residents. Instead of channelization, restoring the Alamar River will improve property values near the river region, improve the quality of life for residents, and improve the image of the city.

## Water Resources in the Alamar River Ecosystem: Issues and Opportunities

With contributions by SDSU students Ralph Stricker, Jason Castañeda, Dillon Gibbons, and Heather Davis and by UABC students Adiel Quiñónez García, Alena Rosales Rojas, Daniel García de León Munguía, and Sonia Martínez Espinoza

## Introduction

In Baja California, the climate is arid resulting in scarce water resources for large scale economic and urban development. However, even though water resources are limited, one finds a rapidly expanding urban population and a commercial/industrial economy in Tijuana. Annually, depending on the amount of surface water captured by the Rodríguez Reservoir and available groundwater supplies, Tijuana imports up to 94 percent of its water from the Colorado River (COBRO 1997). Tijuana's growing population and economy not only place large demands on water resources, but also threaten local drinking water quality with pollutants from agricultural, urban, and industrial activities. This combination of explosive population growth, scant water resources, and increased pollutant generation will further deplete Baja California's already overburdened water resources.

Tijuana's water supply outlook is grim. By 2004, Tijuana may start rationing water for its growing population (González-Delgado 1999). One solution is to increase water imports from the Colorado River, as San Diego also is proposing. While more imported water may be inevitable, its cost in terms of capital investment and energy consumption to pump water over the mountains is enormous. This report recommends a cost-effective measure to maximize local potable water resources within Tijuana by protecting groundwater aquifers beneath the city's urban rivers. To protect the Alamar River's surface and groundwater quantity and quality, the city should first coordinate watershedbased management of the Alamar and Tecate rivers upstream and the Tijuana River downstream. Second, within the river corridor itself, a multipurpose river park plan is suggested.

## The Water Resources Management Approach: Watershed

A watershed captures precipitation from rain and snow that is formed at the mountain peaks. When sufficient precipitation falls to the earth's surface, it produces surface and groundwater flows. These flows form small streams that join together to create a main channel that discharges into a lake, lagoon, or the ocean. The catchment basin that encompasses the stream and groundwater flows is known as a watershed, or an orographic basin, because the surrounding hills form an area much like the shape of an inverted umbrella (Zúñiga 1998). In Baja California, the Colorado River Basin represents a large watershed or river basin. However, most watersheds in Baja California are small coastal watersheds that discharge into the sea. In this paper, the watershed is defined as a hydrogeographic unit that includes the precipitation catchment area, the surface water drainage network, groundwater basins, and other elements, such as vegetation, soil,

rocks, biodiversity, wetlands, farms, and cities.

A watershed-based approach in managing natural resources is characterized by the following elements:

**Geography.** Watershed-based approaches demonstrate a geographic perspective that governs and manages natural resources within the limits of the watershed rather than conventional political jurisdictions such as a city, state, or nation (Natural Resources Law Center 1996). This perspective is advantageous simply because natural resources such as water or habitats do not adhere to conventional political jurisdiction boundaries. For example, the Tijuana River Watershed transcends the municipal boundaries of Tijuana and Tecate, the international boundary between Mexico and the United States, and the boundaries of a number of sovereign Indian tribal groups in San Diego County. Since the river flows through three cities and two countries, so do pollutants, sediments, and viral/bacterial pathogens. Pollutants discharged in Tecate may very well end up in potable water supplies in Tijuana. In addition, riparian corridors and migratory bird habitats along the Tijuana River also transcend political boundaries. To solve these multijurisdictional natural resources management challenges, a watershed-based approach will encourage local government to collaborate and develop comprehensive water and land use management strategies.

Integrated Resources Management. Watershed approaches espouse a broad and interconnected view of natural resources management (Natural Resources Law Center 1996). From this perspective, water resources managers, water users, land use planners, and other stakeholders balance competing interests and determine how to satisfy human needs within the limits of available water resources. As a first step, the provision of a basic amount of clean, reliable, and cost-effective water should be guaranteed to every resident regardless of socioeconomic status. Besides household needs, cost-effective clean water is needed for a sustainable local economy. Similarly, since river ecosystems improve water storage capacity and water quality, efforts should be made to identify minimum ecological water needs to support diminishing riparian ecosystems. In essence, watershed-based approaches tend to integrate numerous resource problems including water quality, water quantity, aquatic ecosystem restoration, storm water management, soil erosion control, flood management, land use planning, and local economic development (Michel 2000). In fact, a primary goal of Mexico's Comisión Nacional del Agua (CNA, National Water Commission) watershed council program is to harmonize the use, management, and administration of all natural resources (soils, water, flora, and fauna) in a watershed (CNA 1998).

**Local Control; Grass Roots Stewardship.** In Southern California, and increasingly in Tijuana, top-down fragmented management of natural resources is being put aside in favor of local approaches that encourage community-based management of the local environment (Michel 2000). From a watershed perspective, diverse stakeholders such as land use planners, farmers, residents, water agencies, academics, environmentalists, recreational users, land developers, and local business owners work together to achieve environmental, economic, and quality of life gains in watersheds (Natural Resources Law

Center 1996; Michel 2000). The participation of a wide range of stakeholders assures broad community support and broad distribution of benefits.

The following sections discuss local water resources in the Alamar River, as well as field research conducted within the watershed perspective. In addition, a discussion of economic value of protecting local water resources is provided.

## Alamar River: An Overview

As with other rivers in Southern and Baja California, the Alamar River is a riparian corridor, consisting of a streambed and floodplain, and a variety of assorted plant life. Nowhere else in urban Tijuana is there a comparable unbroken length of riparian environment and its complement of plant and wildlife species. BorderLink researchers observed three distinct riparian segments of the Alamar River Corridor.

**Zone 1, Urbanized Section.** This section begins at the end of the channelized Tijuana River, directly south of Mesa de Otay, and extends to the bridge on Boulevard Manuel J. Clouthier (see photograph 2, page 21). In this section, the river crosses the coastal plain through a broad valley. Riparian habitat of this zone is disturbed by irregular settlements, sand mining, commercial activities, and unauthorized dumping of solid waste. The water quality in this urbanized section likely contains contaminants from urban and agricultural runoff, as well as from illegal discharges from residential, commercial, and industrial activities. The field research noted at least two active wells in the urbanized section. These wells provide water for drinking, bathing, and recreational and agricultural uses. The primary riparian vegetation species is the willow, which is known to tolerate high levels of water pollution. Other species, such as the California Sycamore are not present, possibly because they do not tolerate high levels of water pollution.

**Zone 2, Transition Section.** This section begins at Boulevard Manuel J. Clouthier and extends eastward to Boulevard Otay-Matamoros. It is an extension of the broad river valley and presents less evidence of irregular human settlements. The primary economic activities in this area are agriculture and sand mining. There is extensive illegal dumping of solid waste. Well water supports agricultural and household uses. In this section, riparian vegetation is disturbed, but not to the extent as observed in Zone 1. California Sycamores and numerous riparian bird species were observed.

**Zone 3, Rural Section.** (see photograph on front book cover.) This section begins at Boulevard Otay-Matamoros and extends to the bridge of the Tecate-Tijuana toll road. Economic activities, such as agriculture, brick making, and cattle ranching, were observed during the field study. Goats, horses, and cattle also graze in this section. Riparian habitat in this region was the least disturbed of the entire Alamar River Corridor. Golden eagles were observed by the research team in the hills adjacent to the river floodplain. In addition, farmers stated that water quality in the aquifer is excellent for all uses. This section could be a potential site for an urban agricultural reserve.

#### Water Resources in the Alamar River Watershed

According to a report for the period 1978–1991, the hydrologic parameters of the Alamar River are as follows: (1) drainage area 1,387 km<sup>2</sup>; (2) annual average volume 74.738 Mm<sup>3</sup>; (3) average annual water consumption 2.528m<sup>3</sup>/sec; (4) annual average discharge 2.528 m<sup>3</sup>; and (5) maximum discharge 383.8 m<sup>3</sup> (IMPlan 2000; Ponce 2000).

The Alamar River watershed provides approximately 50 percent of surface water flows within the Tijuana River basin. Besides surface water flows, the Alamar riverbed is a vital recharge zone for a large groundwater basin or aquifer that lies beneath the Alamar and Tijuana rivers (see Figure 2). This aquifer, known as the Tijuana River Aquifer, is geographically delimited by hill formations to the north and southwest of the Tijuana River; the mesa formations of Otay Mesa; hill formations to the east in Los Alamos; and topographical elevations like Cerro Colorado to the southeast. In the alluvial plains in the riverbeds of El Florido Creek, the Alamar River, and the Tijuana River, there is a semiconfined aquifer (Guzmán 1998: 38). The alluvial fill in the riverbeds and floodplains is composed of mostly medium-grained, fairly well sorted, and loosely packed sand. This material readily transmits water to the wells (California Department of Water Resources 1965). The groundwater flows generally westerly, and follows the configuration of the Alamar and Tijuana rivers.

According to Guzmán (1998), it is difficult to estimate the aquifer's water production potential due to numerous factors. First, since precipitation can vary dramatically in the Tijuana River watershed, recharge to the aquifer will vary. In addition, government estimates do not consider water quality issues—a key variable in determining how much water is potable. For example, it is unknown how much of Tijuana's uncontained sewage flows and urban pollutants percolate into the aquifer (Guzmán 1998). Finally, even government estimates vary. According to the Comisión Estatal de Servicios Públicos de Tijuana (CESPT) (1994), groundwater wells of the Alamar and Tijuana rivers produce approximately 370 liters per second. This was approximately 10 percent of the total local water production for the Tijuana-Rosarito region in 1994 (CESPT 1994). In 1995, a hydrological study revealed that the aquifer produced 18 millions of cubic meters (Mmc), which was approximately 15-20 percent of the region's water production (Guzmán 1998). In 1998, CNA estimated the water production at 14Mmc (Guzmán 1998). The conflicting data demonstrate the need for long-term studies of groundwater water capacity, use, and quality in the Alamar River Valley, and in the entire Alamar-Tijuana river groundwater basin (Guzmán 1998).

Table 1 delineates results of a preliminary water use survey conducted in the Alamar River Valley during the field research period. The water use categories are derived from Mexico's National Waters Law (CNA 1998), the beneficial uses adopted by the State of California (California Regional Water Quality Control Board 1994), and beneficial uses adopted by the Campo Environmental Protection Agency (Campo EPA 1994).



Figure 2: Cross Section of Ground Water Basin (State of California Water Resources Control Board, n.d.)

Water Use Observed	Water Sources
Domestic	Surface and groundwater*, <i>Pipas</i> (water trucks)
Crop irrigation	Surface and groundwater*
Livestock watering	Surface and groundwater*
Industrial activities	Unknown
Commercial activities	Unknown
Groundwater recharge	Surface and groundwater* flows (within the river valley and from upstream sources)
Riparian habitat (aquatic and terrestrial)	Surface and groundwater*
Water purification (wetlands)	Surface water*
Wildlife habitat	Surface and groundwater*
Waterfowl propagation	Surface water*
Noncontact water recreation (hiking, fishing, and bird watching)	Surface water*

## Table 1: Water Use in the Alamar River

\*Indicates source of surface and groundwater is the Alamar River

Follow-up field research is recommended on past, present, and future water uses in this riparian corridor. The research may list *potential new uses* presented by the river park alternative. As indicated in Table 1, the Alamar River's surface and groundwater resources currently support multiple uses. The proposed river park would protect and even expand these uses. A key criterion to safeguard the present and potential uses is water quality protection.

## Water Quality in the Alamar River Corridor

From the watershed perspective, water pollution originates not only from point sources or pipes (such as industrial discharges), but also from multiple, diffuse sources or nonpoint source pollution. The BorderLink research team identified three main sources of water pollution in the Alamar River Corridor: (1) uncontained wastewater discharges, (2) nonpoint source pollution, and (3) pollution from the Tecate River upstream. The following sections discuss these sources of pollution and the results of BorderLink 2000 water quality testing field research.

Tijuana's rapid urban and economic growth has led to increases in the demand for not only water, but also for wastewater services. Border cities and states have little money to spend on water and wastewater projects because the federal government provides inadequate financial resources to municipal or state water districts (Carter 1999). At present, Tijuana's wastewater collection services approximately 70 percent of Tijuana's residents (Guzmán 1998). In addition, many existing sewer lines are aging and in poor structural conditions. One result of the wastewater infrastructure deficit, along with aging sewer lines, is that raw sewage frequently flows into the city's canyons and rivers. These renegade sewage discharges degrade water quality in the city's rivers, groundwater basins, and coastal waters. During the research period (June and early July 2000), raw sewage flows were observed entering the Alamar River.

Besides raw sewage, nonpoint source pollution from agricultural and urban land uses degrades water quality in the Alamar River. Nonpoint source pollution includes human/animal waste, chemicals, oil, fertilizers, pesticides, trash, and other substances that have collected on the ground, and are washed into the river by storm water runoff (Michel 2000). In the case of the Alamar River, the most visible type of nonpoint source pollution were large piles of illegally dumped trash originating from residential, industrial, and commercial sources. Nonpoint source pollution contamination is most severe during Tijuana's wet weather season. According to Gersberg and others, (2000), storm water flows in Tijuana contain heavy metals that are considered toxic and include lead, copper, cadmium, and zinc.<sup>2</sup> In addition, storm water flows enter sewer lines resulting in line breaks and overflows (Michel 2000). Contamination from raw sewage and storm water flows poses a risk to potable water supplies in the aquifers.

The Tecate River is located in the northeast part of the state of Baja California. It flows through the City of Tecate, into the United States via Cottonwood Creek, and the surface water flows of these two water bodies eventually enter the Alamar River. The Tecate River is a tributary that feeds into the Alamar River and Tijuana River system. At present, effluent is discharged from Tecate's wastewater treatment plant and the treated water is not in compliance with Mexico's wastewater treatment standards (Rodríguez 2000). Pollutants discharged into the Tecate River eventually flow downstream to the Alamar River, the Tijuana River, and the Tijuana River Estuary. In previous years, water quality tests conducted by UABC's Chemistry Department have detected significant amounts of heavy metals and dissolved organics in the Tecate River.

During the BorderLink field research study, chemistry students from UABC Tijuana conducted preliminary water quality analysis of surface and groundwater quality in the Alamar River and upstream sites in the Tecate River. Visual observations of the surface water in the Alamar River quality revealed the following:

- Drainage areas with storm water and/or wastewater flows that are not contained or treated. These flows seem to originate from businesses and industrial plants in the Mesa de Otay industrial sector.
- Illegal dumping of trash
- Leaking septic tanks and latrines that degrade surface and groundwater quality
- Foul odors in surface water flows

 $<sup>^{2}</sup>$  In residential areas, chromium, copper, and lead pollutant levels were higher than in areas with industrial land uses. This result is surprising since the assumption has been that export manufacturing plants or *maquiladoras* are the primary source of pollutants in water bodies (Gersberg et. al. 2000).

- Presence of mosquitoes and larvae
- Murky, clouded surface water with a gray to black coloration

In Zone I, the urbanized section of the river, researchers observed large quantities of trash, including dead animals in various stages of decomposition. The trash piles probably originated from local residential dwellers, and from industrial and commercial firms. In this region, water quality was poor, with foul odors present. In certain areas (near the Terán Terán Boulevard), access to the river was quite difficult due to the dense riparian vegetation. In Zones 2 and 3, access to the river was also difficult. However, the surface water did not demonstrate foul odors, nor was there the presence of large trash piles. Cattle grazing in the area does pose a threat of bacterial and viral contamination to surface and groundwater.

BorderLink researchers conducted water quality tests onsite with portable chemistry test kits provided by the Tijuana River National Estuarine Research Reserve. Chemistry faculty from UABC acknowledge that these test kits (which are utilized for elementary and high school environmental education) are not optimal for accurate tests results. Table 2 presents preliminary results of water quality tests. The water use survey demonstrates that Alamar River surface and groundwater supplies are a viable source of water for many services, such as household supplies, agriculture, recreation, and even waterfowl habitat. However, preliminary water quality studies indicate that pollution will diminish, even eliminate local, cost-effective clean water supplies provided within the Alamar River Corridor. This lack of clean water, in turn, will reduce the services or natural capital provided by the Alamar River, a topic that is discussed in the next section.

## Clean Water as Natural Capital

A natural healthy environment provides services to the local economy, including clean air and water, fertile soil, ocean productivity (fisheries), and recreational opportunities. In addition, a healthy natural environment processes both human and industrial waste. The services provided by a healthy environment are known as natural capital (Hawken, Lovins and Lovins 1999). Natural capital includes all the familiar resources used by the city and local economy, including trees, water, fish, soil, air, and others. Conventional economic theories and city accounting systems do not place natural capital on the balance sheet (Hawken, Lovins and Lovins 1999).

Physical Properties	Characteristics and Observations
Color	The color of most water samples was
	murky, ranging from brown to gray to
	black. In certain areas (Zone 3) the water
	was clear.
Odor	The first samples in Zone 1 had a very
	strong odor. In Zones 2 and 3, foul odors
	decreased dramatically.
Temperature	Average air temperature: 25 -32 C,
	depending on the time and place sampling
	was conducted. Average water
	temperature: 28 C.
<b>I urbidity</b> quantifies the degree to which	All the samples demonstrated turbidity.
souttored by the suspended organic and	
inorganic particles. It is of concern in	
drinking water supplies because turbidity	
reduces the efficiency of disinfection by	
shielding microorganisms. It also acts as a	
vehicle for the concentration, transport, and	
release of organic and inorganic	
contaminants, bacteria, and viruses	
(CALFED Bay-Delta Program 1998).	
Dissolved Oxygen is the amount of	All water samples in the River Corridor
dissolved oxygen present at a given	represented no value.
temperature in water. Oxygen-depleting	
substances are found in waste discharges,	
agricultural discharges, urban stormwater,	
sediment, and algae (CALFED Bay-Delta	
Program 1998).	
pH	The samples demonstrated a slightly
	alkaline behavior with an average pH of
	8.2. The exception was at San José with a
	pH of approximately /./.
Nitrates	The majority of the samples demonstrated
	an average of 2, with the exception at San
	Jose, where it was zero.

## Table 2: Summary of Water Quality Testing, Alamar River



Source: Comisión Nacional del Agua (CNA 1998)

As demonstrated in Figure 3, clean water is natural capital that not only provides the economy a valuable service, but is also essential for a healthy society and economy. Clean water supports healthy ecosystems that, in turn, provide more services (such as clean air produced by trees or wastewater treatment by riparian vegetation) to the society and economy. However, if the natural environment receives too much pollution, then water quality degrades. This water quality degradation, or loss of a service, may result in a number of economic, social, and environmental consequences. Relevant to the case of the Alamar River, these impacts may possibly include the following:

**Public Health.** When pathogens or disease-causing microorganisms (bacteria, viruses, and protozoa) from urban and industrial effluent enter drinking water supplies, a variety of human health problems occur, such as typhoid, cholera, hepatitis, dysentery, gastrointestinal diseases, and other water-borne illnesses (American Oceans Campaign 1997; Husted 1997). The most obvious consequence of drinking or contact with contaminated water is a high incidence of water born illnesses and high infant mortality rates. In addition, high levels of nitrates can cause methemoglobinemia, or blue baby syndrome, which is an inability of blood cells to fix oxygen. If nitrate levels continue to accumulate, blue baby syndrome can be fatal for babies and young children (Husted 1997). Agricultural runoff contains high levels of pesticides. Once pesticides enter the water supply, an increase risk of cancer and birth defects may occur. Contamination of drinking water supply not only has severe public consequences, but economic consequences such as an increase demand for public health services, loss of work days, or low productivity by the workers (American Oceans Campaign 1997).

**Agriculture.** Agricultural production is diminished by degraded water quality. Extensive use of pesticides not only contaminate the water supplies on site and downstream, but pesticide residue may remain on plants or may be absorbed by them. People and animals could ingest pesticides on agricultural produce (Husted 1997). Contaminated irrigation water can also cause water-borne diseases to be transmitted by fresh vegetables and fruits.

**Recreational Opportunities.** Local tourist and commercial economic activities are affected by contaminated waters. For example, in Southern California, surfers and swimmers who swim in polluted coastal waters are exposed to pathogens and the risk of contracting gastroenteritis; hepatitis; ear; nose and throat infections; respiratory ailments; diarrhea; rashes; and other illnesses (American Oceans Campaign 1997). If it is known that coastal and local river waters are contaminated, people will avoid recreational activities near these contaminated water bodies. When water is polluted, local residents will travel to other cities for water-based recreational opportunities and, thus, spend their disposable income in other regions. At the same time, contaminated water limits safe recreational sites for local people who do not have the means to travel long distances to clean sites.

**Aquatic Ecosystems.** Heavy metals are concentrated and redistributed through mining and industrial processes. These metals attach themselves to eroding soil particles and enter water bodies during storm events (Husted 1997). The fatty tissue of fish, whales,

and other sea mammals and shellfish and bivalves used for human consumption absorb and accumulate copper, chromium, cadmium, nickel, lead, and iron (American Oceans Campaign 1997). When large amounts of nutrients from urban and agricultural wastewater enter rivers, a rapid increase of plant and phytoplankton growth occurs. Algal respiration and decomposition of dead algae and plankton lead to diminished levels of dissolved oxygen (DO) available for all aquatic species, including fish. If there is not enough dissolved oxygen available, fish and other aquatic species die from lack of oxygen, a condition known as hypoxia. If fish populations are dying or non-existent due to hypoxia, then fish-eating migratory waterfowl do not have a food source (American Oceans Campaign 1997). Heavy metals and pesticides found in agricultural wastewater discharged into the rivers weaken bird immune and reproductive systems.

Water Supply Costs and Infrastructure. When water quality degrades in local ground and surface water reservoirs, water agencies must either treat contaminated water or find alternative sources of water to replace the contaminated water supply. In any event, the cost of water supply increases. If the city chooses to treat the contaminated water, then the local government must pay to buy, install, operate, and maintain water treatment technology. Another option is to import water from distant sources such as the Colorado River. However, the economic burden of importing water is much greater than that of preserving local water resources. For example, in San Diego it costs \$65 to produce one acre-foot of water from local groundwater resource. Water from the Colorado River costs approximately \$550 per acre-foot, a nine-fold increase of water costs (Michel 2000). Water supply costs for Tijuana were not available, but the cost differentials are probably similar in scale. Imported water is expensive because it requires building, operating, and maintaining long distance water transport and storage facilities. Substantial energy costs incur when water is pumped over the mountain ranges that separate Tijuana and San Diego from the Colorado River. A third source of water supply, desalination, is expensive and currently not as cost-effective as the strategy of protecting and recharging local water resources (Dallman and Piechota 2000). Local surface and groundwater resources do not require the economic burden of infrastructure and energy costs associated with water imports and desalination.

Given the increased demands upon local water supplies for Tijuana's growing economy and urban population, the city cannot afford to contaminate or lose a critical economic asset—water resources supplied by local rivers. Local clean water resources provide a healthy and cost-effective service to the city and local economy. This service, or clean water, is a renewable source of natural capital. One efficient strategy to protect the city's local water resources (water supply and water quality) is through watershed management that includes restoration and protection of riparian vegetation corridors.

## **Recommendations**

A watershed approach to integrated water management offers the best long-term mechanism to conserve critical water resources for Tijuana. The first step prior to the implementation of specific actions and activities is to conduct a thorough watershedbased study of natural resources and land use in the Alamar River Valley. In terms of

## **Captions for Photographs**

Photograph 1. Channelization of the Tijuana River. Concrete channelization, urbanization, and industrialization near the river destroy riparian vegetation, thus resulting in reduction of groundwater recharge and degradation of water quality.

Photograph 2. Zone 1, riparian vegetation in Río Alamar. Note the lack of vegetation in the in the channelized section of the river.

Photograph 3. BorderLink students conducting riparian vegetation survey under the supervision of José Delgadillo.

Photograph 4. Groundwater use in the Alamar River Corridor. Farmer stated that this water is potable (Zone 2).

Photograph 5. Residents in Zone 1 must buy water from *pipas* (water trucks) because they do not have access to groundwater resources in the Alamar River Corridor. Lack of swage infrastructure poses a contamination risk to groundwater resources.

Photograph 6. Cattle grazing in Zone 3. Note soil erosion due to hoof imprint from cattle.

Photograph 7. The future of the Alamar River, concrete channelization?

Photograph 8. Alternative to concrete channelization, urban river park San Luis Obispo, California.

Photograph 9. Urban river park San Luis Obispo, California, Note walls channelize certain sections of the river, but the riverbed remains uncovered (see photograph 8).

Photograph 10. Housing and hotel development South Platte River, Denver, Colorado. Note riparian vegetation restoration near the river.

Photograph 11. Commercial development within river park, Denver, Colorado.

Photographs 12 and 13. Confluence Park, Denver Colorado. In areas prone to flooding a levy or wall may be necessary; however, the riverbed remains uncovered. Note the green areas, the recreational activities, and that the bottom of the river is uncovered.

Back photographs. BorderLink 2000 student researchers.



Photograph 1



Photograph 2



Photograph 3



Photograph 5









Photograph 9



Photograph 7



Photograph 8



Photograph 10



Photograph 13



Photograph 11



Photograph 12

water resources, supply and quality parameters must be examined not only within the Alamar River Corridor, but also upstream in the Tecate River and downstream in the Tijuana River. We also encourage the consideration of low cost and low technology research alternatives—many of which are detailed below. Concerning water resources, the watershed study should include the following topics:

**Water use survey.** The survey results should list current uses, *and potential new uses* presented by the river park alternative. The following data are needed from CESPT and CNA: (1) a map of active and inactive wells in the Alamar Valley and well production estimates; (2) the coverage and availability of piped water in the Alamar Valley region; (3) sources, uses, and actual cost of piped water. A geographical survey mapping the location and length of streams (including intermittent streams), and wetlands, is also needed. This survey is key to determining the designation of recreational activities (fishing, camping, hiking, bird watching, and so forth). Once the water quality assessment is completed (see below), a listing and map should be produced delineating to the location and size of waters not fully supporting designated uses identified in the original water use survey (Campo EPA 1994).

**Surface and groundwater assessment.** Using historical records and stream flow gauges, average, high, and low surface water flows must be determined. Data from government and academic studies should be compiled in order to estimate the mean annual natural inflow. In terms of groundwater resources, soil surveys should be conducted to precisely locate recharge areas and estimate mean annual amounts of recharge. Well log data, along with soils analyses, can be utilized to estimate the storage capacity of the aquifer within the Alamar River Corridor (California, Department of Water Resources 1965). Recharge and groundwater storage capacity estimates are needed to establish the natural capital, or economic value of locally produced water resources. Cost estimates of local groundwater production in the Tijuana River aquifer and cost estimates of imported Colorado River (the actual cost including extraction, pumping water, aqueduct maintenance, storage, transportation, and so forth) should be determined.

**Water quality.** Water quality is key to the surface and groundwater assessment. Hence, a long-term monitoring program is necessary to identify baseline conditions, and trends in degradation, to isolate sources of contamination, and to determine water quantity and quality effects of land use in the watershed. Given that watershed monitoring is costly, it is recommend that specific pollutants and pollution sources be identified, not only in the Alamar River Corridor, but also upstream in the Tecate River and any streams that feed into the Alamar River.

In July 2000, three BorderLink researchers participated in a water quality testing workshop in San Diego, California. The primary goal of this workshop was to develop a cost-effective protocol for community-based water quality testing for Chollas Creek (a creek located in the San Diego Bay watershed). The Chollas Creek water quality testing program is designed to yield consistent results using testing methodology and reporting standards developed by the U.S. Environmental Protection Agency. With little cost and training, students and community volunteers can conduct a simple, yet accurate water

quality test known as acute toxicity. Acute toxicity testing uses *Ceriodaphnia Dubia*, a small crustacean found in vernal pools and freshwater ponds throughout the world, to test if a water sample is toxic to aquatic organisms (Katznelson 1997; Riveles 1997). According to Katznelson (1997, 2):

*Ceriodaphnia* are very sensitive to pesticides, heavy metals and other toxic chemicals used by humans and discharged into surface waters. These properties make *Ceriodaphnia* a good organism for testing the toxicity of freshwater. Natural waters can become poisonous to the organisms that live in those waters when pollutants enter the water in too high concentration. Toxicity refers to the effect on aquatic organisms, rather than the concentration of pollutants.

In a typical toxicity test, *Ceriodaphnia* are placed in "test chambers" full of sample water and are periodically observed for a given length of time, for example 48 hours, and their survival (or death) rate is recorded. In addition, some *Ceriodaphnia* are placed in test chambers full of clean, healthy water to provide an experimental "control." If the organisms in the control live and organisms in the sample die, we know that they were initially healthy and something which is present in the sample, and not in the control, caused their mortality. The water sample is considered "toxic."

If water is toxic to aquatic organisms, it is likely that the same water is toxic to terrestrial organisms, including humans. Acute toxicity testing is one strategy utilized by the U.S. Environmental Protection Agency to indicate the existence of pollutants that may cause toxicity to humans and aquatic ecosystems. It is a strategy that may be implemented at a low cost to identify toxicity and hence locate sources of pollutants in Tijuana's urban rivers and groundwater basins.

Besides acute toxicity testing, the Chollas Creek program requires on-site field observations and testing. Figure 4 is a field data sheet delineating field water quality testing protocol, geographical data parameters, visual observation parameters, and chemical parameters (i.e., conductivity, nitrates, color, etc.). The chemical and visual observation parameters are designed for clear and simple data collecting. The Chollas Creek program is an example of a low-cost water quality testing program that can be used to identify sources of pollutants and even, to a limited extent, identify certain pollutants such as nitrates. If funding opportunities expand, the following water quality parameters should be sampled and mapped during dry and wet weather conditions:

- microbial organisms and pathogens
- nitrates
- heavy metals
- total organic carbons
- chlorine
- hardness
- detergents

(Campo EPA 1994; City of San Diego 1996).

- pesticides
- pH
- grease and oil
- biological oxygen demand
- phosphates
- dissolved solids

## **Figure 4: CHOLLAS CREEK SNAPSHOT DAY 2000** Information Center for the Environment (ICE), UC Davis, (530) 752 9381

## FIELD DATA SHEET and CHAIN OF CUSTODY FORM

Station ID     Collector's name and phone #     Date:     Time:	Depth (cm)
---	------------

Sample **source or type** (gutter, creek, outfall, etc.):

## **Station Name**

#### **Station Location**

Chollas Creek Watershed, Chollas Creek, san Diego City & County), Calwater hydro-unit 908.22

Add: landmarks, street address, cross street, orientation (north, southeast, etc) in relation to street junction or creek, etc.

#### Access to station

## Sampling device

if available add:

GPS Instrument ID	Latitude	Longitude	Datum	Elevation

#### Water Quality measurements and general observations

Instrument ID	Parameter	Value	Unit	Bracket	rep/dup
eyes	Weather (cloudy, clear)				
pole	Total Depth (at Station)		Cm		
VB	Flow		Gal/sec		
eyes	Sample color (yellow, green)				
nose	Sample odor (e.g., chlorine)				
EC-STB_	Conductivity		μS		
TR-STB_	H <sub>2</sub> O Temperature		°C		
PHST-STB2_	pH		pН		
eyes	Murkiness (clear, cloudy, murky)				

Diazinon sample ID

Relinquished by: \_\_\_\_\_

Received by:\_\_\_\_\_

Date & Time: \_\_\_\_\_

Date & time:\_\_\_\_\_

## The Alamar River: A River Corridor with Outstanding Natural Resources

With contributions by SDSU students Jennifer Davies and Rey Soto; ASU students Melissa Barry and Allison Yerger; and UABC student Jorge Arámburo.

## Introduction

When looking at the urbanized landscape today, it is easy to forget that at one time riparian vegetation traced the entire length of numerous rivers in the Tijuana-San Diego metropolitan region (Shapiro 1991: 20). For example, riparian habitats once flourished in the Tijuana, San Diego, and Sweetwater river valleys. Today, most riparian vegetation corridors have become concrete flood control channels. In Southern and Baja California, few isolated regions of riparian vegetation exist and most of these are disturbed.

Even though the Alamar River riparian habitat is not pristine, its long, green riparian corridor is "natural" compared to the intensely developed land that surrounds the river and the concrete channelized Tijuana River (Zona Río) downstream (see photograph 2, page 21). The Alamar River forms the most extensive riparian corridor in the Tijuana metropolitan region. It is a virtually unbroken line of riparian woodland and scrub from Mesa de Otay to Tecate. Since so few riparian wetlands exist in California or Baja California, the Alamar River's environment is vital to migratory bird species including the endangered Least Bell's vireo. The benefits of the Alamar River's riparian areas for people, plants, and animals include the provision of basic necessities such as clean water, clean air, shelter for animals from temperature extremes, and food. In addition, wetlands in riparian corridors are instrumental in flood control, groundwater recharge, and improving water quality (Shapiro 1991).

## A Biogeography of Riparian Habitat

Riparian habitats consist of riparian plant associations (vegetation) that occur adjacent to a channel of water and/or in river floodplains (Lowe 1964). Given the optimal conditions of light, water, and nutrients, riparian corridors are extremely productive in terms of plant biomass and biodiversity, or the number and variety of animal and plant species present. Supervised by José Delgadillo, Director of the Herbarium at UABC, Ensenada, the BorderLink 2000 research team conducted a riparian vegetation survey of the Alamar River Corridor (see photograph 3, page 21). A summary of the plant survey is provided in the Appendix. According to Delgadillo, the survey revealed three strata, or layers, of riparian vegetation present in the Alamar River Corridor, and aquatic and semi aquatic plants within the flow of the river. These layers are:

**Arboreal or woodland vegetation.** In Zones 1 and 2, willow woodlands are present, dominated by native willow species (*Salix gooddingii* and *Salix lasiolepis*). Upstream, in less disturbed and less polluted areas, mixed woodlands exist. These are characterized by willows, native Fremont Cottonwood (*Populus fremontii*), and some California Sycamore

(*Platanus racemosa*), and at higher elevations, Coast Live Oaks (*Quercus agrifolia*) thrive. In certain regions, the exotic Tamarisk (*Tamarix aff. aphylla*) is also present.

**Shrub vegetation and phreatophytes.** This vegetation complex coexists with young willows and is dominated by the native mule's fat (*Baccharis glutinosa*), present near the river channel and on riverbanks. Coastal sage scrub and chaparral species such as white sage, black sage, laural sumac, and California buckwheat are present in the coastal plain adjacent to the river channel.

**Herbaceous layer.** This layer represents a high level of variability with native and nonnative or exotic plant species, including the sunflower species (*Helianthus spp.*) due to the alteration of the habitat.

**Aquatic or semi-aquatic plants.** These are plants found within the river channel and areas inundated with water. The distribution of plant species varies greatly including bullrush species (*Scirpus spp.*), rushes (*Juncus spp.*) and some aquatic herbs. Many species are introduced, including giant reed (*Arundo donax*).

Due to the variety of the aforementioned plant layers or strata and its jungle-like aspect, the riparian habitat produces an abundance and diversity of bird species that is unrivaled in Southern and Baja California (Zembal 1998). In addition, riparian areas are "outstanding for breeding neotropical migrants bird species" (Shapiro 1991: 23). According to bird surveys conducted in the Santa Margarita River located approximately 60 miles (96.5 kilometers) to the north of Tijuana, 150 bird species were found in breeding densities ranging from 477 to 935 pairs per 100 acres of riparian habitat (Zembal 1998). The most common and widespread bird species in riparian habitats in the Southern California-Baja California area are the song sparrow (Melospiza melodia), common yellowthroat (Geothylpis trichas), rufous-sided towhee (Pipilo erythrophthalmus), Bewick's wren (Pheucticus melanocephalus), bushtit (Psaltriparu minimus), black headed grosbeak (Pheucticus melanocephalus), red winged black bird (Angelaius phoeniccus), the Great Blue Heron (Ardea herodias), and Snowy Egret (Egretta thula). In the United States, numerous riparian bird species are now closely monitored due to their declining numbers. Several are endangered, including the Least Bell's vireo (Vireo bellii pusillus) and willow flycatcher (Empidonax traillii extimus) (Zembal 1998).

The Alamar River Corridor is a potential site for birdwatching as a recreational and tourist activity. Birdwatching has become a major industry in North America, generating \$25 billion annually (Clines 2001). With proper vegetation protection and restoration, along with more infrastructure such as constructed trails and detention ponds, the Alamar River Corridor could be an important tourist attraction for domestic and international birdwatchers. The commercial returns of just one activity, birdwatching, is an example of the potential economical benefits the Alamar River Corridor has to offer.

Although bird surveys have not been conducted in the Alamar River Corridor, the vegetation strata present optimal habitat for most of the previously mentioned bird

species. In addition, the Alamar River's riparian habitat and adjacent chaparral habitat serve as invaluable resources for avian species such as the Golden Eagle (*Aquila chyrsaetos*), Coopers Hawk (*Accipiter cooperii*), and California Quail (*Callipepla californica*). Besides avian species, mammals, reptiles, freshwater fish, and amphibians occupy river and riparian habitat. As with bird species, numerous amphibian species such as the arroyo toad (*Bufo californicus*), western spadefoot toad (*Spea hammondii*), and Pacific tree frog (*Hyla regilla*) are either threatened or closely monitored in the United States due to declining numbers. If water quality improves, fresh water species, such as the steelhead trout, once again may thrive in the Tecate and Alamar rivers.

#### The Cost of River Channelization for the Alamar River Corridor

The BorderLink 2000 field research team observed a thriving and diverse riparian habitat corridor in the Alamar River Valley; however, the habitat has been significantly altered by human activities. Unsustainable human activities in and near riparian corridors, have three effects: (1) a decrease in the size of riparian habitat, (2) a decrease in biodiversity over time, and (3) a decrease in green areas in the city and loss of the economic and social benefits that are derived from green areas or river parks. Throughout the Alamar River Corridor, numerous unsustainable human activities that degrade the riparian habitat occur. In this report, however, focus is placed on one particular unsustainable activity: the river channelization and its impact on the Alamar River watershed ecosystem.

The purpose of channelizing a river is to increase channel capacity and flow velocity so that water moves more efficiently downstream and thereby reduces flooding. The BorderLink 2000 research team learned that Mexico's National Water Commission proposes to channelize and line with concrete the Alamar River Corridor for the very reason of quickly removing storm water to reduce flood events. However, recent studies have shown that though the frequency of flooding in the location of the channel is reduced, the severity of flooding when the river is channelized is much greater, particularly downstream (Dallman and Piechota 2000). Channelization also produces many other impacts on water resources and additional environmental problems that are detailed in the following paragraphs.

Channelization serves to remove surface and storm water flows as quickly as possible from the river basin, and to deposit storm water into the ocean. When a river is channelized, riparian vegetation is removed. Since there is no riparian vegetation to slow down surface water flows, ripple pool habitats are lost. Removal of surface and storm water flows significantly reduces the amount of water in ripple pools that recharge groundwater basins (Dallman and Piechota 2000). Concrete channel construction, along with urbanization in the river floodplain, changes the natural river hydrology. These two land use practices result in a significant increase of storm water runoff volume, velocity, and peak volumes in and around the river channels and, thus, creates the potential for erosion and downstream flooding (Dallman and Piechota 2000; San Diego Association of Governments 1997).

Is important to consider the hydrology of the region with regard to the sustainable supply of water for human use. Watersheds in Southern California-Baja California usually consist of three primary geological water-bearing formations; sandy alluviums, weathered tonalite, and fractured bedrock (Connolly 1997). These formations are important because they have the ability to hold and contain water, as is the case of the sandy alluviums. The weathered tonalite, however, is key to the hydrology of the area because, after it recharges, it releases water slowly and thus is able to feed and sustain an aquifer with enough water to survive years of drought (Connolly 1997).

An aquifer is unable to recharge without a sufficient vegetation cover on the surface that allows water enough time to percolate into the surrounding land. Tree roots also help by slowing the horizontal flow of groundwater. Both the trees and understory vegetation keep water temperature low, minimizing loss to evaporation (Connolly 1997). Some plants that grow back in restored areas in the Southern California–Baja California region are watercress, nettle, duck weed, yerba mansa, sedges, celery, rushes, and cattails (Connolly 1997). Willow and cottonwood are also favorable trees, for they assist in the growth of smaller vegetation. Trees can form a canopy, supporting the water table elevation increase and encouraging water aboveground to form ponds. Along the edge of a pond, a canopy helps reduce evaporation of surface water and help keeps temperatures cool and favorable to wildlife. The restored river invites nesting ducks, red-tailed hawks, kestrels, migratory song birds, least bells vireos, as well as deer, bobcat, coyote, and mountain lion, all of which are native wildlife species to the region. The diverse native vegetation and wildlife are important to this region for they have learned to adapt to one another and many have symbiotic relationships.

Prior to the arrival of European settlers, erosion in the Tijuana River watershed (including the Alamar River) was kept to a minimum by the Kumeyaay (a Native American tribe that inhabited western Baja and Southern California), with careful management through controlled burning of native vegetation and other techniques. On steep slopes in and near river corridors, the Kumeyaay placed small rock formations parallel to the slope in order to slow rainfall that would carry silt down hill. These also served to spread the flow of rainwater to other areas (Blackburn and Anderson 1993: 384). The slow pace of the storm water runoff also helped the ground absorb more of the moisture and the areas behind the rock alignments were often used for planting. Riparian vegetation (such as willows), of which some species are medicinal plants, were used to slow the running of storm water down slopes and through valleys. Riparian vegetation was planted along the stream sides, and if a cut would occur in the stream, willow would be planted at the cut to encourage vegetation growth and help the break to close naturally (Blackburn and Anderson 1993). Wet meadows, watery bogs, and groundwater were fed by streams controlled by boulder-brush alignments and check dams. By using these techniques, even in drought years, the Kumeyaay maintained groundwater levels close to the surface, providing water for people and wildlife (Blackburn and Anderson 1993).

However, present land use conditions, river channelization, and the destruction of riparian habitat have resulted in a decrease of groundwater levels and a significant increase in erosion in not only the Alamar River valley, but in most arroyos throughout

the City of Tijuana. Sediment flows (due to erosion upstream) in the Alamar and Tijuana rivers could result in the destruction of one of the largest coastal wetlands in Southern and Baja California that is at the mouth of the Tijuana River. Located in the United States, the Tijuana National River Estuarine Research Reserve (TRNERR) includes 2,500 acres of coastal wetlands. As with most wetlands in Southern California and Baja California, coastal estuaries are a rarity since most have been paved over by urban development or river channelization (Michel 2000). Coastal estuaries, and other wetlands in the Alamar and Tijuana rivers, are significant in terms of preserving biodiversity, since these wetlands are part of the Pacific Flyway, a network of wetlands that are a wintering habitat for a variety of waterfowl, songbirds, and other migratory species (Vincent 1999).

Storm water flows from Tijuana carry not only pollutants from the city and other upstream locations, but also large amounts of sediment. For example, during the 1994–95 winter rains, storm water flows deposited 30 centimeters of sediment in the Tijuana River estuary. The average range of sediment accumulation is between one millimeter to one centimeter per year (Southwest Wetlands Interpretive Association 1999). The increasing rate of sediment deposition is filling up the estuary habitat, resulting in its loss.

Besides pollution prevention and treatment of discharges into the river, wetlands or riparian habitats can be utilized to improve water quality in the Alamar River Corridor. What makes wetlands uniquely suitable to improving water quality? The filtration of pollutants is a natural function of wetland or riparian ecosystems. Wetlands improve local water quality by trapping sediment and removing nutrients and toxic contaminants (Husted 1997: 12). Because a riparian habitat is positioned between water and land, it serves as a buffer zone that intercepts and even breaks down pollutants found in nonpoint source pollution or polluted runoff.

Expansion of human development in river corridors has caused the destruction of riparian habitats. Unfortunately, when riparian or wetland habitats are destroyed, the quality of water inevitably deteriorates. An economic analysis conducted in California estimated that the water purification benefits provided by the wetlands are worth approximately \$6,600 per acre (Husted 1997 citing Allen et. al. 1992). To replace or destroy the natural pollution control functions of riparian habitats imposes more costs to residents that use local water resources.

To summarize, riparian habitat destruction that comes along with river channelization has led to a number of fundamental environmental problems including the following (adopted from Dallman and Piechota 2000):

- Decreased wildlife habitat and biodiversity
- Decreased groundwater infiltration
- Decreased stream base flows
- Decreased surface and groundwater storage
- Increased storm water runoff and volume
- Increased storm water peak discharge rate
- Increased channel erosion

- Increased frequency of local flooding
- Increased pollutant concentrations and quantities in storm water

## **Recommendations**

In order to sustain an adequate and sufficient abundance of diverse wildlife and vegetation in a watershed, the watershed must first be in good health and have an adequate supply of clean water. The importance of a diverse wildlife and plant population is related to the ability of a watershed to perform at an optimal level, supplying its rivers, creeks, and streams with water that can be used by all. By implementing sustainable and use practices, a watershed can supply and help sustain a human population with drinking water even in periods of severe drought. It is important that natural resources in the watershed are protected and restored if a human population wishes to use the water supplied by the watershed.

In order to facilitate a watershed-based perspective, a habitat survey should be conducted in the Alamar River Valley, with emphasis on identifying riparian and wetland habitats, groundwater recharge areas, and places in which riparian habitats can be restored at a minimum cost. In addition, amphibian and bird surveys should be conducted in the winter and spring to identify significant bird habitats for migratory birds and endangered species, such as the least bell's vireo and the arroyo toad.

There are low-cost landscape architecture techniques and river restoration alternatives that are appropriate for application in the Alamar River and would serve multiple purposes such as flood control, riparian habitat protection, recreation, retaining storm water resources on site, groundwater recharge, and water quality improvement. In addition to landscape architecture techniques, land use planning ordinances can be designed and enforced to ensure the protection of water and biodiversity resources in the Alamar River Corridor and upstream in the larger watershed. Storm Water Asset Not Liability, published by the Los Angeles and San Gabriel Rivers Watershed Council, provides an overview of landscape architecture techniques and zoning ordinances, some of which may be good models for the Alamar River. A number of examples of river parks with riparian habitat protection or river restoration projects are to be found in Southern California and include the Santa Margarita River, San Diego River (Mission Trails Park and Santee), Campo Creek, Santa Ana River, and Los Angeles River. These are relevant to the Río Alamar case due to similarities in topography, vegetation, rainfall, and encroaching human uses. It is suggested that IMPlan staff and regional stakeholders review river park plans, visit the river parks, and interview planning staff in these nearby sites.

## Land Use Problems and Opportunities

With contributions by SDSU students Wayne Gomez, Susan Tinsky, Angélica Villegas, Maggie Walker and exchange students Judith Landau (University of Paris) and Eric Miranda (SDSU/CETYS)

#### Field Research Observations of Land Use Problems in the Alamar River Corridor

In the last 10 years, economic development in Tijuana has been a leading factor in its annual rate of population growth, which is currently about 6 percent. Put in another way, each year Tijuana grows in population the size of the City of Tecate; Tijuana is doubling every 12 to 15 years. As a result, the city is struggling to develop the necessary infrastructure to accommodate for the current growth rates.

Irregular settlements reflect the need for affordable housing; public transportation; services such as electricity, running water, and sewage facilities; recreational and open spaces; and an organized system of land tenure and land use. The present style of "ad hoc" growth leads to unsuitable and incompatible land use and environmental degradation. Commercial and industrial uses are often inappropriately placed adjacent to residential areas, thereby producing negative impacts on the larger society and environment.

It is estimated that fifty thousand people reside in the Alamar River Corridor (IMPlan 2000). The Corridor's landscape in Zones 1 and 2 is characterized by illegal electrical hookups, lack of sewage facilities, unpaved roads, scarcity of potable water, and an absence of trash collection. Hence, existing settlements and their geographical proximity to the Alamar River translate into concentrated human impacts. A principal source of pollution in both the Tijuana River and the Alamar River is superficial runoff from wastewater produced by human settlements that lack sewage services. Many of these settlements have few or no infrastructure services such as potable water and electricity. In Zone 1, a primary source of water is the supply delivered by water trucks, or *pipas* (see photograph 5, page 22). The scarcity of piped water can lead to use of contaminated water, resulting in diseases that include intestinal infections and dermatosis.

The unplanned development leads to other problems. Electricity is illegally tapped and transported by wires laid on the ground. These wires pose a safety hazard to children playing near the lines and to residents in general, especially if floodwaters make contact with the electrical lines. Trash collection is often inadequate in irregular settlements due to lack of equipment and human resources in the municipal government. The trash is often placed in the floodplain, which can ultimately lead to water contamination as well as an altered flow of floodwaters. BorderLink researchers observed large mounds of trash near the riverbed in Zone 2. Large volumes of garbage are also breeding grounds for pathogens and insects and should not be located near to human habitation. The presence of unpaved roads in these settlements is likely a contributing factor to respiratory illness due to the inhalation of fine dust particles (particulate matter or PM 10). Irregular settlements within the floodplain of the Alamar River pose serious risks due to hazards caused by flood events. As recently as 1998, residents experienced flooding. Local residents informed researchers that up to five feet of water flooded their residences (interviews with local residents, June 23, 2000). The rainy season should be a concern for river dwellers as flooding can threaten lives and property. Irregular settlements within the floodplain destroy the riparian habitat, alter stream flows, and change the shape of the floodplain. This land use activity increases stream bank erosion, and increases the danger to property and lives during a flood event, particularly downstream.

Within the urban core (Zone 1), farming is predominantly for subsistence; however, farther east (Zones 2 and 3), commercial farming and ranching activities are carried out. Agricultural activities in the Alamar River Valley include crops and livestock. In terms of water quality, fertilizers and pesticides utilized in crop farming can be carried off by irrigation or storm water runoff, and pose potential contamination threats to surface and groundwater. Most of the agriculture in the Alamar River Corridor is irrigation farming with water drawn from local groundwater supplies. Interviews with local farmers reveal that groundwater quality in Zones 2 and 3 is excellent for irrigation, as well as for domestic and drinking uses (see photograph 4, page 22).

Livestock, including hogs, horses, beef cattle, milk cows, and goats were observed in Zones 1, 2, and 3. Livestock were seen grazing in the streambed and riparian areas (see photograph 6, page 22). Livestock grazing can impair wetlands in two ways: (1) cattle trample the stream banks and riparian vegetation, which results in sparser, less diverse wetland vegetation, and decreased stream bank stability, and (2) they graze on young or emergent riparian vegetation including cattails and rushes, as well as young willows, sycamores, and oak trees (Campo EPA 1994: 3–25). Overgrazing wetland vegetation in streambed and riparian areas alters the hydrology and impairs the water quality of the area. By reducing the vegetative cover of the streambed and riparian areas, livestock indirectly increases stream bank erosion (and sedimentation rates downstream), lowers the groundwater table, reduces surface water stream flows, and increases peak flood flow rates downstream (Campo EPA 1994: 3–25).

Other land uses in Zones 1 and 2 include industrial activities such as sand and gravel mining and manufacturing facilities. Commercial use, legal status aside, varies in intensity. Food stands, nurseries, and transient vendors are some of the lighter commercial uses, while more intense uses are as varied as auto shops and building material sales.

Recreational use in Zone 1 of the Alamar River Corridor is seen at the two water parks near the end of the channelization. However, it will be impossible to improve recreational conditions if refuse and trash dumps scattered throughout the urbanized section of the corridor are not removed. Zones 2 and 3 are characterized by low density legal housing, sand mining, natural habitat, and limited infrastructure including paved and gravel roads. In Zones 2 and 3, there is a rural atmosphere conducive to recreational activities such as bird watching, camping, hiking, and even equestrian pursuits.

## **Opportunities and Recommendations**

Improvement of water quality, restoration of natural habitat, and increased green areas near or around the Alamar River Corridor require changes in existing land use and human activities. From the perspective of the Tijuana River watershed, the following is an overview of particular land use activities and opportunities within the framework of the proposed multiple use Alamar River Park.

**Human Settlements.** Tijuana, like other Mexican northern border cities, has been growing at a rapid rate. Urban population growth and expansion are generated by favorable economical conditions in the border areas. The population growth has outstripped the supply of housing stock and public services. Consequently, a substantial number of immigrants resort to substandard, often self-built, housing in *colonias* that frequently lack electricity, sewerage, paved roads, and other amenities.

This report proposes that Tijuana plan an expansion of urban services and provide affordable housing in the Alamar River Corridor (see example of affordable housing photograp10, page 24). To prevent conflict with current residents in the river corridor (both legal housing and irregular settlements), a collaborative planning approach should be followed. In collaborative planning, public relations experts and planners should hold a series of meetings with residents in the Alamar River Corridor to obtain their input and support. In addition, construction and post construction housing requirements must be compatible with the protection of water quality and riparian habitat in the region. Sample construction guidelines can be found in the publication titled *Storm Water Asset Not Liability* (Dallman and Piechota 2000).

**Agriculture.** As in Southern California, agricultural land in Baja California is rapidly being converted to industrial uses or urban commercial/residential uses. This rapid conversion of agricultural land may not be desirable in the case of Tijuana. In Tijuana, local food production provides local supplies that avoid transportation costs, while preserving open space and employment. To lessen the ever-growing deficit of agricultural lands in or near Tijuana, it is proposed that Zone 3 and portions of Zone 2 of the Alamar River Valley be designated as an urban agricultural preserve. In addition, an open-air market to sell produce from the agricultural preserve, as well as local artisan-produced items could attract local residents and tourists. In the northern part of the City of San Diego, the San Pasqual Valley has been zoned and designated as an urban agricultural preserve will provide relevant information for planners of the Alamar River Valley.

An integral activity for this Alamar River Agricultural preserve could be organic farming. Organic farming reduces or eliminates the use of chemical fertilizers and pesticides—two probable contaminants of water resources in the Alamar River Valley. Although more applicable to a small producer scale, it lends itself economically to an agricultural model of the "farmer first," which empowers, learns from, and supplements local natural resources and agricultural knowledge. In the United States, sales of organic farm products have increased 20 percent annually. In 2000, sales are expected to reach

nearly, eight billion dollars. Supermarket officials in the United States state that organic produce is "one of their most profitable and fastest growing niches" (Fulmer 2000). Organic farm products are, and will continue to be, in high demand in North America and Europe. Given the proximity of the Alamar River Valley to San Diego's organic farm product consumers, it is believed that organic farming in the Alamar River could be a profitable enterprise.

The Campo Indian Reservation in the upper Tijuana River watershed has implemented cost-effective techniques that allow for livestock grazing and riparian vegetation protection. These techniques can be implemented throughout the entire Tijuana River Watershed. They have proven to be successful in improving water quality, increasing biodiversity, and increasing groundwater table elevations. One technique utilized is fencing the riparian regions to prevent cattle from grazing on and destroying riparian vegetation. Cattle can obtain water from the river through the use of tanks or other sources located outside the fenced riparian areas.

Sand Mining. Sand mining in the Alamar River Corridor is an important industry because it generates employment opportunities and is a valuable resource for construction materials. By having local sand resources, the transportation costs of shipping sand into the city are reduced, thereby cutting the costs of construction. However, removal of significant amounts of sand greatly alters the configuration of the riverbed, destroys riparian habitat, and tends to worsen flooding conditions and potential. Excavations can cause deep pits in the riverbed and can lower the streambed in some places. When there is a flood, sand mining accelerates erosion, causing damage to utility lines in the river, river road crossings, and habitats downstream (County of San Diego 1983: 14). In addition, the sand mining process results in an increase of microscopic solids or sand and rock particles entering surface and groundwater resources. In the San Diego River, for example, total dissolved solid levels in groundwater basins near sand mining sites have double or tripled, making well water in certain regions unpotable (Huntley and Serratore 1999). All sand-mining endeavors should be permitted and documented in the Alamar River region. Also, the remaining riparian habitat on or near sand mining sites should be protected. Additionally, no new sand mining permits should be issued until reclamation and restoration projects are initiated to stabilize the riverbed and stream banks. Erosion control measures should be researched and implemented.

**Parks and Recreation.** Tijuana is one of the most park-poor cities in the world, with only a small amount of park land and open space for its urban population. The river park in the Alamar River Corridor would provide much needed recreation in a natural setting. The park can include trails for biking, hiking, and equestrian uses; picnic areas; and open space for local wildlife. River park areas can dramatically increase green space for Tijuana and serve multiple uses. For example, soccer fields could provide needed recreation area for the community and serve as flood detention basins during storm events. The soccer field/detention basin could also allow for recharge of storm water into the groundwater basin.

The river park could also support an educational and research center with the participation of local universities, businesses, and elementary and secondary schools. A public visitor's center might be combined with an educational-research center to educate the public regarding the local biodiversity of the region, the indigenous culture, and the concept of an urban river park. BorderLink researchers visited such a facility in the San Diego River watershed, the Mission Trails Regional Park visitor/education center. It is an appropriate model that suggests possible activities and elements for the Alamar River. This educational center could complete a chain of three education centers to represent the diverse habitats in the Tijuana River watershed. The Tijuana River National Estuarine Research Reserve (TRNERR) represents estuarine and salt marsh ecosystems. The Alamar River Education-Research center could represent urban fresh water riparian habitat and coastal sage scrub ecosystems. The Tecate River Education Center represents montane and riparian ecosystems.

Table 4 summarizes land uses discussed and new land use suggestions. The listed land uses are intended to be complementary uses, situated along the river in accord with factors such as vulnerability to flooding, potential to draw users from different social and economic backgrounds, and potential for private and public funding. In choosing the locations and land allocations for any and all of the uses, planners should take into account the beneficial and detrimental impacts to endemic biodiversity, especially riparian habitat.

Land Use	Comments
Open space/biodiversity preserve	This land use would emphasize the
	importance of the river corridor's sensitive
	wetlands, flora, fauna, and other natural
	resources. Open space is land use that best
	protects water supply/quality in
	groundwater recharge areas and near wellheads.
Educational-research center	In cooperation with local universities,
	maquiladoras, tourism businesses, and
	local schools, this center would provide
	students with learning and field research
	experience in natural resources sciences,
	management, river restoration, and policy.
	Exemplary model: Mission Trails Regional
	Park Education Center, San Diego River.
Visitor's center (same site as Education-	Would serve to educate the public on the
research center)	importance of clean water, local river
	ecosystems, riparian habitat, local
	biodiversity, and indigenous culture.

Table 4 Alamar River Park Proposed Uses

Land Use	Comments
Recreational parks and trails	A series of trails for hiking, bird watching,
	biking, and equestrian uses. Recreational
	parks for families for picnicking, athletics
	(soccer), and playgrounds.
Open air theater/amphitheater	Would serve multiple purposes, including
	concerts, plays, operas, and festivals. Can
	also serve as a site for educational or
	business conferences/symposiums.
Agricultural reserve	Would serve to lessen the deficit of
	agricultural lands, while maximizing water
	resources protection and other space.
	Model: City of San Diego Urban
	Agricultural Preserve, San Pasqual Valley.
Farmer's outdoor market (open air market)	Provide a central area for farmers to sell
	organic produce, and for area craftsmen to
	sell wares.
Affordable housing	Housing for inhabitants at irregular
	settlements or people displaced by
	development in the area.
Aquatics center	The existing swimming pools seem to have
	a popular use. The center could be
	expanded to include other uses, and water
	reclaimed for urban irrigation.
Water reclamation site, park facility, and	Using gravity fed ponds, wastewater from
campgrounds	maquiladoras or residential areas in Mesa
	de Otay would flow through a series of
	lakes. In the lower lakes, fishing, boating,
	picnicking, and camping are possible.
	Model: Santee Lakes, Padre Dam
	Municipal Water District, Santee,
	California.
Golf course/resort/conference facility	Facility for tourists and local residents for a
	weekend retreat. Could sponsor local
	conferences, especially for maquiladoras.
	Model: Carlton Oaks Golf Course, San
	Diego River, Santee, California. Golf
	courses benefit from flooding events and
	prevent erosion downstream.

# Table 4 (continued)Alamar River Park Proposed Uses

## **Conclusion: Why Plan Now?**

The Alamar River is the only major free flowing and unchannelized river in the Tijuana metropolitan region. With restoration, this river has the potential to become a source of economic revitalization, a cost-effective reservoir of potable groundwater, and a key wetlands region in a large and diverse functioning ecological unit—the Tijuana River watershed. Those concerned with the future of the Alamar River should consider shifting natural resources management and economic issues. Why not select elements from sustainable natural resources practices devised by the region's Native American populations? Why not create a watershed-based management strategy emulating the river's ecosystem that, in turn, would protect and restore the free services (i.e., clean water) or natural capital provided by the Alamar River's wetlands ecosystem? In a metropolitan region desperately in need of parks and green spaces, the Alamar River is a transcendent source of value due to ecological, water resources, and economic benefits.

The concept of an urban river park, linked with trails, exhibits, and other interpretive materials telling the story of the city's natural and cultural history, will give Tijuana a unique, major regional park to stimulate public imagination and private enterprise. The park will protect water resources and provide facilities for recreational and commercial activities. In the heart of an urban area, people will be able to go fishing or hiking in a peaceful, natural setting with views of surrounding mountains, woodlands, and wildlife. Cyclists and equestrian riders will enjoy a scenic, uninterrupted ride for at least 10 kilometers, with many of picnic sites, rest areas, and opportunities to visit historic sites, natural history exhibits, and a farmer's market. The Alamar River region will provide locally grown organic foods that will provide not only local food supplies, but also income and jobs in the region. In addition, the park could serve as a cultural center with plays and concerts in the open-air theaters, or art exhibits in the region's interpretive center.

The parks and recreation facilities in the Alamar River Corridor should prove to be a marketable amenity for developers of homes and commercial enterprises within or near the urban river park. With flood protection and water quality assured, new lands can be developed to standards that make them assets to the surrounding land uses and complement the river park project concept. Attractive commercial and office parks, shops, and homes along the river are important to the Alamar River project. The private development linked to the urban agricultural preserve and a proposed series of parks and recreational areas will give residents and other property owners a stake in assuring and maintaining a high standard of landscape design along the river.

This report is a beginning, a concept, and a call for creative and innovative thinking. Now is the time to start. Flood hazard, loss of local water supplies, loss of natural and rural areas through urbanization, and a growing population with growing recreation needs—all these and other factors underscore the need for immediate action. An urban river park in the Alamar River Corridor can assure a legacy of natural beauty, parks, recreation, water resources protection and economic vitality for future generations.

## Appendix

## Vegetation Survey of the Alamar Creek José Delgadillo

The flora of the Alamar Creek presents a low diversity of native plants, and a great amount of introduced plants, which is a characteristic of highly altered sites. According to Mexico's environmental law (*Norma* (environmental regulation) NOM-059-1994) there are no endemic, rare and/or endangered plants found in the region. Table 1 delineates the preliminary results of the BorderLink 2000 vegetation survey. The first column in Table 1 lists the plant species observed, whereas the second column lists biological forms (trees, shrubs, and herbs).

Alamar Creek's vegetation can be classified for the most part as riparian. Riparian vegetation usually grows along the banks of rivers, creeks, and gullies forming a narrow "corridor," and is dominated by species of deciduous (leaf-shedding) trees. For many years, ecologists have referred to the wide-leaf deciduous riparian species as *Populus, Salix, Fraxinus, Platanus,* and others, as *obligated* riparian. This term and others, including *facultative riparian* and *pseudoriparian*, have been applied to various "riparian" species. The United States Fish and Wildlife Service adopted the nomenclature *obligated riparian* for "real riparian," and *facultative riparian* for "pseudoriparian" (Reichenbacher, 1984). Some riparian plants are highly dependent on surface water flows, and others on groundwater. From an evolutionary perspective, these communities represent mesophilic ancestral forests that need humidity, and flourished in Baja California millions of years ago. Robichaux (1977) states that the history of the riparian communities in California during the last 20 million years is found in some flora fossils in the state and neighboring regions.

The native vegetation of the Alamar Creek consists of tree species of "willows" (*Salix* spp.), "cottonwoods" (*Populus fremontii*), and "sycamores" (*Platanus racemosa*). Almost all of these species have been extripated, except for the various species of "willows." There still remain a few samples of "cottonwoods" and "sycamores" which are restricted to the margins and banks of the riverbed. The *potential vegetation* for a restored creek would be an association of "willow-cottonwood." Creek vegetation restoration will only occur if the original natural conditions are reestablished and that these communities begin their regeneration process until reaching their equilibrium (climax).<sup>1</sup> In addition, to the willow-cottonwood-willow" (*Populus-Salix*) association. This association is known as an aggressive colonizer of altered sites found in a wide variety of ecological conditions (Reichenbacher, 1984). The cottonwood-willow association coincides with the high degree of colonization that the "willow" (*Salix gooddingii*) presents throughout Zone I, where trees can have up to 100% coverage. The presence of the "willow" is due perhaps to the high degree of alteration of the environment and to large deposits of

<sup>&</sup>lt;sup>1</sup> Natural conditions required by healthy riparian vegetation are stable segments of the substrate and humidity gradient of the soil.

organic matter and nitrates. In contrast, zones with little alteration do not present large populations of the willow species.

In general, the riparian zones of Baja California are characterized by having deciduous trees in the winter season. At times they reach a height of 15 meters, (*Platanus, Salix,* and *Populus*) and are the only ones are in the arboreal stratum. However, at times the "oak" (*Quercus agrifolia*) presents itself with phreatophyte behavior (Delgadillo, 1998). Currently, the vegetation of the Alamar Creek is constituted by three strata: arboreal, shrubby, and herbaceous in areas where there is plenty of vegetation coverage, and also by some aquatic and semi-aquatic plants.

**Arboreal.** Dominated by the "willow" (*Salix gooddingii*), and subordinately by *Salix lasiolepis*. These species are indigenous, with heights that vary from 4 to 15 meters and are in contact with it the river surface water.

**Shrub.** Dominated by one native shrub, "mule fat"(*Baccharis gluitinosa*). It is mainly observed outside of the river channel in sandy soil.

**Herbaceous.** This stratum is very diverse with native and introduced plants; the latter benefit from the altered environment.

Aquatic and semi-aquatic. Plants that are found in surface water or on sites where small lagoons have formed.

## Aquatic vegetation

In general, the regional floral studies of Mexico lack detailed representation of taxa from the aquatic habitat. Except for the species described generally by Wiggins (1980), floral studies of the aquatic vegetation of Baja California are not available. Aquatic communities appear near the creek banks, or in stable bodies of water. At these sites the water current is minimal, providing for an optimum condition for the development of rooted, floating, and submerged plants. The distribution of this type of vegetation is very diverse, although the majority is found in the Juárez and San Pedro Mártir mountain ranges, and in creeks on the Pacific slope, as a community of riparian habitats. The most frequent species in these aquatic ecosystems are:

Azzola filiculoides, Anemopsis californica, Callitriche orcutti, Cyperus laevigatus, Cyperus lanceolatus, Eleocharis acicularis, Eleocharis geniculata, Eleocharis palustris, Eleocharis parishii, Epilobium adenocaulis var. parishii, Juncus acutus, Juncus bufonius, Juncus sphaerocarpus, Juncus rugulosus, Juncus xiphioides, Lemna trisulca, Lemna valdiviana, Lemna gibba, Lilae subulata, Marsilia fournieri, Mimulus gutatus, Nasturtium officinale, Ophioglossum californicum, American Pilularia, Ranunuculus cymbaralia, Sagittaria cuneata, Sagittaria greggi,

*Scirpus acutus, Typha dominguensis, Typha latifolia* (tule) and *Zannichella palustris*; and also the "introduced reeds" *Arundo donax* and *Phragmites australis*.

Concerning the presence of other species of plants with a harvesting or ruderal behavior, "tree tobacco" (*Nicotiana glauca*) and "tumbleweed" (*Salsola kali* var. *tenuifolia*), are distinguished by establishing themselves and growing rapidly, as in other parts of the world, in agricultural and urban zones. The species initiate, in some cases, a succession dynamics in the presence of disturbances, for example fire. The most significant species that act in these conditions are *Baccharis sarathroides, Baccharis salicifolia, Erodium cicutarium, Brassica rapa, Haplopappus venetus, Taraxacum officinale, Xanthium strumarium, Ambrosia chenopodifolia, Ambrosia psilostachya, Cirsium vulgare, Sonchus oleraceus and Datura discolor, to mention only a few.* 

SPECIES	COMMON NAME	BIOLOGICAL FORM	ORIGIN
Ambrosia confertiflora	Ragweed	Herb	Native
Anemopsis californica	Yerba mansa	Semi aquatic herb	Native
Apium graveolens	Wild celery	Aquatic herb	Introduced from Eurasia
Arundo donax	Giant reed	Long stem herb	Introduced from Europe
Baccharis salicifolia	Mule fat	Shrub	Native
Brassica rapa	Wild turnip	Herb	Introduced from Europe
Chenopodium murale	Nettleleaf goosefoot	Herb	Introduced from Europe
Chrysanthemum coronarium	Crown Daisy	Herb	Introduced from Southern Europe
Cotula coronopifolia	Brass buttons	Semi-aquatic herb	Introduced from Africa
Cynodon dactylon	Bermuda grass	Herb/grass	Introduced from Africa
Foeniculum vulgare	Fennel	Herb	Introduced from Europe
Elianthemum annum	Sunflower	Herb	Introduced from Europe

## Table 1. PRELIMINARY VEGETATION SURVEY OF THE ALAMAR CREEK

Table 1. Continued				
Heliotropium curassavicum	Heliope	Herb	Introduced from American tropic	
Juncus acutus	Rush	Herb	Native	
Marrubium vugare	White horehound	Herb	Introduced from Europe	
Nicotiana glauca	Tree tobacco	Shrub	Introduced from South America	
Platanus racemosa	California Sycamore	Tree	Native	
Populus fremontii	Western Cottonwood	Tree	Native	
Ricinis communis	Castor bean	Scrub	Introduced from Europe	
Rorrippa nasturtium-aquaticum	Watercress	Aquatic herb	Native	
Rumex crispus	Dock	Herb	Introduced from Eurasia	
Rumex salicifolius.	Willow dock	Herb	Native	
Salix lasiolepis	Pacific Willow	Tree	Native	
Salix gooddingii	Goodding's Willow	Tree	Native	
Scirpus spp.	Bullrush species	Herb	Native	
Solanum spp.	Night shade	Herb		
Tamarix aff. Aphylla	Tamarisk	Tree	Introduced from Eurasia	
Urtica holosericea	Hoary nettle	Herb	Native	
Xanthium strumarium	Cocklebur	Herb	Native	

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