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The State of the Arizona-Sonora Border Region: Shared Pollution, Shared Solutions

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"There is a projection that the entire border community from the Gulf of Mexico to the Pacific Ocean will double in size by the year 2020. A major concern for us on the environmental side is that we have already seen the impacts of that rapid growth and we know we will only get further and further behind unless we do something today." (Placido dos Santos 2002)

ABSTRACT

The Arizona-Sonora border region is commonly identified as the four counties in Arizona and 11 *municipios* in Sonora adjacent to the international boundary. In Arizona they include Yuma, Pima, Santa Cruz, and Cochise County. In Sonora, the 11 border *municipios* are San Luis Río Colorado, Puerto Peñasco, General E. Calles, Caborca, Altar, Saric, Nogales, Santa Cruz, Cananea, Naco, and Agua Prieta. The region's population growth, expected to exceed 2.1 million by 2010, has placed tremendous pressure on available resources and infrastructure. Local and regional governments on both sides of the border struggle to meet growing demands for water, sewage, health care, roads, housing, and other services. Like elsewhere in the U.S.-Mexican border, Sonora's border cities are several times larger in population than their counterparts on the Arizona side. Largely attributable to migration from the interior of Mexico in search of jobs, this disparity creates severe implications for Arizona border cities, which struggle to absorb the impacts of increasing trade, traffic, and migration without adequate financial resources.

Hot and dry climate, scarce water resources and varied desert topography characterize the Arizona-Sonora border region. The combination of topography, surface water, and climate result in two distinctive ecological regions: the Apache Highlands in the east and the Sonoran Desert in the west. The Apache Highlands Ecoregion encompasses higher elevations and the watersheds of the San Pedro and Santa Cruz rivers. Both rivers cross the U.S.-Mexican border to drain north into the Gila River and include some of the most valued and important ecosystems in Southern Arizona. Distinguished by the number of species, endemism, and evolutionary processes, the Sonoran Desert Ecoregion, located in the western part of the Arizona-Sonora border, is a fragile and stunning landscape, the most tropical of the three deserts found in North America and recognized worldwide for its ecological importance.

Habitat fragmentation, endangered plant and animal species, air quality, hazardous waste, and water and soil contamination are issues for many communities. The border region is unique because the solutions and strategies

to address these issues often requires binational collaboration. Institutional barriers—such as incompatible data systems and regulatory requirements, lack of enforcement and the inability to sustain expert links between agency personnel—hinder cross-border partnerships. In the Arizona-Sonora border region communities, state and federal agencies and non-governmental organizations (NGOs) are engaged in an extensive body of work. A promising development even in light of constant struggles for sustained resources and bad economic conditions, environmental NGOs already strong on the U.S. side for the past decade are emerging in Mexico. The Annual Meeting on the Border Environment organized by the University of Arizona Latin American Area Center, drew more than 100 Mexican NGOs working to protect the environment and public health. NGOs today, unlike in the past, consist of a broad base of stakeholders and are effective in raising awareness of key issues.

Water is arguably the most debated and coveted resource in the arid desert region of Arizona and Sonora. Population growth and climatic changes are largely influencing competition among users for this increasingly fixed supply. In the Upper San Pedro River Basin, the major threat is groundwater withdrawals to meet population growth and economic development demands. Communities like Ambos Nogales, heavily dependent upon the Santa Cruz Basin aquifer for its fresh water needs, exemplify the interdependency of water resources. A study in 2001 detected the presence of PCE in wells on both sides of the border that exceeded state-level standards. The ability to meet future needs and sustain a treasured riparian area in the northern portion of the Santa Cruz on the U.S. side of the border is contingent upon management activities in Nogales, Sonora. The Colorado River infuses the Upper Sea of Cortez and Delta region with its only freshwater inflows. Due to diminishing fresh water flows, Mexico's lower Colorado Delta region is impacted by increased salinity levels, high nutrient concentrations from agricultural drainage,, and heavy metal contamination. In the long term, the lack of water could affect endemic species as well as commercially valuable varieties like shrimp.

Hazardous waste is by definition a threat to human health and eco-resources. Appropriate management (transportation, tracking, and disposal/storage) of hazardous waste is compromised by the maze of conflicting jurisdictional requirements and incompatible tracking systems in place at the border. The lack of trained personnel prevents the detection of improperly labeled shipments. Arizona's Department of Environmental Quality, in partnership with federal agencies on both sides of the border, is conducting training to encourage compliance. A binational pollution prevention initiative, the Arizona-Mexico International Green Organization (AMIGO), facilitates information exchange on waste management and annually awards companies for environmental stewardship. In 2002, two maquiladoras in Nogales, Sonora, were recognized for diverting 15 tons of plastics from municipal landfills and initiating a community reforestation effort in a local *colonia*. The four major industrial twin cites along the Arizona-Sonora border have adopted emergency response and contingency

plans. These plans are a critical mechanism for addressing the potential threat of an accident, as seen in Naco in 2002 when a burning landfill not only shut the port for two days, but required an emergency federal response.

Unpaved roads, idling trucks, brick kilns, mining, exposed agricultural lands, landfills, and residential activities such as heating homes and cooking food all impact air quality. Binational monitoring projects in Ambos Nogales and the Douglas-Agua Prieta areas are yielding critical data on pollution sources and supporting feasible remediation efforts. Research findings over the past nine years indicate that nearly 80% to 85% of the emission pollution in Arizona border communities can be attributed to sources in Sonora. Human health threats from particulate matter exposure include increased risk of respiratory illness, asthma, and premature deaths. A major source of particulate emissions is unpaved roads—nearly 80% of the roads in Nogales and Agua Prieta, Sonora, are unpaved. An analysis conducted by ADEQ to determine the paving projects that would yield the greatest reductions in pollution was successfully used to receive Border Environment Cooperation Commission (BECC) certification and North American Development Bank (NADBank) funding for a project in Agua Prieta.

Human activity, most notably in the past century, has dramatically altered the landscape of the Arizona-Sonora border, affecting both the quality and quantity of its ecological resources. Agriculture, mining, and increasing international trade shape the use of the land in ways that impact vegetative communities, soil structure, and faunal and habitat ranges. Large-scale water diversion projects reduced energy costs and enabled irrigated agriculture but also decreased fresh water inflows to areas such as the Lower Colorado River basin and delta, which fragmented plant and animal habitats. Increased cattle density—two- to five-times the recommended stocking rate in Sonora—and the introduction of exotic forage to improve grazing productivity on both sides of the border have influenced the character of vast amounts of the region's landscape. A consequence of advanced transportation and communication infrastructure, ex-urbanization, or subdivision housing developments on retired farms and ranches not only reduces the amount of open space but threatens the scenic, historic, and biological value of the areas.

One of the most pressing issues for the Arizona-Sonora border is the impact of illegal human and vehicular traffic through unique and environmentally sensitive areas. Many of these locations now bear the scars of wildcat trails, abandoned refuse and trampled vegetation. Resource managers describe the traffic as "being overrun." A report prepared for the U.S. House of Representatives Appropriation Committee indicates that some areas are no longer considered safe for use by federal employees and visitors. Last year smugglers killed a park ranger in Organ Pipe Cactus National Monument. Federal border security operations to curb illegal flows in California and Texas over time have diverted the traffic to more isolated and remote areas along Arizona's border with Mexico. Resource management officials are working with Border Patrol to design

strategies that curb proscribed traffic without fragmenting wildlife corridors and habitat. Extensive study is still required to establish a causal relationship, but increased traffic and vegetative destruction is assumed to be impacting Sonoran Pronghorn, now estimated to be less than 20 in number, and the lesser long nosed bat.

Much of Arizona's border region consists of public lands, including more than 8.3 million acres of protected parks, monuments, and wilderness areas. Agreements formalized the U.S. Department of Interior's National Park Service and Mexico's Secretariat of Environment and Natural Resources' National Commission for Protected Natural Areas establish an important and valuable framework for monitoring activities, information exchange, training, and cooperation on unique sister park subjects. A holistic approach to eco-resource management and the development of compatible data is imperative to rehabilitate and preserve the rich diversity of biological features that exist along the U.S.-Mexican border. The lack of available data is a major challenge in assessing environmental issues. In many cases the data is not available or not practically assessable, or dispersed throughout the Internet on a variety of websites.

The challenge of transboundary environmental management of shared resources (air, water, waste, and ecosystems) is vividly demonstrated along the U.S.-Mexican Border Region. Described as one of the most environmentally stressed areas in the world, the border region is impacted by population growth, economic integration, and climatic conditions. Policy decisions in the federal centers of the United States and Mexico and the natural migration of resources (air, water, and species) continue to shape and influence the region's fragile and unique environment (Liverman et al. 1999).

With thousands of people and vehicles crossing the border daily to work, shop, attend school, and visit family, Arizona's border communities are integrally joined with their sister cities in Sonora. The air they breathe, the water they use, and the waste they generate are shared. A dynamic cross-border economy based on manufacturing and winter produce impact the quality and quantity of the region's environmental resource base.

The following sections provide an introduction to the demographic, economic, and geographic characteristics of the Arizona-Sonora Border Region and the various environmental issues that influence its biologic, historic, and aesthetic value. Although an exhaustive review was not possible, a wide variety of articles, reports, and web-based materials were consulted. Interviews were conducted with a recognized network of key regional experts and organizations to solicit information on the opportunities and challenges confronting this part of the U.S.-Mexican border.

Demographic, Economic, and Geographic Characteristics

The Arizona-Sonora Border Region is commonly identified in terms of four counties in Arizona and 11 *municipios* in Sonora that are adjacent to the international boundary. In Arizona these are, from west to east: Yuma, Pima, Santa Cruz, and Cochise County. In Sonora, the 11 border municipios are, from west to east: San Luis Río Colorado, Puerto Peñasco, General E. Calles, Caborca, Altar, Saric, Nogales, Santa Cruz, Cananea, Naco, and Agua Prieta.

Table 1 shows the distribution and population growth in the border counties and municipios during the period 1940-2000. About one-fifth of each state's population is located along the border. The combined population in the Arizona-Sonora Border Region was close to 1.7 million in 2000. The Sonoran border population has been increasing faster that the state's average and faster than Arizona's border population; between 1990 and 2000 the population in the Sonoran border municipios increased by 33.4% compared to Sonora's average (21.6%) and the average increase in Arizona border counties (27.8%). By the end of the next decade, Arizona's border population will exceed 1.4 million. In conjunction with continuing high growth rates south of the border, the combined population in the Arizona-Sonora Border Region is expected to exceed 2.1 million by 2010 (Peach 2003).

One of the unique qualities of the Arizona-Sonora Border Region is the lack of a large border metropolitan city. Instead, there are six pairs of twin communities, from west to east: San Luis-San Luis Río Colorado, Lukeville-Sonoita, Sasabe-Sasabe, Nogales-Nogales (Ambos Nogales), Naco-Naco, and Douglas-Agua Prieta. Tucson, Pima County's seat and the state's second largest city (486,699 in 2000), is located about 75 miles north of the border. Tucson's economy depends heavily on links with Mexico and its various organizations and the private sector plays an important role in border issues. However, unlike San Diego, California, or El Paso, Texas, Tucson does not deal with the same kinds of border-related issues. The second largest city in the border zone is Yuma, Arizona (population 75,000 in 2000), located 20 miles north of San Luis-San Luis Río Colorado.

Like elsewhere in the U.S.-Mexican border, Sonora's border cities are several times larger then their counterparts on the Arizona side (Table 2). The largest is Nogales with a population of 159,000 (official data for 2000), closely followed by San Luis Río Colorado with a population of 145,000. The actual size of the population in Sonora's border communities is likely much higher than the official figures due to a significant number of temporary residents seeking to cross the border into the United States.

The two sides of the border also differ in terms of population growth rates. On the Arizona side, with the exception of San Luis and Yuma, growth is mostly outside city limits, in suburbs and several smaller communities. This has severe implications for Arizona border cities. Struggling to absorb the impacts of

increasing trade, traffic, and migration, these communities lack adequate revenue streams to address the growing demands for services and infrastructure.

During the last decade the fastest growing cities along Sonora's border were Agua Prieta (58.3%) and Nogales (48.5%). The rapid population growth in Sonoran border cities has been largely a consequence of migration from the interior of Mexico in search of maquiladoras jobs and opportunities for employment across the border in the United States.

Economic Characteristics

With the exception of a few growth centers, such as Tucson and Sierra Vista, the Arizona border counties are less economically diverse than the state. Services, government, and trade sectors dominate the economies of Arizona's border counties. The services sector provides between 30.2% of all jobs in Yuma County and 38.9% in Pima County. At the community level, the government sector dominates in Douglas (37.8%) and Yuma (34.8%), while the trade sector is more important in Nogales (30.9%) and San Luis (21.9%).

Pima County's economy benefited—with several thousand new engineering jobs—from the restructuring of the defense industry. The Fort Huachuca military base is a major employer and economic force for Sierra Vista, a rapidly growing city in Cochise County. Regional economic development efforts have focused on supporting six industry clusters: aerospace, bioindustry, environmental Technologies, information technology (teleservices), optics, and plastics (composite materials).

The majority of manufacturing jobs are concentrated in Tucson and Pima County. By the mere size of its economy within the border region, Tucson has attracted a larger number of new jobs and several companies with maquiladoras in Sonora. Nogales, and to a smaller extent Douglas and San Luis/Yuma, have benefited from the development of maquiladoras in Sonora by primarily providing warehousing and distribution services. Nogales is a major gateway for Mexican fresh produce from Sinaloa and Sonora, however the seasonal nature of the fresh produce industry results in high unemployment rates (above 25%) during the summer months. Yuma County is also affected by the seasonality of its agricultural sector, which is the source of employment for approximately 9% of employed people. Countywide unemployment in the Yuma area rises to more than 30%, with consistently higher unemployment rates in San Luis, exceeding 70% between May and October (Arizona Department of Economic Security, Annual Reports).

Arizona's border communities are heavily dependent on cross-border shopping by Mexican residents. Since the 1982 peso devaluation, efforts to diversify their economic structure and reduce their dependence on retail trade remain high on local agendas.

Significantly lower than the state ($20,275 in 2000), average per capita income in Arizona's border cities illustrates the economic hardship experienced by these communities. Among the worst is San Luis ($5,377 per capita). Nogales and Douglas have averages barely over $10,000 ($10,178 and $10,232 respectively). The City of Yuma ($16,730 per capita), still considerably below the state average, is better off than the rest of the communities in its county.

The 1999 poverty levels for all four-border counties exceeded Arizona's average of 13.9%. Santa Cruz County, where every fourth person was living in poverty, stands out relative to the other counties. With the exception of the City of Yuma (14.7% versus 19.2%), border cities surpass the poverty levels in the counties. In Nogales, San Luis, and Douglas, more than a third of the population lived in poverty (33.9%, 35.8%, and 36.6%, respectively).

High poverty levels correlate with high unemployment rates and low educational attainment. County-level unemployment rates varied from 5.3% in Pima to 12.1% in Yuma (in 2000), whereas at the city-level ranges went from 9.1% in the City of Yuma to 27.3% in San Luis. San Luis has the lowest percentage of the population with a high school diploma (34.9% in 2000), compared to the county (65.8%) and the state (81%). Only Pima County (83.4%) exceeded the state average.

The maquiladora industry has served as the backbone of the industrialization of Sonora's border cities. At its peak in 2000, Nogales had 90 maquiladora plants with more than 39,000 workers, followed by San Luis Río Colorado (39 plants, 11,500 employees) and Agua Prieta (34 plants, 7,500 employees). By 2002, Nogales lost more than 9,000 jobs and another 8,000 jobs vanished in San Luis Río Colorado and Agua Prieta.

Although no hard data exists to document the most recent changes, the outlined trends suggest increasing stress on the economies and infrastructure of border cities. Newspapers have reported the increased congestion in the Sonoran border cities as a result of both, growing numbers of potential migrants, and U.S. Border Control and security operations.

Geographic Characteristics

Hot and dry climate, scarce water resources, and varied desert topography characterize the Arizona-Sonora Border Region. Vegetation in the most eastern part near Agua Prieta and Janos is dominated by desert scrub and natural pastureland, however moving westward toward Naco and Nogales evergreen oak and cedar forests become prominent features in the landscape mix. The western portion of the Arizona-Sonora Border Region is distinguished by extremes. It is possible to encounter lush green spots in the midst of the most inhospitable desert salt flats. Several of these areas along the Arizona-Sonora border are recognized as critical ecological connections between a chain of

diminishing habitats and flyways, riparian corridors for resident and migratory species.

The combination of topography, surface water and climate result in two distinctive ecological regions: Apache Highlands in the east and the Sonoran Desert in the west. The Apache Highlands Ecoregion encompasses higher elevations and watersheds of the San Pedro and Santa Cruz rivers. Both rivers cross the U.S.-Mexican border and drain north into the Gila River. In Sonora, there are two additional river basins, Sonora and Yaqui, which drain into the Gulf of California.

The San Pedro and Santa Cruz rivers are intermittent with a number of perennial reaches along their riverbeds and tributaries. The surface water depends on precipitation, melting snow in the nearby mountain ranges and base flow from groundwater. Climatically, this is a semi-arid region, with average annual precipitation ranging from 290 millimeters (mm) in the river valleys to more than 700mm in the mountainous areas. Stream flows are highest during the summer monsoon season between the months of July and September. The lowest flows are during the late autumn and late spring.

Both river basins include some of the most valued and important ecosystems in Southern Arizona. In 1986, the San Pedro Riparian National Conservation Area was established to protect and enhance the area, which supports the second highest known number of mammal species in the world and more than 300 bird species (SALSA 1998). The Arizona side of the Santa Cruz basin is managed within the Active Management Area (AMA). Future water use in Nogales, Arizona is heavily dependent on water management in Sonora, especially groundwater pumping, quality management, and effluent. Increased pumping on the Sonoran side of the Santa Cruz valley could make regions downstream in Arizona more vulnerable to drought, degrade riparian areas, and limit their future development (Liverman, Meredith, and Holdswarth 1997).

As of 1990 an estimated 54% of the water in the San Pedro River Basin was used for agriculture (irrigation and stock ponds). Mining and other industrial activities accounted for approximately 30% and private domestic and municipal water systems used 16% (Liverman, Meredith, and Holdswarth 1997). In the Santa Cruz basin on the Arizona side, about one-third is used by agriculture, 18% by municipalities, 4% by industry and most of the reminder is lost due to evapotransportation. On the Mexican side 54.6% was used by the City of Nogales with the remaining 45.4% divided between agriculture (44.6%) and livestock (0.8%) operations. By 1996 rapid population growth combined with outdated infrastructure created a deficit in public demand of almost 30% in Nogales, Sonora (Liverman, Meredith, and Holdswarth 1997).

Well-known for the number of species, endemism, and evolutionary processes, the Sonoran Desert located in the central and western portions of the Arizona-

Sonora border is part of a fragile and stunning ecoregion. The most tropical of the three deserts found in North America, the Sonoran Desert is recognized as a natural treasure. The boundaries of the Sonoran Desert Ecoregion extend far beyond the Sonoran Desert, encompassing nearly 55 million acres (40.4% in Arizona, 39.8% in Sonora and the remaining 19.8% divided between California and Baja California). The region is differentiated by arid climate and annual precipitation of about 100mm. In Sonora, El Pinacate represents the largest extent of volcanic area, while El Gran Desierto de Altar contains the most extensive system of dunes. The waters of the region are drained either in the Colorado River or directly into the Gulf of California.

The ecoregion is home to indigenous communities of Seri Indians, Tohono O'Odham, and Cucupá. In Sonora, the major portion of land, including *ejidos*, is in private ownership. Much of Arizona's border region consists of public lands, more than 8.3 million acres of protected parks, monuments, and wilderness areas. Table 3 lists the unique and environmentally sensitive areas along Arizona's border with Sonora.

Agreements between the U.S. Department of Interiors' National Park Service and Mexico's Secretariat of Environment and Natural Resources' (SEMARNAT) National Commission for Protected Natural Areas establish a valuable framework for monitoring activities, ecosystem restoration, information exchange, data collection, training, and cooperation on unique sister park subjects. Dating back to 1988, Arizona parks have established several work plans with parks in Mexico, including:

- Saguaro National Park's (Arizona) and both Parque Nacional San Pedro Mártir and Parque Constitución de 1857 (Baja California)
- Organ Pipe Cactus National Monument (Arizona) and El Pinacate y Gran Desierto (Sonora)
- Coronado National Memorial (Arizona) and Parque Nacional El Chico (Hidalgo)
- Chiricahua National Monument (Arizona), Coronado National (Arizona), and Ajos-Bavispe (Sonora)
- Chiricahua National Monument (Arizona) and Area de Proteccion de Flora Y Fauna Sierra de Alamos (Sonora)

A holistic approach to ecoresource management and the development of compatible data is imperative to rehabilitate and preserve the rich diversity that exists along the U.S.-Mexican border. The lack of available data is a major challenge in assessing environmental issues. In many cases the data is not available or not practically assessable, or dispersed throughout the Internet on a variety of websites.

Cross-Border Regulation, Research, and Capacity Building

Habitat fragmentation, endangered plant and animal species, air quality, hazardous waste, water, and soil contaminations are issues for many

communities. The border region is unique because the solutions and strategies to address these issues often require binational collaboration. Institutional barriers, such as incompatible data systems and regulatory requirements, lack of enforcement, and the inability to sustain expert links between agency personnel, hinder cross-border partnerships. In spite of these obstacles, communities, state and federal agencies and non-governmental organizations (NGOs) are engaged in an extensive body of work in the Arizona-Sonora Border Region.

Federal agencies, such the EPA and SEMARNAT actively support a growing number of state and local initiatives to improve air and water quality, waste management, and emergency preparedness. Arizona Department of Environmental Quality (ADEQ) engagement in the border region is exemplified in Table 4, which summarizes a prolific number of binational projects and initiatives. ADEQ and the state of Sonora's Secretariat for Urban Infrastructure and Ecology (SIUE) often work in conjunction with individuals, institutions, and companies under the institutional umbrella of the Environmental Committee of the Arizona-Mexico Commission and the Comisión Sonora-Arizona.

The states of Arizona and Sonora have long been distinguished in the border region for the length and quality of their formal ties. For over forty years under the mantra of "God made us neighbors let us be good neighbors," public and private sector representatives meet biannually to address the myriad issues in agriculture, arts, education health, economic development, and the environment.

During 2002, the Environmental Committee recommended to the governors of both states that their intent to support a binational air quality study in the twin communities of San Luis-San Luis Río Colorado embed the Border 2012 Environmental Program into a regional scope of work, strengthen clean air and recycling educational activities, and design sound management practices for the reuse of waste tires.

A promising development even in light of constant struggles for sustained resources and bad economic conditions, environmental NGOs, already strong on the U.S. side for the past decade, are emerging in Mexico. The Annual Meeting on the Border Environment, organized by the University of Arizona Latin American Area Center, drew more than 100 Mexican NGOs working to protect the environment and public health. NGOs today, unlike in the past, consist of a broad base of stakeholders and are increasingly effective in raising awareness and implementing solutions to key environmental issues.

The University of Arizona and Arizona State University, through research and capacity building activities, contribute a significant degree of continuity to address fundamental issues affecting the environment. Complex questions concerning the intersection between land use and climatic variations, the consequences of natural and human-induced change on water balance and ecological diversity, and the mechanisms by which environmental chemicals affect human health are

the focus of several academic programs (i.e., SOMBHERO, SALSA, SAHRA, SEHSC). The Udall Center at the University of Arizona, a prominent voice regarding the institutional aspects of water management, particularly in the San Pedro River basin and the Lower Colorado River basin and delta, is currently facilitating a cross-border dialogue on the links between groundwater variability and climate. Beyond the discussion and exchange, optimism exists for the development of viable responses to watershed issues. A key component recognized by most is the need to solidify a relationship between environmental groups, universities, and governmental agencies. These types of collaborations can serve as a catalyst for better decision-making and development.

Environmental Issues

Water Quality and Quantity

Water is arguably the most debated and coveted resource in the arid desert region of Arizona and Sonora. Population growth and climatic changes are largely influencing competition among users for this increasingly fixed supply. The pressure of urban sprawl coupled with unprecedented drought conditions could pose tremendous economic and environmental implications if sustained. In the Upper San Pedro River basin, a narrow watershed extending more than 300km north of its source in northeastern Sonora to southeastern Arizona, the major threat is groundwater withdrawals to meet population growth and economic development demands. A focal point in the tense debates on consumption verses conservation, the management of this physically and biologically distinctive basin—one of the last remaining perennial streams in the Southwest—is complicated by a lack of information on surface and groundwater interconnections and the lack of legal recognition of water rights.

In the far southwestern portion of Arizona, the Colorado River infuses the Upper Sea of Cortez and Delta region in Mexico with its only freshwater inflows. Over-committed in many respects since it was divided among seven Western states in the U.S. in 1922, increasing demands by Native American tribes and Mexico coupled with drier climatic conditions affect not only quantity, but quality, as well as potential impacts to the biologic and economic value of the area. A result of diminishing inflows, increasing salinity levels, high nutrient concentrations from agricultural drainage, and heavy metal contamination impact Mexico's lower Colorado Delta region, which at one time was a lush riparian area. In the long term the lack of water could certainly affect endemic species as well as commercially valuable varieties.

Although the Arizona-Sonora Border Region reflects a variety of unique water quality and quantity issues, the twin cities of Nogales, Arizona and Nogales, Sonora exemplify several transboundary water problems.

Originating on the valley floor of the Nogales Wash, their central business districts remain there even today; flooding routinely impacts these two communities. Major floods swept through the binational area in 1905, 1909,

1914, 1915, 1926, and 1930 resulting in loss of life and property until a joint flood control project was designed and built in the 1930s and 1940s.

Ambos Nogales share a common watershed and a wastewater collection and treatment system, but their water supply and distribution systems are nearly independent of each other. Nogales, Arizona, entirely dependent upon groundwater for its fresh water needs, has two main well fields that provide water to the municipal supply and distribution system (Potrero Wash and Santa Cruz). Although the two well fields provide an adequate supply of fresh water for the city's current needs, their future productivity is to some extent threatened by a cone of depression and a plume of contamination.

The city supplied 4,290 acre-feet of water to 18,975 people in 1995. The water usage rate was 202 gallons per capita per day (GPCD). This high rate of per-capita usage stems from several causes. On a daily basis nearly 40,000 people cross the international border from Nogales, Sonora. Additionally visitors arrive from the north via 1-19. None of these daily visitors who may or may not consume the city's water are counted as part of the service area population. Moreover the city's water system suffers from a high volume of unaccounted water losses. It is estimated that in 1990 10% of water usage was lost through leakage in the delivery system and an additional 10% went unrecorded either through un-metered or under-metered deliveries.

The Nogales Water Department still supplies some water to customers in Nogales, Sonora, through four separate water mains. One of these lines is inactive, but two of them are among the water department's 50 largest customers.

Aside from the above-mentioned water lines, the Nogales, Sonora, fresh water delivery system is entirely separate from the Nogales, Arizona, system. However because of the shared watershed and topography, the maintenance, operation, and plans for the Sonoran water system have a direct effect on the system in Arizona. The underlying water problem in Nogales, Sonora, is the lack of a sound distribution system. Water mains are too small for the number of hookups, water pressure is too low and many pipes are too old or of poor quality and the piping have been added to on an ad hoc basis over the decades so that the whole system does not function efficiently. Pipes frequently break, causing high water loss and infiltration of underlying sewer lines, which further burden the wastewater system.

About 15% of the Nogales, Sonora, population is not connected to the water supply system. Primarily these are the poorest and newest residents who have settled into *colonias* that are as yet unsupplied with any sort of infrastructure. These residents must haul their own water or buy it from large water trucks, or *pipas*. Connection to the water system does not, however, guarantee a steady supply of water. Only 38% of the population has 24-hour-per-day water service.

Because of the difficulties residents encounter in acquiring water, it is estimated that average water usage in Nogales, Sonora amounts to about 60 GPCD.

An effort to mitigate a water crisis and rapid growth, a water supply augmentation plan, commonly referred to as the Acuaferico Project, was submitted in 1995 and finally received North American Development Bank (NADBank) funding in November 2002 with an award of $8.7. The three-phase plan, estimated to cost $39 million, emphasizes a significant impediment to addressing environmental concerns, namely the ability of designated institutions to secure financing and initiate construction (Varady and Morehouse 2000). Concern exists that the project could severely impact the Santa Cruz well field in Nogales, Arizona, both increasing pumpage costs from a much-lowered water table and exposing the well field to greater susceptibility to drought. There is currently no international agreement to guarantee that there is water in the Santa Cruz when it reaches Arizona. The Arizona Department of Water Resources and the IBWC are engaged in a hydrologic modeling effort to understand the relationship between pumpage and flows.

The shared groundwater basin and the topographical gradient have guided the development of the fresh water and wastewater systems, but the international line separating the communities have repeatedly complicated the building and maintenance of this infrastructure. Nogales, Arizona, led the way in the development of a sewer system. By the end of World War II this system served virtually all the City's residents and businesses. Nogales, Sonora, in contrast relied on cesspools and outhouses until plans emerged in the early 1940s. The topography of the Nogales Wash however dictated that a treatment plant and its sewage outfall line be located in the United States. The International Boundary and Water Commission (IBWC) persuaded the U.S. Congress to fund a joint treatment plant, which was completed in 1951.

Several expansion and improvement efforts to boost capacity have been undertaken since the initial facility, a 1.6 million-gallon per day plant, was constructed on Blankard Avenue in Nogales, Arizona. In 1972 a new larger plant was constructed nine miles north near Río Rico at the confluence of the Nogales Wash and the Santa Cruz River. An $11 million expansion of the plant increased capacity to 15.75 million gallons per day. The constant struggle to keep the capacity of the Nogales International Wastewater Treatment Plant (NIWWTP) ahead of, or at least not too far behind, the area's population growth has been just one of the difficulties facing the ambos Nogales wastewater system.

Despite a large operating budget and expanded capacity, the NIWWTP has repeatedly had difficulty meeting water quality standards and on occasion has released wastewater before treatment was completed. The plant has been cited for excessive levels of suspended sediments in its effluent and for excessive levels of phenols, cyanide and mercury, because the plant was not designed to remove these chemicals. The only way to remove the chemicals from the effluent

is to prevent them from entering the sewage system in the first place. The lack of an industrial pretreatment program in Nogales, Sonora, is another of the system's inadequacies.

Eco-resources and Eco-footprint
Human activity, most notably in the past century, has dramatically altered the landscape of the Arizona-Sonora border, affecting both the quality and quantity of its natural resource base. Agriculture, mining, and international trade shape the use of the land in ways that impact vegetative communities, soil structure and faunal ranges.

Large-scale water diversion projects beginning in 1908 (17 major dams in Arizona and 21 in Sonora) lowered energy costs and enabled irrigated agriculture but also reduced the amount of water, silt, and nutrients to the Lower Colorado River Basin and Delta and fragmented the habitat of various plant and animal species. Drilling for fresh water wells in the coastal region near Hermosillo, Sonora, established commercial irrigated agriculture and attracted over 25,000 workers to the area known as Costa de Hermosillo. However years of poor water resource management has resulted in increased pumping costs, soil contamination, and high salinity, ultimately reducing economic gains and rendering the area largely unusable. The Biological Division of the U.S. Geological Service located at the University of Arizona in collaboration with the Sonoran Institute and the University of Sonora is identifying a group of researchers and political stakeholders in Sonora to restore this area, which encompasses nearly 80,000 hectares. Initial land use solutions include growing mesquite trees, which require less water and a longer development period, but could address the inhabitants' continued need for firewood.

Cattle density and the introduction of exotic forage species have influenced the development of vast amounts of land in the region since the 1530s when European livestock was first introduced. Arizona's cattle herd has decreased from 1.3 million head of cattle in the 1970s to 830,000 in 1995. In contrast, Sonora cattle figures grew from approximately 80,000 in the 1950s to more than 2 million in the 1990s. Mexican government statistics indicate that in Sonora cattle density is two- to five-times the recommended stocking rate. Ranchers on both sides of the border have planted non-native grasses such as Bufflegrass and African Star to increase grazing productivity. By 1995 at least 700,000 hectares of the Sonoran Desert Ecoregion had experienced large-scale vegetation removal by non-native grass varieties altering fire regimes and prohibiting the reseeding of natural plant types.

Land use developments, for example the construction of housing subdivisions on retired farms and ranches, continue to transform the region's landscape. Advances in transportation and communication infrastructure facilitate a process of ex-urbanization, whereby population growth and housing site development can feasibly occur in rural areas and the desert outskirts. This growth not only

reduces the amount of open space, but also threatens the scenic, historic, and biological value of the area. The Malpai Borderlands Group, a non-profit organization formed by ranchers in Southeastern Arizona in 1994, pursues several activities to restore and preserve the surrounding habitat. Motivated by a concern about maintaining their way of life and a “wild landscape,” the group has protected 42,000 acres from subdivision development through the use of conservation easements. Described as an innovative cooperative of land management, neighboring ranchers experiencing serious drought can rest their ranches from grazing under a concept of “grassbanking.”

One of the most pressing issues in the Arizona-Sonora Border Region is the impact of illegal human and vehicular traffic through unique and environmentally sensitive areas. Federal border security operations attempting to curb the flow of illegal conveyances in urban areas have, over time, diverted traffic to more isolated and remote areas along Arizona’s border with Mexico. Many of these areas bear the scars of wildcat trails, abandoned refuse, and trampled vegetation. At Coronado National Monument, the grasslands exhibit a spider web network of trails. U.S. Fish and Wildlife Service employees note that two large open valleys in the Cabeza Prieta National Wildlife Refuge “are now riddled with trash, vehicles, and wildcat roads.” They describe the amount of traffic as being “overrun.” Monitoring activities by the U.S. National Park Service estimate that annually 300,000 individuals illegally cross through Organ Pipe Cactus National Monument. Video surveillance equipment erected in Coronado National Monument indicates traffic volumes ranging from 100 immigrants to 150 immigrants each night.

A report prepared for the U.S. House of Representatives Appropriations Committee indicates that federal employees and visitors no longer consider some areas safe for use. Last year smugglers killed a park ranger in Organ Pipe Cactus National Monument. New policies now require employees and volunteers to “buddy up” when working within two miles of the international border. The safety of immigrants is a serious concern as well; many sustain injuries crossing the rough terrain, often at night or during the exceedingly hot summer months.

The Sonoran pronghorn, the last surviving species of antelope-like goats native to only North America, became endangered in 1967 due to habitat fragmentation, over hunting, and other human activities. Although these creatures can cover great lengths, their movement has become increasingly restricted due to border infrastructure and traffic. While they can jump, years of evolutionary development on the plains and desert flatlands make Sonoran pronghorn reluctant to leap physical barriers, such as the international border delineated by a fence that extends 52 miles to separate Cabeza Prieta National Wildlife Refuge from Mexico. This barrier, exacerbated by additional fencing to support livestock operations in Mexico, inhibits interaction between the U.S. population and the two remaining herds in Mexico, resulting in genetic bottlenecks. Monitoring in 1992 yielded data estimating the healthiest number, 282, to date on the U.S.

side. Since that time, the population has precipitously declined, culminating in only 18 remaining animals as of last year. An aggressive binational recovery effort, since all the populations show signs of stress, is being designed. U.S. Fish and Wildlife officials caution that unprecedented drought conditions could be a major factor in the decline, however they also note the stress of human and vehicular traffic on an already weakened population. A National Park Service manager noted that beyond the serious threats to humans, animals, and the landscape, this unregulated traffic also has severe implications on wilderness values and experiences; resulting in fewer opportunities and locations for solitude.

Colonias

Housing and Urban Development (HUD) and the U.S. Department of Agriculture (USDA) Rural Development, the two federal agencies that earmark funding for colonias in the four U.S. Border States define *colonias* as non-metropolitan, unincorporated neighborhoods and incorporated communities within 150 miles from the U.S.-Mexican border that lack sewer, water, or adequate housing, or a combination of all three.

In Arizona, *colonias* include a wide range of community types, such as tribal communities, long-established mining towns, fast-growing retirement communities, as well as rural utility districts and high-poverty illegal subdivisions (Dolesen and Holguin 2002a). Unlike in Texas, where studies have shown that many of the colonias are relatively new illegal developments, in Arizona most colonia-designated areas are long-standing. The exceptions are “wildcat” subdivisions. These developments on illegally subdivided land are not typical Hispanic farm worker communities, but rather both lower and higher income property owners who do not wish to conform to government regulations. This has been a problem in places outside the urban core and suburban fringe of Pima County where many large parcels without infrastructure are split into smaller residential tracts. Underscoring the sheer magnitude of unregulated growth in Pima County, the County Administrator’s office released a report in 2000 estimating that almost 41% of new development was not regulated (Donelson and Holguin 2002a). As in New Mexico, subdivision regulations (or the lack of them) encourage *colonia*-like conditions. In Arizona, subdivision regulations allow an owner to divide property up to five times without complying with legal requirements. Another problem is the lack of enforcement, especially in the poorer border counties, a consequence of inadequate staffing and weak political commitment (Donelson and Holguin 2002a).

In 1990, Arizona had 77 designated *colonias* with approximately 162,000 people, which amounted to almost 5% of the state population (Donelson and Holguin 2002a). In 2000, the number of designated colonias increased to 182 (Ratcliffe 2003).

There are several problems associated with monitoring *colonias* for the purpose of improving their situation through HUD, USDA Rural Development, or NADBank funding. First is the lack of a common standard for designating a *colonia* area. As the case of Arizona exemplifies, there is a wide range of *colonias* types. A second problem is the lack of a complete assessment of infrastructure, housing needs, and community assets of the colonia-designated areas, which is the basis for HUD and other federal agencies' funding decisions. For example, HUD has required that communities using community development block grants (CDBG) have at least a 51% low-income population as verified by Census data or door-to-door income surveys. Donelson and Holguin (2002a and 2002b) have developed a template to assess those needs. A third problem is the lack of a direct relationship between census geographic units and most colonias. Despite improvements in 2000 Census (Ratcliffe 2003), the boundaries rarely correspond neatly with Census Designated Places (CDP) or census block groups, the most detailed level of analysis available for non-metropolitan areas (Donelson and Holguin 2002a). For example, a smaller number of colonias in Arizona are identified as CDPs; of the 182 designated colonias, only nine were defined as CDPs for the Census 2000 (Ratcliffe 2003). Of these, seven are in the border counties: Ajo and Three Points in Pima County; Gadsden and Tacna in Yuma County; and Naco, St. David, and Whetstone in Cochise County (Ratcliffe 2003). Colonia-CDPs in Arizona's border counties have an average population of 2,202, ranging from 555 in Tacna to 5,273 in Tree Points (Table 5).

Donelson and Holguin (2002b) have observed that federal funding provides an incentive to mobilize a number of *colonia*-designated communities to action, but at the same time, the formal structures required by federal funds threaten the innovation and enthusiasm involved in serving in local affairs. Specifically, NGO networks are found to be important for strengthening local capacities in developing a wider sense of community and assisting in lobbying.

Like elsewhere in Mexico, the development of colonias in Sonora is closely related with Article 27 of the Mexican Constitution that guarantees the settlement of unused land (although at times contested by local authorities). In simple cases, squatters locate the absentee landowner and negotiate a selling price and terms of payment. When an agreement cannot be reached, city or state authorities may intervene and expropriate the land so it can be divided and sold (Cravey 1998). Fighting the eviction and obtaining services (electricity, water) usually requires that the squatters be well organized.

Unlike in Arizona, Sonoran *colonias* tend to be built in the vicinity of industrial parks and maquiladoras. Migrants first settled in an informal fashion much of the territory in Nogales that constitutes the city (Cravey 1998). A particular problem in Nogales is the hilly topography that creates additional obstacles for delivering basic services. According to the latest census, 5.5% of Nogales' households have no electricity, 16.1% have no access to water, and 11.7% have no

drainage. In San Luis Río Colorado, more than 20% of households are without drainage.

Hazardous and Solid Waste and Toxic Substances Management
Hazardous waste by definition is a threat to human health and natural resources. When improperly handled they are easily ignited, reactive, or toxic. Appropriate waste management (transportation, tracking, and disposal/storage) is imperative to minimize risks to human health. The border, however, is a maze of conflicting jurisdictional requirements, incompatible tracking systems, and minimal inspection resources. A situation that at times creates a considerable obstacle to environmental stewardship and serves as an inducement for criminal behavior.

In the U.S. federal and state transportation departments (such as the U.S. Department of Transportation and Arizona Department of Transportation) track the shipment of hazardous materials whereas federal and state environmental protection agencies (like EPA and ADEQ) monitor hazardous waste, a subset of materials. HAZMAT data for 2001 suggest that only 53 truckloads of hazardous materials crossed the Arizona-Sonora border. However, inaccurate reporting and limited regulatory oversight hinder estimations on the real volume of hazardous or toxic materials transported across the border.

Hazardous waste definitions between the United States and Mexico are not uniform, nor do they accurately represent the degree of risk posed to the public. EPA developed the HAZTRAKS data system to manage hazardous waste shipments exported from Mexico to the United States. U.S. companies are legally required to export waste generated during industrial production. In recent years Mexico updated their tracking system, Sistema de Rastreo de Residuos Peligrosos (SIRREP), unfortunately different definitions and reporting requirements (actual verses permitted shipments) reduce the ability to harmonize information on transboundary shipments and make the two systems largely incompatible. Conversations with ADEQ officials indicate that HAZTRAKS is no longer in operation due to budgetary constraints.

The U.S. HAZTRAKS data system is dependent on receiving accurately documented manifests from U.S. Customs, which in turn rely on companies to correctly label exports. The vulnerability of this process is exemplified in an historic case in Arizona and Sonora, the first time EPA issued a fine. EPA in the late 1990s began to adopt more stringent enforcement actions on companies violating labeling requirements. In 2000, Chambers Belt Company (Phoenix, Ariz.); Joffroy Customs Broker Inc. (Nogales, Ariz.) and Chambers de Mexico S.A. de C.V. (Pitiquito, Sonora) were fined more than $50,000 for labeling hazardous waste “U.S. Goods Returned.” As part of their penalty the Mexican manufacturing plant agreed to train other facilities on U.S. and Mexican legal requirements for hazardous waste shipments.

The lack of “cradle to grave” tracking continues to be a major management challenge for both federal and state officials in the United States and Mexico. Officials in Arizona suggest that the U.S. is only able to track five to 15% of all hazardous waste generated. In Mexico, government officials indicate that only 12% of the hazardous waste produced is reported. Table 6 emphasizes the discrepancy between estimated waste and reported waste among Border States in Mexico.

To encourage legal compliance requirements, state and federal authorities have initiated incentive programs. ADEQ partners with U.S. and Mexican federal authorities to conduct binational training events on environmental regulations, sampling, and other technical activities associated with hazardous materials and environmental crimes. ADEQ’s events train U.S. Customs agents on RCRA regulations, sampling procedures, and proper environmental inspections through the Hazardous Waste Border Surveillance, Compliance and Enforcement Program.

The Arizona-Mexico International Green Organization (AMIGO) a binational pollution prevention initiative established by ADEQ, facilitates information and technology exchange between companies on both sides of the border. The program recognizes responsible stewardship in waste management by acknowledging, annually, the efforts by companies to minimize the amount of waste they generate. Companies are presented with an award by the governors of Arizona and Sonora. In November 2002, two maquiladoras located in Nogales, Sonora, were acknowledged for diverting 15 tons of plastics from municipal landfills, reducing hazardous waste by 15%; and for initiating a community reforestation program in which more than 5,000 trees were planted in a Nogales *colonia*.

Emergency response plans are critical to address the consequences of an accident at the border. ADEQ and EPA have developed joint emergency response and contingency plans for four industrialized sister city communities along the Arizona-Sonora border (Ambos Nogales, San Luis-San Luis Río Colorado, Douglas-Agua Prieta and Cochise County-Naco).

Several years ago Arizona emergency response personnel intercepted a truck transporting expired lab samples to Sonora. Originated from a college in the Midwest, the improperly packaged samples were in route to the University of Sonora. Emergency representatives described the shipment as “a rolling bomb.” U.S. Customs agents were engaged in a comprehensive interdiction exercise when the shipment arrived at the Nogales Port of Entry and the heightened level of awareness facilitated detection.

The accumulation of tires along the border is not only visually unappealing but a potential fire and health hazard to surrounding communities. In the southwestern corner of Arizona, aerial photos identified more than 500 tires in 30 different

locations between the communities of San Luis Río Colorado, Sonora, and Yuma, Arizona. The municipality of San Luis Río Colorado has traditionally stored thousands of tires at a landfill, located in an area with high concentrations of brick-making operations in the southern part of the city. The tires are typically covered in sand to prevent the spread of fires. Although not substantiated in this area, tires are used as a source of fuel for brick kilns in other regions, such as the Mexican community Ciudad Juárez south of El Paso, Texas. EPA and ADEQ have designated a 15-mile stretch of this area a test site to implement a program to quantify and properly store the waste tires.

Air Quality

Unpaved roads, idling trucks, brick kilns, mining, exposed agricultural lands, and residential activities such as heating homes and cooking food impact air quality. Burning landfills, for example, have been a particularly problematic along the Arizona-Sonora border. Both Nogales and Agua Prieta experienced near constant burnings at their old landfills until new sites were development. ADEQ officials recall that in the case of Nogales its was possible to “drive into the valley and it would be full of smoke, it would look like a fog in San Francisco” (ADEQ 2003). In Naco the potential for episodic burning has been reduced with equipment provided by both IBWC and EPA, however a fire in 2002 required a U.S.-Mexico emergency response and closed the border for several days.

Carbon monoxide, particulate matter, and ozone emissions can cause respiratory distress and other health problems, particularly for the young, elderly and those with weak immune systems. A study by ADEQ in 1999 found that particulate matter exposure in the Ambos Nogales region increased the risk of premature death by ages five and 42 respectively. Sulfur dioxide pollution, emitted by smelters and mining operations, were blamed for respiratory illness and acid rain in the eastern part of the Arizona-Sonora border during the 1980s. The Grey Triangle, a reference to three copper smelters, contributed significantly to poor air quality in the region. The smelters in Douglas, Arizona, and Cananea, Sonora, closed in the 1980s due to the La Paz Agreement, however the Nacozari Smelter expanded and modernized after opening to address air contamination concerns. Douglas, Arizona, and Agua Prieta, Sonora however continue to exceed sulfur dioxide standards.

Mining operations contribute to contamination by releasing heavy metal particles in the air or through a leaching process that pollutes local groundwater and surface water sources. Arsenic, an inorganic environmental contaminant, is a major concern in the desert southwest due to its ubiquitous presence and its occurrence in drinking waters. Chronic exposure to arsenic frequently results in skin, lung, bladder, and kidney cancer.

Air quality monitoring and attainment designations have been largely defined by political jurisdictions as opposed to natural air basins. Nogales, Arizona, designated a non-attainment area for failing to meeting U.S. particulate matter

standards, has struggled to address air pollution sources originating across the border in its sister city in Sonora. Research estimates that between 80% to 85% of the emission pollution in Nogales, Arizona, is attributable to sources in Nogales, Sonora, mainly unpaved road dust. A special federal exemption (179b) allows U.S. border cities to avoid sanctions, typically a loss of transportation funding, if the emission sources are outside of their jurisdiction.

ADEQ and SEMARNAT collaborated to assess human health effects of emissions, specifically atmospheric transport of hazardous air pollutants (HAPs), and particulate matter (PM_{10} and $PM_{2.5}$) in the Ambos Nogales region between 1994 and 1999. Air sample collection began early in 1994 at two locations in the Arizona side, one of which exhibited an unusually high concentration of cancer cases. Sonoran sites included its fire station and a technical school near an industrial zone south of downtown. An atmospheric emissions inventory of 83 different HAPs, PM_{10}, and $PM_{2.5}$ components and atmospheric simulation models replicating the movement of emissions were completed by 1996.

A concern among local residents, the health assessment focused on the probability of developing cancer, adverse health effects, or premature cardiovascular and respiratory-associated deaths from exposure. For the typical resident the risk of developing cancer was found to be minimal, only a 0.4% chance over a lifetime. The study did find, however, an increased risk of respiratory effects, asthma episodes, and premature deaths.

In 1997, ADEQ and SEMERNAT embarked on a similar air quality assessment in the communities of Douglas, Arizona and Agua Prieta, Sonora. Completed by the end of 2003, initial findings support the significance of unpaved roads as a major source of air pollution. Nearly 84% of the road system in Agua Prieta is not paved. An additional component, relative to the work in Nogales, this project determined which road paving projects would yield the greatest reduction in emission levels. The data informed a proposal for 16.7 miles of paving in Agua Prieta that received BECC certification (December 2002) and NADBank funding (March 2003). The expansion of NADBank's mandate to include air and transportation projects may provide financial support for other projects along the border.

Residential burns—for example cooking food, heating homes, and burning trash—have a tremendous impact on air quality. While developing an emission inventory, more than 200 community surveys in Agua Prieta were administered to residents on burning practices. The surveys, based on a sample of the entire city of Agua Prieta, including *colonias*, estimated that annually 33 tons of wood are burned and nearly 70,000 brick are produced. These results help to explain the higher emission readings registered in air samples relative to Nogales. The Douglas/Agua Prieta area also frequently experiences winds of up to 30 miles per hour that facilitates a significant amount of air pollutants.

An air quality assessment (air sampling, atmospheric emissions inventory and simulation models, and health risk assessments) is planned for the Yuma/San Luis, Arizona—San Luis Río Colorado, Sonora region. A more complex and ambitious project relative to other twin city sites, the study will monitor an area approximately 60km by 80km, encompassing three nations and four states.

The greater Yuma region is attempting to receive a status reclassification from non-attainment to maintenance by EPA, based on previously collected data. It is quite possible that new data will hinder these efforts. Air samples should detect dust from agriculturally disturbed land and the occurrence of pesticides. High particulate matter readings from unpaved roads (estimated to be 83% in San Luis Río Colorado) and the impact of almost 230 kilns in operation in the urban and surrounding areas should be captured in samples. Many of the brick kilns are small family run operations, which contrary to assumptions produce a disproportionate environmental impact on air quality relative to their size. Conversations between ADEQ and the Ecology Department in San Luis Río Colorado suggest that approximately 10 million bricks are produced in the region annually.

In 2000, using the findings of the Ambos Nogales Air Quality Study as its foundation, the Arizona Department of Environmental Quality initiated an outreach campaign to raise pubic awareness to prevent air polluting activities. EPA and the National Oceanic and Atmospheric Administration provided funding. Recognized as unique along the border, activities include a clean air calendar featuring artwork by school children, announcements, and special features in newspapers, on TV, and on the radio. The project also participates in binational discussions organized as part of the Border Liaison Mechanism.

Environmental Health Risk

The specter of disease outbreaks in Ambos Nogales has been the driving force behind improvements to the water systems, discussed previously. A Mexican typhoid epidemic in 1927 spurred the City of Nogales to invest in a chlorination system. In the summer of 1990, monsoon rains broke numerous sewer lines all over Nogales, Sonora. The resulting contamination of Nogales Wash was linked to 42 cases of hepatitis A among residents clustered around the wash. Cholera has been found in the wash and a February 1991 test detected the poliovirus.

It is estimated that 14% to 21% of the Nogales, Sonora, population faces health risks due to sewer line breaks. Estimates of the portion of Nogales, Sonora, population without access to wastewater drainage varies from a low of 19% to a high of 40%. Of those without sewer connections, about one-half use septic tanks, one-third use simple latrines and the remainder use “natural drainages,” i.e., hill slopes. All three methods are sanitarily ineffective due to steep terrain, impermeable ground, and the high density of habitation. Between Nogales, Sonora’s broken fresh water lines, its broken sewer lines, and its leaky septic tanks and cesspools there is a fairly constant flow of contaminated water in the

storm drain system that empties into the Nogales Wash. Santa Cruz County, on the Arizona side of the border, was prompted in 1990 to declare a health emergency because fecal coliform levels in the wash exceeded state allowances by a factor of 4,000. Chlorination systems have since been installed and generally keep fecal coliform counts at an acceptable level. However the system cannot handle renegade sewage flows produced during flooding events.

Border residents are increasingly concerned about environmental impacts to their health. Several studies in the Arizona-Sonora Border Region have been initiated following considerable public inquiries and requests. Establishing a direct cause and effect between the environment and illness can be problematic in the border region because of a lack of baseline data and the inability to control for adequate nutrition, access to health care, the prevalence of infectious disease, and behavioral factors.

In 1996 following concerns about air quality and respiratory symptoms, Arizona Department of Health Services Office of Border Health collected baseline data from more than 632 fifth grade students and their parents in Ambos Nogales. The study found a prevalence of respiratory symptoms and a corresponding increase between symptoms and higher PM levels, however cigarette smoke was prevalent within the households.

Several studies in Yuma County have been conducted to assess the impact of both agricultural and household pesticide exposure on children. Agriculture is a major industry sector in the Yuma County economy and the region is a leading producer of winter vegetables such as iceberg lettuce. Household pesticides, typically insecticides or disinfectants, are typically stored at levels accessible to children, most often in a cabinet beneath the kitchen sink. Exposure to some pesticides can result in nausea, weakness, dizziness and headaches. A serious concern is the accessibility of pesticide chalk containing DDT, which continues to be sold illegally at some flea markets in Mexico and the United States. The product is used to create lethal barriers for insects. Children easily mistake the chalk and are subject to exposure while playing with it.

In a dramatic case, a neighborhood in Nogales Arizona reported evidence of above average rates of systemic lupus, two- to seven-times higher than the U.S. national average. Lupus is a chronic inflammatory disease in which the body’s immune system is unable to distinguish foreign substances from its own antibodies. Systemic lupus is considered the most severe form. Symptoms vary widely but the most common are achy and swollen joints, fever, and fatigue. Although the cause of lupus is unknown, scientists believe genetics and environmental factors can activate the disease. In March 1997 the Arizona Department of Health Services and the Centers for Disease Control and Prevention conducted a study to determine the impact of environmental chemical exposure on the SLE cases. The study was unable to substantiate a direct link.

Environmental health problems vary by type of toxic and length of exposure. In the case of hazardous waste health risks can include miscarriages, birth defects, genetic problems, autoimmune diseases, cancers, pulmonary disorders, and gastrointestinal ailments. Exposure to lead, an environmental toxicant, can cause anemia, seizures, and in extreme cases, coma and death. Even modest exposure can create learning and behavioral problems in young children. Fuel, emissions and paints from automobiles and smelters are leading sources of lead poisoning. It was not until the 1990s that Mexico introduced unleaded fuel, raising concerns about potentially high levels of lead in children. Arizona Department of Health Services Office of Border Health initiated a pediatric blood lead assessment over a two-month period in 1998. A total of 1,517 children were included from several border communities, Agua Prieta an San Luis Río Colorado (Sonora) and San Luis, Sommerton, Yuma, Orange Grove, Wellton and Dateland. Blood samples and blood lead analyzer results suggest that lead was not a major public health problem.

Conclusion

Population growth, economic integration, and climatic conditions influence the environmental resource base of the Arizona-Sonora Border Region. The combined population, close to 1.7 million in 2000, is expected to exceed 2.1 million by 2010. In Arizona, the communities located along the border are economically dependent on a few industry sectors, experience high seasonal unemployment and have significantly lower per capita incomes and educational attainment than the State. Between 2000 and 2002 more than 17,000 maquiladora jobs vanished in Sonora's border zone. Local and regional governments on both sides of the border struggle to meet growing demands for water, sewage, health care, roads, housing and other services. Struggling to absorb the impacts of increasing trade, traffic, and migration, these communities lack adequate revenue streams to address the growing demands for services and infrastructure.

Geographically the Arizona-Sonora Border Region is distinguished with a unique blend of topography, surface water, and climate. Several areas along the length of the shared border are recognized as vital, but also threatened corridors, ecologically linking some of the world's most treasured habitats and species.

Landscape fragmentation, endangered plant and animal species, air quality, hazardous waste, water, and soil contamination are environmental issues for many communities. The border region is unique because the solutions and strategies to address these issues often times require binational collaboration. Institutional barriers, such as incompatible data systems and regulatory requirements, lack of enforcement and the inability to sustain expert links between agency personnel, hinder cross-border partnerships. However, in the Arizona-Sonora border region communities, state and federal agencies and NGOs are engaged in an extensive body of work. Binational collaboration on ecosystem management and the development of compatible data is proving

essential to conservation efforts and ensuring the rich diversity that still exists along the Arizona-Sonora Border.

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Table 1. The Arizona-Sonora Border Region: Population by County/Municipio

County/municipio	1940	1950	1960	1970	1980	1990	2000
Arizona							
Pima	72,838	141,216	265,660	351,667	531,443	666,880	843,746
Yuma	19,326	28,006	46,235	60,827	76,205	106,895	160,026
Cochise	34,627	31,488	55,039	61,918	85,686	97,624	117,755
Santa Cruz	9,482	9,344	10,808	13,966	20,459	29,676	38,381
AZ border total	136,273	210,054	377,742	488,378	713,793	901,075	1,159,908
% change		54.1	79.8	29.3	46.2	26.2	28.7
Sonora							
Nogales	15,422	26,016	39,812	53,494	68,076	107,936	159,103
San Luis RC	2,364	13,593	42,134	63,604	92,790	110,530	145,276
Caborca	5,850	9,192	12,400	28,971	50,452	59,160	69,359
Agua Prieta	6,552	13,121	17,248	23,272	34,380	39,120	61,821
Cananea	11,890	18,869	21,048	21,315	25,327	26,931	32,074
Puerto Penasco			5,749	12,436	26,755	26,625	31,101
Other border mun.	7,101	7,468	9,623	12,044	14,307	24,419	27,726
Sonora border total	49,179	88,259	148,014	215,136	312,087	394,721	526,460
% change		79.5	67.7	45.3	45.1	26.5	33.4
Arizona-Sonora border	185,452	298,313	525,756	703,514	1,025,880	1,295,796	1,686,368
% change		60.9	76.2	33.8	45.8	26.3	30.1

Sources: For Arizona: U.S. Census of Population (http://www.de.state.az.us/links/economic/webpage/popweb 3/13/03); Sonora: for 2000: INEGI 2000. Anuario Estadistico. Sonora. Edicion 2000; for 1940-1990 Lozano (1998) based on INEGI, various volumes.

Table 2. The Largest Border Cities in the Arizona-Sonora Border Region

City	1,940	1950	1960	1970	1980	1990	2000
Nogales, AZ	5,135	6,153	7,286	8,946	15,683	19,489	20,878
Nogales, Son	13,866	24,478	37,657	52,108	68,076	107,119	159,103
Yuma, AZ	5,325	9,145	23,974	29,007	42,481	56,966	75,515
San Luis, AZ				189	1,946	4,212	15,322
San Luis RC, Son	558	4,079	28,545	49,990	92,790	111,508	145,276
Douglas, AZ	8,623	9,442	11,925	12,462	13,058	13,137	14,312
Agua Prieta, Son	4,106	10,471	15,339	20,754	34,380	39,045	61,821
Total	37,613	63,768	124,726	173,456	268,414	351,476	492,227
% annual change		69.5	95.6	39.1	54.7	30.9	40

Sources: For Arizona: U.S. Census of Population (http://www.de.state.az.us/links/economic/webpage/popweb 3/13/03); for Sonora 1940-1990: Arreola and Curtis(1993); for 2000: INEGI. Sonora. Anuario Estadistico. Edicion 2000.

Table 3. Unique and Environmentally Sensitive Areas along Arizona's Border with Mexico

Area	Acreage	Management
Cochise County, Arizona		
Chiricahua National Monument	12,000	NPS
Coronado National Monument	2,475,000	USFS
Chiricahua Wilderness Area	87,700	
Miller Peak Wilderness Area	20,228	
Mt. Wrightson Wilderness Area	25,260	
Coronado National Memorial	4,750	NPS
Kartchner Caverns State Park	560	ASP
Ramsey Canyon Preserve	300	TNC
San Bernadino/Leslie Canyon Wildlife Refuges	3,549	USFWS
San Pedro Riparian National Conservation Area	56,500	BLM
San Cruz County, Arizona		
Appleton-Whittell Research Ranch	8,000	NAS
Canelo Hills Ciengega	254	TNC
Coronado National Forest	2,475,000	USFS
Parajita Wilderness Area	7,553	
Goodding Research Natural Area	545	
Empire-Cienga Ranch	45,000	BLM
Patagonia Lake State Park	640	ASP
Patagonia/Sonoita Creek Preserve	850	TNC
Tubac Presidio State Historic Park	11	ASP
Tumaccacori National Historic Park	16	NPS
Pima County, Arizona		
Baboquivari Peak Wilderness Area	2,040	BLM
Buenos Aires National Wildlife Refuge	115,000	USFWS
Cabeza Prieta National Wildlife Refuge	860,000	USFWS
Coyote Mountains Wilderness	5,080	BLM
Kitt Peak National Observatory		NOAOR
Organ Pipe Cactus National Monument	330,689	NPS
Saguaro National Monument	91,116	NPS
Yuma County, Arizona		
Cabeza Prieta National Wildlife Refuge	860,000	USFWS
Cibola National Wildlife Refuge	16,627	USFWS
Eagletail Mountains Wilderness Area	97,800	BLM
Imperial National Wildlife Refuge	25,125	USFWS
Kofa National Wildlife Refuge	665,400	USFWS
Muggins Mountains Wilderness Area	7,711	BLM

ASP=Arizona State Parks; BLM=Bureau of Land Management; NAS=National Audubon Society; NOAOR=National Optical Astronomy Observations; NPS=National Park Service; TNC=The Nature Conservancy; USFS=U.S. Forest Service; USFWS=U.S. Fish and Wildlife Service.
Source: INS 2002.

Table 4. Arizona Department of Environmental Quality Border Environmental Projects and Ongoing Initiatives

Project/Activity	Area/Location	Participants
Ambos Nogales Binational Air Monitoring Project	Urban area of Nogales, Arizona and Nogales, Sonora	U.S. Environmental Protection Agency (EPA); Arizona Department of Environmental Quality (ADEQ); Secretaría de Medio Ambiente, Recursos Naturales y Pesca (SEMARNAP); the municipal government of Nogales, Sonora, and the Santa Cruz County Health Department
Nogales Wash Joint U.S./Mexico Groundwater Monitoring	Urban area of Nogales, Arizona and Nogales, Sonora	EPA; ADEQ, International Boundary and Water Commission (IBWC), Comisión Nacional de Agua (CNA)
Ambos Nogales Binational Sanitary Facilities Planning	Urban area of Nogales, Arizona and Nogales, Sonora	EPA, ADEQ, Arizona Department of Water Resources (ADWR); IBWC, Comisión Internacional de Límites y Aguas (CILA), CNA, Secretaría de Infraestructura Urbana y Ecología (SIUE), and the municipal governments of Nogales, Sonora and Nogales, Arizona
Water Supply Studies in the Binational Santa Cruz River Watershed	Binational groundwater basins in the Nogales, Arizona and Nogales, Sonora vicinity	ADWR, CAN, SIUE, Comisión de Agua Potable y Alcantarillado del Estado de Sonora (COAPAES), City of Nogales, Arizona, ADEQ, IBWC
Project-Wellhead Protection Program (WHIP) for Nogales, Arizona	Santa Cruz River and Nogales Wash water basins in the Nogales, Arizona vicinity	ADEQ, ADWR, Southeastern Arizona Governments Organization (SEAGO), City of Nogales, Arizona

Asthma/Air Quality Study of 5th Grade Children in Ambos Nogales	Urban area of Nogales, Arizona and Nogales, Sonora	Arizona Department of Health Services (ADHS), Secretaría de Salud Pública del Estado de Sonora, ADEQ
Northeastern Sonora Water Quality Monitoring Project	Communities of Naco, Agua Prieta, Cananea, and the San Pedro River Basin in Northeastern Sonora and Southeastern Arizona	University of Sonora, SIUE, ADEQ, municipal governments of Agua Prieta, Cananea, and Naco, Sonora, U.S. Agency for International Development (USAID), EPA, ADHS and non-governmental organizations including Enlace Ecológico and the Border
Douglas, Arizona-Agua Prieta, Sonora Binational Air Monitoring Project	Urban area of Douglas, Arizona and Agua Prieta, Sonora	EPA, ADEQ, SEMARNAT, the municipal government of Agua Prieta, Sonora, and the Cochise County Health Department.
Douglas/Pirtleville, Arizona Lead (Pb) Contamination Study	Urban area of Douglas, Arizona and Agua Prieta, Sonora	EPA, ADEQ, and Secretaría de Salud Pública del Estado de Sonora
Lower Colorado River Binational Pesticide Sampling	Yuma, Arizona and San Luis Río Colorado, Sonora border area	EPA, ADEQ, U.S. Geological Survey (USGS), State of California, IBWC, CILA, and CNA
Binational Emergency Response/Contingency Plan for Ambos Nogales	Nogales, Arizona and Nogales, Sonora	Procuraduría Federal de Protección al Ambiente (PROFEPA), ADEQ, EPA, Protección Civil del Estado de Sonora, U.S. Customs Service (USCS), Aduana de Nogales, and local governments on both sides of the border
Arizona-Mexico Commission	Arizona-Sonora border region	ADEQ, ADHS, SIUE, and Secretaría de Salud Pública del Estado de Sonora
Border Communities Health and Environmental Fairs and Workshops	Arizona-Sonora border region	ADEQ, ADHS, SIUE, and Secretaría de Salud Pública del Estado de Sonora

Arizona-Mexico International Green Organization (The AMIGO Project)	Arizona-Sonora border region	ADEQ, EPA, PROFEPA, SIUE, municipal governments of Nogales, Arizona and Nogales, Sonora
Environmental Compliance and Enforcement Training and Collaboration	Arizona-Sonora border region	ADEQ, EPA, PROFEPA, USCS, Mexican Aduana, U.S. and Arizona Attorney General's Office, Procuraduría General de la República

Table 5. Arizona Colonias Identified as Census Designated Places, 2000

County/Colonia	2000 Population
Pima	
Ajo	3,705
Three Points	5,273
Yuma	
Gadsden	953
Tacna	555
Cochise	
Naco	833
St. David	1,744
Whetstone	2,354

Source: Department of Housing and Urban Development; U.S. Census Bureau, Census 2000; Ratcliffe (2003)

Table 6: Estimated and Reported Hazardous Waste in Mexico's Border States, 1997

State	Estimated 1997	Reported 1997
Baja California	395.1	29.5
Coahuila	298.2	2.4
Chihuahua	388.5	779.2
Nuevo Leon	773.1	47.8
Sonora	207.4	4.1
Tamaulipas	232.8	218.6
Mexican Border Region	2,295.10	1,081.60
National	12,700.00	3,328.10