II-1

Overview of the Border+20 System Model Prototype: The Paso del Norte Region

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Abstract

Chapter I-1 outlines how a systems thinking approach can be used to map the interactions among social, political, environmental, and economic aspects of communities at the U.S.-Mexican border. In Section II, members of the Border Plus Twenty Years (B+20) team explain how the system dynamics modeling approach is used to explore alternate futures for the Paso del Norte binational community. This particular chapter provides a background context for the Paso del Norte community and outlines how various aspects of that community are linked in the system model.

Many important political boundaries cut Paso del Norte and complicate planning and management for urban growth and natural resource use. Its cities share a binational air basin and aquifer system. Its economies are integrated and have largely risen and fallen together with the economic fortunes of the United States. The history of migration and settlement in Paso del Norte has led to a distinctive border community culture that reflects more than a century of contact and diffusion between people from the Spanish-Mexican

North and Anglo-American Southwest. As a consequence of sharing natural and urban environments, Paso del Norte communities also share an interrelated human health context.

It is generally assumed that improving quality of life in Paso del Norte is best done through binational collaboration that leads to an increasingly integrated community context. Unfortunately, developing the collaborative networks in a binational context is difficult, time consuming, and not always successful. Adopting a systems thinking perspective to attain the goal of improved quality of life requires an attempt to identify the feedbacks, tradeoffs, and lags in the overall urban ecosystem that might lead to unintended consequences of the policy decisions designed to mitigate the challenging situations.

Visión General del Prototipo de Modelo de Sistema Frontera+20: Región Paso del Norte

Craig B. Foster

Resumen

El Capítulo I-1 delimita como un enfoque de sistema de pensamiento puede ser utilizado para trazar las interacciones entre los aspectos sociales, políticos, ambientales y económicos de las comunidades de la frontera México-Estados Unidos. En la Sección II, los miembros del grupo de trabajo del Proyecto Frontera Más Veinte Años (F+20), explican cómo el enfoque del modelado de sistema de dinámicas es utilizado para explorar alternativas para el futuro de la comunidad binacional del Paso del Norte. Este capítulo proporciona

un antecedente para la comunidad del Paso Norte y delimita cómo diversos aspectos de esa comunidad están interrelacionados en el sistema de modelo.

Muchos límites políticos importantes cortan el Paso del Norte y complican la planeación y administración para el crecimiento urbano y el uso de recursos naturales. Sus ciudades comparten una cuenca binacional de aire y un sistema acuífero, sus economías están integradas y han crecido formando parte de la fortuna de los Estados Unidos. La historia de la migración y acuerdo en el Paso del Norte ha llevado a una cultura comunitaria de la frontera particular que refleja más de un siglo de contacto y difusión entre las personas españolas-mexicanas del norte y anglo-americanas del suroeste. Como consecuencia de compartir ambientes naturales y urbanos, las comunidades del Paso del Norte también comparten un contexto de salud humana interrelacionado.

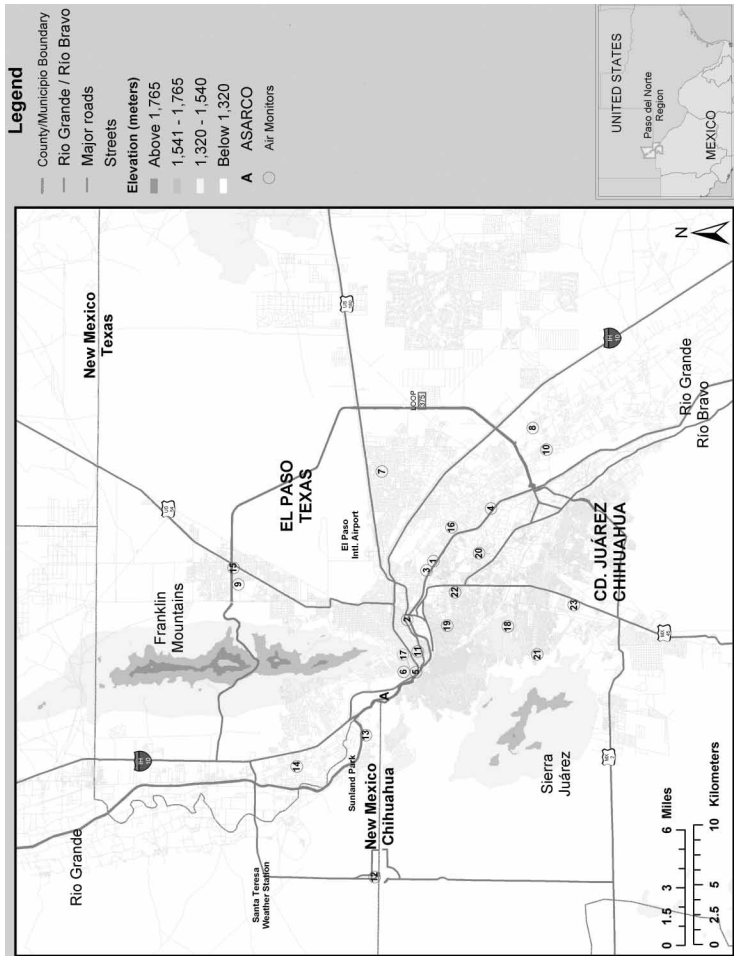
Se asume generalmente que se mejora la calidad de vida en el Paso del Norte a través de una colaboración binacional que lleva a un contexto comunitario integrado. Desafortunadamente, desarrollar las redes de colaboración en un contexto binacional es difícil, toma tiempo y no siempre es exitoso.

Adoptar una perspectiva de sistemas de pensamiento para lograr el objetivo de mejorar la calidad de vida requiere intentar identificar las retroalimentaciones, equilibrios, y retrasos en los ecosistemas urbanos generales que pueden llevar a consecuencias no intencionadas de las decisiones de política diseñadas para mitigar los retos.

Overview of the Paso del Norte Region

Paso del Norte sits at 3,760 feet above sea level in a wide basin bounded by steep mountains that rise more than 7,000 feet above sea level (Figure 1). It is this geography that led to the naming of the area; Paso del Norte means “the pass of the north” in Spanish. In past centuries, this pass through the southward extension of the Rocky Mountains attracted Spaniards traveling between Mexico City to Santa Fe. For more than 1,000 years Paso del Norte has been an important crossroads for trade as people travel through the region.

Figure 1. The Paso del Norte Region



Source: Rincón, et al. 2005

Situated in a high desert environment traversed by the Rio Grande, El Paso, Tex., (located in the middle of Paso del Norte) has average temperatures of 63°F with average highs of 96°F in July and average lows of 29°F in January. Mean annual precipitation is 8.8 inches (climateZONE.com 2004). Winds exceeding 50 miles per hour are not uncommon. These winds create dust storms yet also clear the region of air pollutants emitted by the urban community.

Many important political boundaries cut Paso del Norte and complicate planning and management for urban growth and natural resource use. Signed in 1848, the Treaty of Guadalupe Hidalgo fixed the U.S.-Mexican border at the Rio Grande and created today's Paso del Norte border community. Judged one of the largest urban border communities in the world (its population was 1.9 million in 2000), the Paso del Norte communities are intertwined economically, socially, and culturally in ways that reflect the historical evolution of the region. At the same time, however, the binational community exhibits the greatest border economic disparity in the world by juxtaposing a highly developed United States beside a developing Mexico (Stoddard 2001). The international border has led to a shared community context within multiple local, regional, and national jurisdictions that affect quality of life in this binational community. Key issues affected by the multiple jurisdictions include water supply and quality, air quality, and human health. The arid environment, multiple overlapping jurisdictions, and rapid population growth of Paso del Norte have led the U.S. Department of the Interior (2004) to identify this area as a region with substantial potential for future water conflicts.

Shared Air Basin and Watershed

This community shares a binational air basin bounded by mountains and collects the combined emissions from the border communities. This airshed is at the same time impacted, managed, and monitored by the different institutional and legal systems of the United States and Mexico. The free movement of airborne pollutants across state and national borders means that one city cannot control emissions within its borders because of pollution traveling from the other cities. For example, studies have shown that pollutant emissions

from Ciudad Juárez, Chih., contribute to heightened concentrations of criteria air pollutants in El Paso that, in turn, contribute to levels of nonattainment on the U.S. side that can lead to federal sanctions (Texas Environmental Profiles 2004). As a consequence, the U.S. Environmental Protection Agency (EPA) has classified the El Paso region as one of "serious," rather than the higher level, "severe," nonattainment. This reclassification enables EPA to impose less-onerous sanctions and penalties than would otherwise be possible. Another proposed, but yet unapproved, solution is to allow El Paso companies to help meet clean air obligations by investing in emissions-reduction strategies in Ciudad Juárez.

Surface water contained in the Paso del Norte region of the Rio Grande/Río Bravo system is administered by the U.S. Bureau of Reclamation, the State of New Mexico, the State of Texas, the Comisión Nacional del Agua (CNA), and the International Boundary and Water Commission (IBWC). IBWC is the binational agency that oversees surface water resources on the border between Mexico and the United States and administers treaties between the two nations. The joint U.S.-Mexico Rio Grande Project agreement dictates that 60,000 acre-feet per year of water must be delivered to Mexico, except in drought years, when the delivery would be reduced according to a predetermined formula (Stoddard 2001). Although Mexico is interested in obtaining greater river flow by renegotiating the water delivery treaty, almost all agree this is an unlikely outcome (Ganster 2005).

The binational aquifer system, comprising the Hueco and Mesilla aquifers that underlie the border, forms a critical source of potable groundwater that underlies three state boundaries (New Mexico, Texas, and Chihuahua). Groundwater in the U.S. section of Paso del Norte is administered by the State of New Mexico and individual landowners in Texas. In Mexico, groundwater is administered by the federal government. Managing the binational groundwater resource is complicated because U.S. states lack the power to engage in international negotiations with Mexico. Thus, the potable groundwater resource is highly prone to overexploitation as water suppliers on each side of the border attempt to capture as much water as possible as quickly as possible, which in turn inevitably leads to tension and conflict.

Economy

For more than a century, the integrated economies of El Paso and Ciudad Juárez have largely risen and fallen together with the economic fortunes of the United States. For example, the depression of the 1920s slowed both economies, but then military personnel stationed at Fort Bliss during World War II helped spur the economies of both El Paso and Ciudad Juárez in the early 1940s. Increasing industrialization of Ciudad Juárez was sparked by Mexico's Border Industrialization Program, which in 1967 led to the first significant maquiladora in Ciudad Juárez. Maquiladoras (sometimes referred to as maquilas) are factories operated by non-Mexican companies in Mexico that take goods and raw materials from the United States and other countries, assemble the final product in Mexico, and then ship the product back to its point of origin, paying duties only on the value added to the product while in Mexico. Between 1990 and 2000, maquiladoras in the border region more than doubled from 1,683 to 3,562 (Bloom 2000). During the same period, the number of people employed in the maquiladoras grew from 418,306 to 1,055,343. Most of this growth occurred between 1995 and 2000 (Bloom 2000). Despite a significant reduction in maquiladora-related trade between the United States and Mexico (approximately a 30% decline in production between 2000 and early 2002), in 2001 the maquila-related exports to Mexico were $46 billion while maquila-related imports from Mexico were $64 billion, according to the U.S. Government Accountability Office.

Growth in the maquila industry in Ciudad Juárez has led to growth in the service-oriented and maquiladora-related economies of El Paso (Cañas and Coronado 2002). Some of the economic growth in El Paso is offset by the 1994 signing of the North American Free Trade Agreement (NAFTA), which is blamed for the subsequent loss of manufacturing jobs in the traditional apparel industry of El Paso. In addition to being directly affected by the maquila industry, the economic health of El Paso also depends on the ability of Ciudad Juárez residents to cross the border, shop, and thus help support the retail economy of El Paso. For example, the devaluation of Mexico's peso in 1994 (reducing buying power of Ciudad Juárez residents) led to significant declines in retail sales in

El Paso (Cañas and Coronado 2002). More recently, the 2000–2002 downturn in the U.S. economy caused reduced demand for maquila products, thus leading to a significant loss of maquila jobs, which in turn caused decreased retail sales in El Paso. Timmons (1990) reports that one El Paso resident stated, "El Paso and Ciudad Juárez are Siamese twins joined together at the cash register. They are welded together, and you cannot do anything in El Paso that does not affect Juárez."

Unfortunately, the conditions that stimulate economic growth at the border have yielded lower per capita incomes and higher unemployment rates in El Paso when compared to elsewhere in the United States. Although per capita incomes in Ciudad Juárez are much greater than in the interior of Mexico, minimum wage rates are approximately 10% of that of El Paso (Peach and Williams 2000). At the same time, rapid population growth with inadequate infrastructure development (for example, water supply and wastewater systems) leads to unhealthful conditions and a poor quality of life for many Paso del Norte residents.

Cultural Context

The history of migration and settlement in Paso del Norte has led to a distinctive border community culture that reflects more than a century of contact and diffusion between people from the Spanish-Mexican North and Anglo-American Southwest. The Spanish town of Paso del Norte was settled on the south side of the Rio Grande/Río Bravo in 1659, 78 years after the first Spanish priests and soldiers traveled through the area. In the 1680s, the community was joined by Pueblo Indians aligned with Spanish settlers driven from the north. El Paso City was founded on the north side of the river by Spaniard Ponce de Leon in 1827. Americans from the north began moving to El Paso in the 1840s. Since that time, the town of Paso del Norte has become Ciudad Juárez, and the El Paso suburb of Sunland Park, N.M., has grown to the north and west of El Paso. Northward migration of Mexican nationals that began in the 1880s was reinforced by the 22-year-long Bracero Program (which started in 1942) and has continued to the present day through the recent and rapid expansion of the maquiladora industry in Ciudad Juárez.

In 1960, the cities of El Paso and Ciudad Juárez had an equal population of approximately 276,000 in each city. Since that time, however, more rapid growth through migration and natural causes resulted in the population of Ciudad Juárez doubling El Paso's and reaching 1.2 million. This ratio of populations is projected to continue through 2020, when the combined population of El Paso and Ciudad Juárez is expected to rise to about 3.6 million (Peach and Williams 2000). The northward migration of Spanish-speaking people has caused the El Paso population with Spanish-speaking origins to rise from 70% in 1990 to 78% in 2000. The other residents of El Paso are largely of English-speaking origins.

Although considerable intermingling of cultures has occurred, there remain distinct differences in the way those of Spanish-speaking and English-speaking origins approach life in the binational community. For example, Stoddard (1984) suggests that many of the elite from Ciudad Juárez are educated in U.S. schools, speak English well, and understand the principles and practices underlying the U.S. social and economic systems. These elites look to the United States as a source of values, ideas, and economic benefits from border trade and traffic. Meanwhile, influential El Pasoans of English-speaking origin may retain Spanish-speaking housemaids that influence some of their household context. Stoddard (1984) notes that the influential El Pasoans likely do not look to Mexico for new ideas and have internalized little Mexican culture.

Human Health

As a consequence of sharing natural and urban environments, the Paso del Norte communities also share an interrelated human health context. For example, residents in the shared watershed and air basin have the potential to contract waterborne disease or succumb to air quality-related respiratory complications that might be derived from the crossborder travel of contaminants or people, or might be a consequence of living conditions at the border.

The incidence of waterborne disease such as dysentery, hepatitis, and tuberculosis is greatest in *colonias,* which are unincorporated and largely unregulated settlements found on both sides of the border that lack essential services such as water, sewers, electricity,

paved roads, and safe and sanitary housing. The poor sanitary conditions of *colonias* are important contributors to the incidence of waterborne disease in El Paso County, which is higher than the national average. Because a water supply infrastructure is generally lacking or minimal, *colonia* residents often transport and store their own water, thus increasing the likelihood of contamination. The lack of adequate wastewater disposal systems also increases the likelihood of waterborne diseases spreading. Although it is clear that reducing the number of households lacking potable water and sewer systems will help reduce the incidence of waterborne disease, data are insufficient to quantitatively link the incidence of waterborne disease to the number of households lacking water and sewer infrastructure.

Airborne pollutants emitted from the cities of Paso del Norte, including significant contributions associated with border crossing congestion, mix with emissions from surrounding non-urban land and circulate within a complex, transborder air basin. The presence of air quality conditions that exceed regulatory thresholds imply a potential for heightened incidence of respiratory disease, including asthma. In the United States, El Paso is classified as a nonattainment area for particulate matter, carbon monoxide, and ozone. Pollutant levels in Ciudad Juárez are no less than those of El Paso (Emerson, et al. 1998; Li, et al. 2001). Nonattainment conditions continue to the present day in Paso del Norte, although air pollutant levels have been declining since the 1980s (Rincón and Emerson 2000). Although it is clear that increased emissions of criteria air pollutants will lead to less-healthy conditions, direct relationships are lacking between emission rates, pollutant concentrations, and the incidence of respiratory disease in Paso del Norte.

Because the community is an important migrant destination and crossroads for human travel, Crespin and Kallishman (1991) recommend that Ciudad Juárez, El Paso, and Las Cruces, N.M. (located 38 miles north of El Paso) be viewed as a single epidemiological unit when accounting for the transmission of communicable disease. Yet, language and cultural differences combined with different national approaches to immunization, vaccination, regular health care, and reporting practices complicate the ability to prevent the resurgence of vaccine-preventable diseases and other infectious conditions

(Brandon 1996). In addition, a complex pattern of health service usage and pharmaceutical purchase has evolved, with residents of one country accessing the resources of the other country depending upon relative availability, quality, and cost of the resource.

Efforts to Build Collaborative Binational Cooperation

It is generally assumed that improved quality of life in Paso del Norte is best effected through binational collaboration that leads to an increasingly integrated community context. Unfortunately, developing the collaborative networks in a binational context is difficult, time consuming, and not always successful. The past 125 years have seen a series of formal and informal collaborative initiatives emerge at both local and border-wide scales that have helped shape the Paso del Norte community. Some initiatives have been sustained while others have emerged only to disappear over time. Most initiatives strive, with reasonable success, to involve representatives of federal, state, and local governments from both the United States and Mexico. Principle areas of collaborative action include:

- Public health (e.g., Pan American Health Organization, U.S.-Mexico Border Health Commission, and Border 2012 Environmental Health Work Group)
- Water resources management (e.g., IBWC and the Paso del Norte Water Task Force)
- Urban planning (El Paso Metropolitan Planning Organization shares planning personnel with Ciudad Juárez's Instituto Municipal de Investigacion y Planeacion [IMIP])
- Environmental and natural resource management (e.g., La Paz Agreement, Border XXI Program, and Border 2012 Program)
- Air quality (e.g., Paso del Norte Air Quality Task Force and the local International Joint Advisory Committee on Air Quality Improvement)

Additional collaborative efforts to work on economic and environmental issues are embodied in NAFTA. Effective in 1994, NAFTA brought together 360 million consumers from the United States, Mexico, and Canada in a $6 trillion market. As a conse-

quence, trade tariffs between Mexico and the United States have been eliminated to enable the free flow of goods and capital. Yet, while goods and services move freely across the border, human migration across the border is restricted (Sadowski-Smith 2002). NAFTA was implemented with environmental side agreements intended to address the environmental consequences of increased border trade and development. These agreements led to the creation of the North American Commission for Environmental Cooperation (CEC), the Border Environment Cooperation Commission (BECC), and the North American Development Bank (NADBank). CEC works to alleviate regional environmental concerns, help prevent potential trade and environmental conflicts, and promote environmental law enforcement. BECC and NADBank were created to provide environmental infrastructure along the U.S.-Mexican border.

Overview of the Paso del Norte System Model

System Story

Explaining the prototype system model for Paso del Norte is best approached by first outlining the narrative, or story, that underlies the model. This narrative is founded on the historical overview provided in the previous section, combined with anticipated scenarios for demographic, economic, and environmental futures.

Local economic opportunity in Paso del Norte, driven by international opportunities for trade and traffic across the U.S.-Mexican border, is the fundamental source of change in the binational community. Although present since the border was established, border-driven economic activity has grown rapidly in recent decades through the establishment of maquiladoras, which take advantage of tariff elimination and wage rate differentials between the two nations. Economic growth, combined with population growth, has yielded concomitant growth in commercial and industrial jobs in both El Paso and Ciudad Juárez.

People have been drawn to the intertwined community of Ciudad Juárez and El Paso by attractive opportunities for employment. This attraction is enhanced because some are also leaving their traditional

homes in Mexico to escape dwindling agricultural opportunities, resource damage due to population growth, and political strife. Once in Paso del Norte, births within the relatively young population yield a high population growth rate. Each year, however, a portion of the growing population leaves the area to work and live elsewhere.

Population growth in Paso del Norte places increasing demands on local natural resources, including land, air, and water. Although following different patterns and rates of urban growth, both El Paso and Ciudad Juárez are consuming desert land and some former agricultural land. Both communities are emitting particulates and other air pollutants into the common air basin. On occasion, pollutant concentrations of ozone, carbon monoxide, and particulates exceed levels deemed unhealthful by both nations. The principal contributors to the particulate concentrations represented in the system model include the following: growing transportation emissions associated with the urban sprawl of El Paso, the rapidly increasing population in Ciudad Juárez, residential and industrial emissions, emissions from brick kilns supporting new home construction in Ciudad Juárez, particulates generated by traffic on unpaved roads, border crossing congestion, and the natural dust storms that often bring high concentrations of particulates into the community from the surrounding territory. The higher population density and greater intensity of urban emissions in Ciudad Juárez suggests that more people there are exposed to unhealthful, urban-derived air quality conditions than in El Paso.

Increasing urban water demand has caused declines in water levels and water quality in local aquifers. Methods for meeting the increasing water demand include conversion of Rio Grande water from agricultural to urban use, water recycling, desalination of brackish groundwater, aquifer recharge by reinjecting treated wastewater, water conservation, and water imports from other areas. El Paso is already experimenting with desalination and expects to have an operational, high-capacity desalination facility within the next two years. Meanwhile, lagging construction and maintenance of water supply and sewer infrastructure in the *colonias* of El Paso County and Ciudad Juárez increase the likelihood of unhealthful living conditions. Developing collaborative, community-based

approaches to resolving water-related issues is complicated by the need to deal with the overlapping national and state jurisdictions that administer water rights in the region.

A principal goal of the Border Plus Twenty Years (B+20) Program is to obtain insight about ways to improve quality of life for residents of Paso del Norte. Although cause and effect relationships can be identified between human health and the lack of sewer connections (or elevated air pollutant emissions), insufficient data are available to develop quantitative relationships between the incidence of disease and the number of sewer connections or magnitude of air pollutant emissions. For example, it is logical to expect that reducing particulate emissions from brick kilns and unpaved roads will reduce negative health consequences in both Ciudad Juárez and El Paso. Elsewhere, health researchers have identified direct quantitative relationships between contaminant concentrations and incidence of upper respiratory disease or asthma. However, the quantitative relationships needed to link emissions rates and contaminant concentrations in a modeling context are currently lacking. There is a similar lack in researchers' ability to link quantitatively the number of households without sewer connections to the incidence of waterborne disease. These quantitative relationships are lacking, in part, because insufficient surveillance data have been collected to characterize the complex interrelationships among emissions rates, contaminant concentrations, and disease. At the same time, it seems that public health agencies are focused more on reducing the incidence of health problems (such as diabetes, obesity, and drug use) that are less directly linked to the environmental conditions emphasized in the B+20 project.

Adopting a systems thinking perspective requires an attempt to identify the feedbacks, tradeoffs, and lags in the overall urban ecosystem that might lead to unintended consequences of the policy decisions designed to mitigate the situations previously outlined. For example, how might the combined effects of transferring agricultural land and water to urban uses negatively impact the agricultural economy, urban economy, or water quality? Might attempts to reduce urban sprawl through compact urban development in El Paso and Sunland Park lead to greater exposure to unhealthful air quality, but reduce total water use? If funding is limited, should efforts to

reduce particulate emissions be implemented instead of increasing the number of households connected to sewer systems? When evaluating the net health benefit, might the funds needed to pave roads, reduce automobile emissions, or increase the number of households with sewers be better spent in Ciudad Juárez than in El Paso?

Instigating change requires both funding and political will. At present it does not appear that community managers are evaluating the interagency tradeoffs that might be associated with deciding whether or not to invest in air pollution control versus water supply development. As water use outstrips water availability, investments are being made in the water supply strategies needed to supply the growing population. How will water managers maintain the level of funding required to keep up with the growing demand for water? Perhaps higher tax rates, water use fees, or federal subsidies will be required. Meanwhile, air quality strategies are afforded different priorities, draw on different funding sources, and are being designed and implemented by different agencies and people. The array of different policymaking, regulatory, and funding environments associated with water supply, air quality, public health, and urban planning inhibits communication between decision-makers from each arena. Thus, each decision-making and policymaking group in the air and water management arenas is proceeding along its own path to finding solutions within its media, but with active binational cooperation within each. This relatively independent approach to problem solving leads the B+20 team to ask: What interaction and interventions should occur between arenas that might lead to reduced overall costs and optimal solutions?

Questions to be Addressed

The B+20 project team has grappled extensively with attempting to define the systemic questions needed to configure the system model for useful explorations of alternate future scenarios in Paso del Norte. Input into this process has been provided by Paso del Norte stakeholders and decision-makers, SCERP managers and researchers, and others studying or living in the U.S.-Mexican border region. Although a broad range of questions were considered, two principal questions were ultimately identified by D. Rick Van Schoik, Managing Director of the Southwest Consortium for Environmental Research and Policy (SCERP):

1. Given the various state and national water management agencies involved in supplying water from common sources to urban communities and agriculturalists, what changes in agency policies and approaches might be made to increase the likelihood of achieving water sustainability and satisfactory quality of life for border residents?
2. Given transborder disparities in minimum wages and household income, what policies might be affected to increase the likelihood of providing a healthy economy and satisfactory quality of life for border residents?

These questions have led to the prototype Paso del Norte system model. The model represents:

- Population growth in El Paso and Ciudad Juárez
- Migration of Mexican nationals toward the border
- Variations in the local maquiladora economy in response to changes in the U.S. national economy
- Land use policies and urban growth processes
- Variations in water availability and quality in response to climate variability and water use
- Conservation alternatives
- Water supply infrastructure alternatives
- The dynamics of surface water rivers, reservoirs, and groundwater aquifers

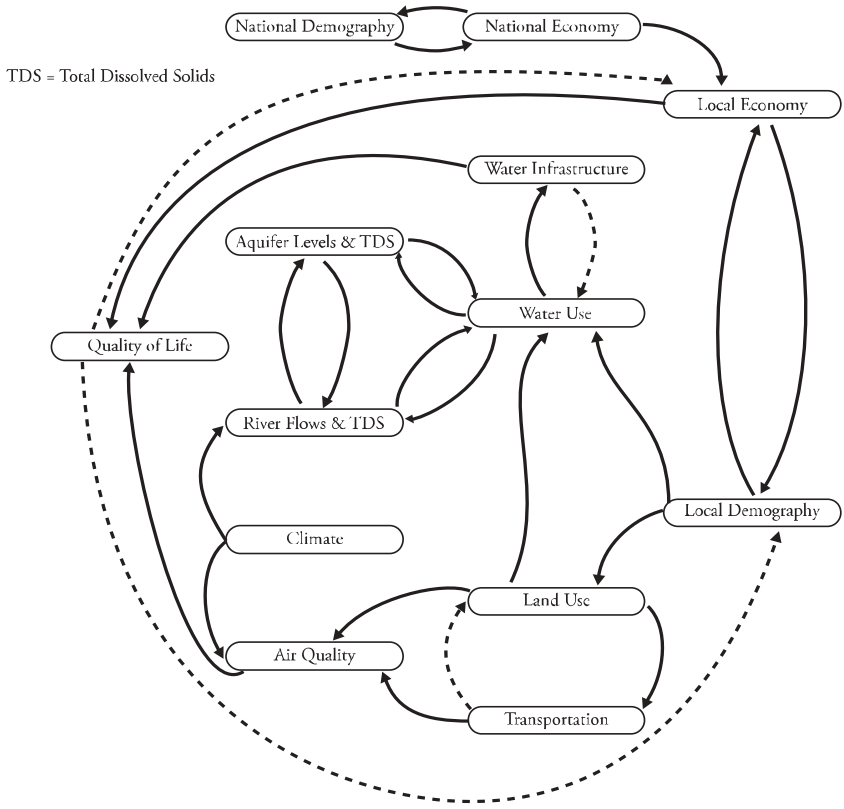
Idealized Map of the Paso del Norte System Model

Subsequent chapters in this section outline how different aspects of the Paso del Norte system—demography, economy, land use, transportation, air quality, transportation, water use, water availability, and quality of life—are incorporated in the system model. Figure 2 shows how the various sectors interact with one another in the model. Although the Paso del Norte system model continues to evolve, the following descriptions outline the model structure and operation at an earlier point during its development when all the key elements are incorporated and the system was operational.

Figure 2 shows the various sectors, or model components, incorporated into the Paso del Norte system model. It is important to note that most sectors contain internal relationships that represent the operation of binational processes that lead to transborder transfers of people, water, air pollutants, money, or goods. For example, the national demography sector accounts for population growth in both the United States and Mexico while accounting for the migration of Mexican nationals to the United States. Similarly, the local demography sector accounts for natural population growth in both El Paso and Ciudad Juárez while accounting for migration between each community and between the communities and the national populations. Analogous relationships are implemented for the national and local economy sectors. In addition, the river, aquifer, and air quality sectors account for the transfer of water and air between the United States and Mexico. Transportation, land use, and water and wastewater infrastructure operations and development in El Paso and Ciudad Juárez are assumed to operate quasi-independently on each side of the border.

The links indicated with solid arrows in Figure 2 are represented in the model at the stage of development described here. The links indicated with dashed arrows, and other model features not shown, are being incorporated to varying degrees in the current version of the evolving system model. As outlined in the system story, the economies of the United States and Mexico vary in response to changes in national and global economic conditions and population growth. The national-level economic variations are transmitted to

Figure 2. Schematic Map of the Links between Sectors of the Prototype Paso del Norte System Model



Note: Links shown with solid arrows are incorporated in the operational model while dashed links illustrate features being considered in ongoing model development.
Source: Author

the local economies of El Paso and Ciudad Juárez. The local economies, however, have a negligible impact on the national economies. Population growth in El Paso and Ciudad Juárez cause increased demand for potable water, sewage infrastructure, and urban land. Growth in urban land leads to road building in the transportation sector that in turn causes increased transportation-related particulate emissions that accompany increased emissions from stationary sources such as factories, brick kilns, ports of entry, and residential waste burning.

A complex interaction exists between the surface water, groundwater, agricultural, and urban elements of the hydrologic system. For example, a portion of the water extracted from the Rio Grande and groundwater aquifers for urban uses is returned to the aquifer system, after treatment, through aquifer recharge. The remainder of the water used is returned to the river after treatment. Thus, aquifer water levels, river flows, and water chemistry (represented in the model by tracking the concentration of total dissolved solids [TDS] concentrations) depend upon a variety of water management decisions that might include water conservation, water recycling, conversion of agricultural water for urban use, desalination of brackish aquifer water, water treatment technologies, and aquifer recharge strategies. Climate is represented in the model as an external, variable factor that causes changes in upstream river flows and river water chemistry in addition to affecting the windy conditions that control dilution of airborne pollutants in the air basin. The quality of life sector represents the ways changes in the local economy, water and wastewater infrastructure development, and air quality might affect the lives of Paso del Norte residents.

It is important to note that the prototype model structure shown in Figure 2 contains few mechanisms for feedback or interaction between groups of sectors. Several feedback mechanisms are indicated when the links represented by dashed arrows are considered. Dashed links include feedback between land use and transportation where traffic is induced by road building to reach sprawling suburbs (Emmi 2003). A similar positive feedback loop is anticipated to occur in cases where improved water supply infrastructure leads to increased per capita water consumption. Although discussed at length by the B+20 team, it is difficult to assess how feedback from

the quality of life sector might affect other sectors. For example, the team concludes that the unhealthy living conditions of workers likely exert only a weak influence on the health of the local economy. Similarly, unhealthy living conditions that lead to small increases in the death rate likely have little impact on local population growth rates. Furthermore, few people will likely be dissuaded from migrating to Paso del Norte, nor induced to leave, if economic conditions are advantageous but living conditions are poor. The economic attraction of employment opportunities in Ciudad Juárez are explicitly incorporated in computing migration of Mexican nationals to Paso del Norte.

Even if the dashed links shown in Figure 2 are incorporated in the model, the model structure fails to provide the mechanisms needed to evaluate tradeoffs and links between the various sectors (water supply, air quality, urban planning, and environmental health). Adding a public finance sector (which is under development) that accounts for how funds are generated and spent in public works and services will improve the ability of the model to represent links and tradeoffs between sectors. Because financial issues are often key factors in decision-making, additional links and model elements that help compare the costs of alternative policies will increase the ability to explore how decisions made in one arena might affect people through impacts in another arena. For example, adding the differential costs of delivering potable and recycled water to urban, agricultural, and industrial customers will also help improve the assessment of alternative policies. The B+20 team suspects that working to increase collaboration between decision-makers and policymakers in the various sectors, in addition to increased collaboration between countries, will enhance on-the-ground interaction and feedback that can be represented in the model. Additional stakeholder engagement is needed, however, to map out, characterize, and influence the possible links. Future stakeholder engagement processes should be designed to assess the barriers to communication that likely exist between decision-makers and policymakers in the arenas of water supply, air quality, urban planning, and public health.

Model Application

As configured at the time of publication, the Paso del Norte system model is operational and embodies the features outlined in this and subsequent chapters of this monograph. The user interface is readily accessible to those who receive limited training with the model concepts and model operation. The potential value of using the model to explore tradeoffs in the binational Paso del Norte urban ecosystem has been demonstrated to several stakeholder groups, including water managers, public health workers, air quality managers, city mangers, and urban planners, among others. As a result, the model is ready for use in a stakeholder engagement process designed to help the model developers tune it to stakeholder interests and improve the representation of feedback and links between model sectors.

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