The Economics of Non-Market Goods and Resources

Both Sides of the Border

Transboundary Environmental Management Issues Facing Mexico and the United States

Linda Fernandez and Richard T. Carson (Eds.)

The Economics of Non-Market Goods and Resources

Series Editor
Ian J. Bateman

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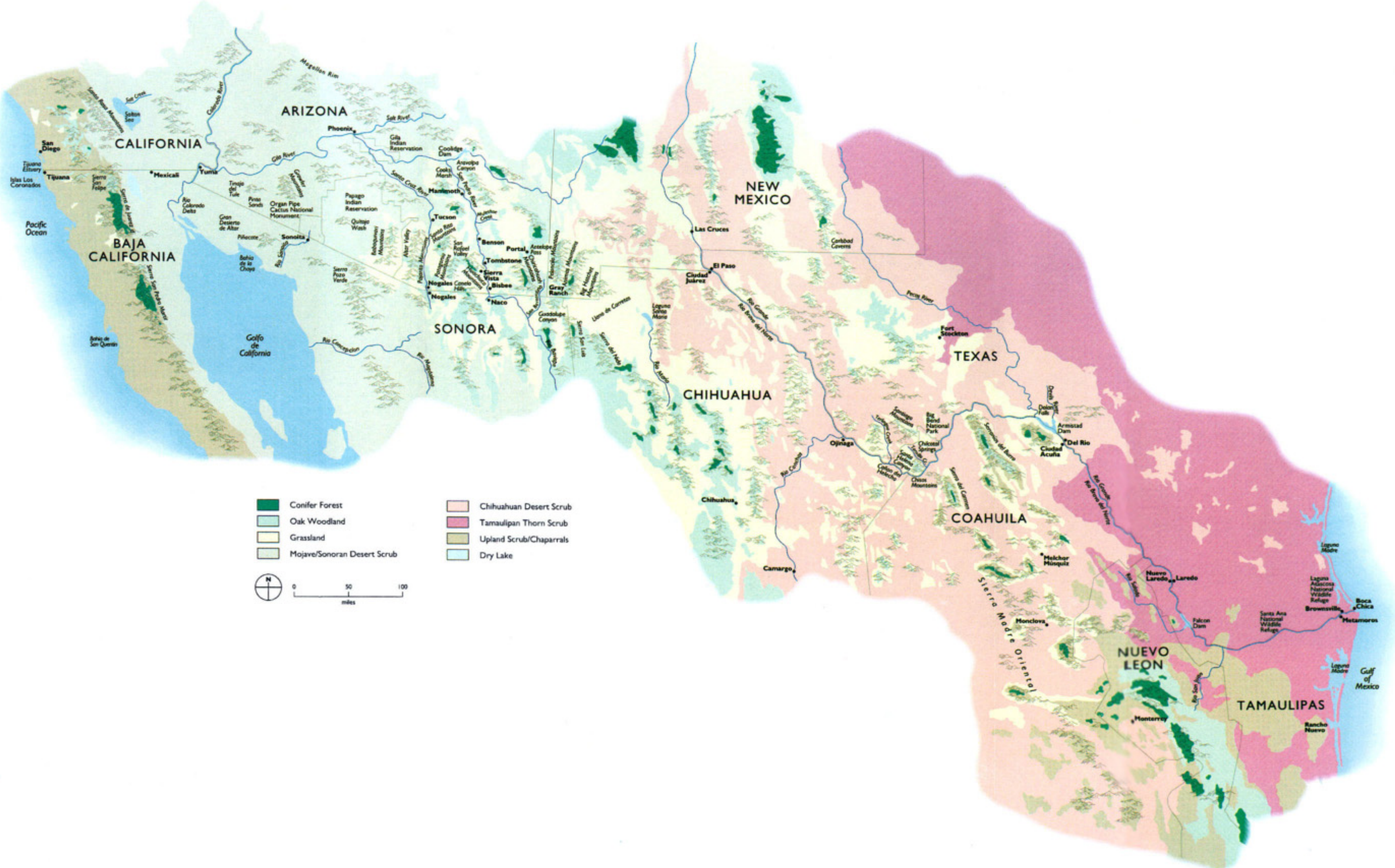
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BOTH SIDES OF THE BORDER

THE ECONOMICS OF NON-MARKET GOODS AND RESOURCES

VOLUME 2

Series Editor: Dr. Ian J. Bateman

Dr. Ian J. Bateman is Professor of Environmental Economics at the School of Environmental Sciences, University of East Anglia (UEA) and directs the research theme Innovation in Decision Support (Tools and Methods) within the Programme on Environmental Decision Making (PEDM) at the Centre for Social and Economic Research on the Global Environment (CSERGE), UEA. The PEDM is funded by the UK Economic and Social Research Council. Professor Bateman is also a member of the Centre for the Economic and Behavioural Analysis of Risk and Decision (CEBARD) at UEA and Executive Editor of Environmental and Resource Economics, an international journal published in cooperation with the European Association of Environmental and Resource Economists (EAERE).

Aims and Scope

The volumes which comprise *The Economics of Non-Market Goods and Resources* series have been specially commissioned to bring a new perspective to the greatest economic challenge facing society in the 21st Century; the successful incorporation of non-market goods within economic decision making. Only by addressing the complexity of the underlying issues raised by such a task can society hope to redirect global economies onto paths of sustainable development. To this end the series combines and contrasts perspectives from environmental, ecological and resource economics and contains a variety of volumes which will appeal to students, researchers, and decision makers at a range of expertise levels. The series will initially address two themes, the first examining the ways in which economists assess the value of non-market goods, the second looking at approaches to the sustainable use and management of such goods. These will be supplemented with further texts examining the fundamental theoretical and applied problems raised by public good decision making.

For further information about the series and how to order, please visit our Website
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Both Sides of the Border

Transboundary Environmental Management Issues Facing Mexico and the United States

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Foreword

The Mexican -- United States border represents much more than the meeting place of two nations. Our border communities are often a line of first defense -- absorbing the complex economic, environmental and social impacts of globalization that ripple through the region. In many ways, our success or failure in finding solutions for the environmental, social and economic issues that plague the region may well define our ability to meet similar challenges thousands of miles from the border zone. Border residents face the environmental security concerns posed by water scarcity and transboundary air pollution; the planning and infrastructure needs of an exploding population; the debilitating effects of inadequate sanitary and health facilities; and the crippling cycle of widespread poverty.

Yet, with its manifold problems, the border area remains an area of great dynamism and hope -- a multicultural laboratory of experimentation and grass-roots problem-solving. Indeed, as North America moves towards a more integrated economy, citizen action at the local level is pushing governments to adapt to the driving forces in the border area by creating new institutional arrangements and improving old ones. If there is one defining feature of this ground-up push for more responsive transboundary policies and institutions, it is a departure from the closed, formalistic models of the past to a more open, transparent and participatory model of international interaction. These models reflect a deeper commitment to democratic principles of participation and information sharing -- a recognition that our border institutions must serve a wider purpose than simply to represent the official views of two sovereign states.

Historically, bi-national institutions charged with managing natural resources were forced into narrow alleyways of allocation or allotment and steered away from the wider avenues of cooperative, long-range regional planning guided by ecosystem-based management principles. Slowly, inexorably, this is changing. As our border and regional institutions undergo a steady re-orientation, they are also beginning to glimpse the daunting complexity of incorporating a more holistic approach that acknowledges the relevance of social, economic, cultural and environmental forces in both the understanding of problems and the design of solutions.

To be sure, our transborder institutions play a relatively modest part among the larger cast of actors that ultimately will determine how effectively we address the many needs of the border region. Yet, small as they may seem, the importance of these institutions goes beyond their formal mandates. As models of cooperation, they have the ability to help channel and coordinate the thousands of cross-border cooperative arrangements that have proliferated in recent years. They are, in many ways, only the most visible tip of the iceberg, whose submerged foundations depend on the cooperative spirit of the inhabitants of the border area.

The important themes addressed in this text illustrate the often paradoxical, and always complex, nature of the challenges facing border institutions and the sustainable management of shared natural resources. Policies that contribute to unsustainable practices in one area may be tolerated to account for other interests elsewhere in the border where the roles are reversed; gross disparities in information available to the public and policymakers vary from state to state in both countries; and all too often patently unsustainable practices rooted in national management practices lead to a collective shrugging of shoulders when confronted with the prospect of trying to improve policies against the will of vested interests.

Facing these and other challenges, the authors focus on the region's natural resources that are the life and economy-sustaining component of sustainable development. The authors identify the driving forces that impact on these resources in the region. By bringing fresh ideas to the policy arena, the authors provide the new political administrations with another opportunity to attack root causes rather than treat symptoms. Far from a sterile academic exercise, this collection of essays represents a dynamic look at the forces shaping a region where all of us have a great deal at stake.

Greg Block, Director of Programs and Janine Ferretti, Excutive Director at the Commission for Environmental Cooperation and support from Ernesto Ruffo Appel, Mexico’s Commissioner of Border Affairs.

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The following prominent policymakers are important to the project: Greg Block, Director of Programs and Janine Ferretti, Executive Director of the Commission for Environmental Cooperation who wrote the foreword for the volume and Ernesto Ruffo Appel, Mexico's Commissioner of Border Affairs, who supported Block and Ferretti's efforts and is referenced throughout the conclusion section of the volume. The interest in having trinational policymakers represented in this volume serves the purpose of disseminating the papers to the policy arena where cooperation on environmental issues is implemented.

Ken Miller of California Department of Forestry, Keith Pezzoli in the Urban Studies and Planning Program at UC San Diego, and Francisco Lara, Visiting Scholar at the Center for U.S.-Mexico Studies, UC San Diego provided useful peer review and participation in the authors meeting that helped with finalizing a few of the paper drafts. C.R. Hibbs was helpful with contact information for a variety of the participating authors at the beginning of the project.

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The authors include their own acknowledgements in their papers contained in the volume.

A note for the map in the binding follows.
Map created by Steve Reineck after consultation with: Frank Reichenbacher and David E. Brown, "The Biotic Communities of North America, Central America, and the Islands of the Caribbean Sea" (unpublished map, courtesy of David Brown); David Brown and Charles Lowe, Biotic Communities of the Southwest" (U.S. Department of Agriculture, Forest Service, 1980); Roy Frye, Kirby Brown and Craig McMahan, "The Vegetation Types of Texas" (Texas Parks and Wildlife Department, 1984); Gaudencio Flore Mata, Jorge Jimenez Lopez, Xavier Madrigal Sanchez, Francisco Moncayo Ruiz and Francisco Takaki Takaki, "Mapa de Tipos de Vegetacion de la Republica Mexicana (Secretaria de Recursos Hydraulicos, 1971).

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Introduction

Borders were once seen simply as frontier buffers between countries. Today, many border areas are better viewed as bustling central commercial areas. These areas are often characterized by conflict rather than cooperation due to competing cultural, economic, and political interests. Problems frequently arise as a consequence of scarcity of natural resources and environmental degradation in transboundary areas (Worldwatch, 2000). Therefore, it is critical to study factors contributing toward environmental problems at the border and possible solutions to those problems especially in the presence of an ever-growing array of international policies and their accompanying institutions intending to foster economic, political and social interaction between countries.

The papers in this volume offer a variety of perspectives on the factors contributing to environmental concerns between the border of Mexico and the United States and the potential of different institutions and policies to deal with those concerns. While specific examples are used to illustrate issues, the case studies presented are grounded in theoretical and analytical frameworks from social science and natural science disciplines. Both academic and policy audiences can find inspiration from the well-rounded work contained here in thinking about how to develop and implement environmental policy in border regions around the world. The papers in this volume integrate natural science information and a social science perspective in the context of binational policy analysis. Different analytical techniques illustrate an array of approaches to dealing with integrated systems, and accounting for both the natural and social sciences. These papers provide examples for conducting integrated environmental analysis, making systematic and simultaneous use of social, economic, ecological and environmental data to account for critical linkages. They illustrate how different types of data and information can be used to improve all stages of planning and management. As such, the volume provides empirical support for the approach put forward by Kates *et al.* (2001) that argues that researchers should be asking and analyzing questions about environmental issues that integrate ecological and social policy components across different time and spatial scales. Crucial to being able to do this is identification of what impacts in economic, social, and environmental spheres are likely to identify feedback effects between them. Cases where impacts may be irreversible over long time horizons are particularly important.

The timing of the volume is ideal given the recent changes in the national administrations in Mexico and the United States, as well as changes in environmental institutions at the border, such as the ending of U.S. EPA's Border 21 program and proposals to revamp the North American Development Bank and the Border Environmental Cooperation Commission. The September 2001 meeting between President Fox and President Bush highlighted both presidents' recognition that Mexico-U.S. relations have entered into a promising time in history where both countries are aiming for mutual trust and cooperation in an authentic partnership of neighbors to address shared responsibility over economic, environmental, cultural and political connections at the border and beyond (White House, 2001). This volume seeks not only to identify problems but also to offer directions for carrying out binational solutions with attention to different scales (local, regional and international). It can help to advance the understanding of connections between relevant factors, with an eye toward promoting increased cooperation for border environmental protection. In Mexico and the United States, many academics carry out research that can contribute to environmental problem solving. This volume provides an avenue to present this work in a cohesive way.

Until recently, the relevant literature for the proposed volume has been scattered and difficult to synthesize. This has blurred vital connections between the different research efforts aimed at solving border environmental problems. Two recent volumes *Shared Space: Rethinking the U.S.-Mexico Border Environment* edited by Lawrence Herzog and *Environmental Management on North America's Borders* edited by Richard Kiy and John Wirth have begun to rectify that situation. This volume is intended to complement those two efforts by enhancing the range of evolving issues and analyses considered in a border context.

Kiy and Wirth's volume emphasizes integration of the continent and what this means for the U.S., Mexico, and Canada. They make particular reference to NAFTA's role in raising public awareness concerning environmental and natural resource issues and their role in trade agreements. Our volume addresses NAFTA and non-NAFTA related environmental concerns between the U.S. and Mexico along the border. Border environmental issues are addressed in terms of the quality of land, air and water (fresh, marine) resources, as well as flows of transportation, agricultural and industrial products, people, hazardous materials and resources (migratory aquatic and terrestrial species) that influence the environment at the border through pollution generation or resource depletion. Beyond identifying the problems, the authors of papers in this volume investigate public, private, government, civic, and academic actions to help deal with them. The authors provide an historical context for the various binational efforts made either through institutions, policies, actions at different scales to address the specific environmental topics highlighted. Therefore, this introduction will not provide a limited historical view but rather characterize the relevance of the analyses contained in the volume.

Significance and Relevance to Global Conflict and Cooperation

The U.S.-Mexico border region can serve as a model of what is likely to happen along other border regions as they become increasingly active. The U.S.-Mexico border is currently one of the most dynamic regions in the world. Large increases in economic activity have been accompanied by rapidly growing populations on both sides of the border and by increasing demands on the region's environment infrastructure. The first key question is whether the border's binational environment warrants binational action and, if so, what level of action and actors are involved? The level may range from low-level informal agreements for cooperation between border city pairs to complex international treaties. The challenges the U.S.-Mexico region faces in regard to current constraints as well as plans for future needs are likely to be relevant to other areas around the world with rapidly growing border areas with shared environments.

A particular feature of the U.S.-Mexican border is that it consists mostly of arid and semi-arid land surface traversed by a few main rivers as well as containing some important common coastal zones. This border is characterized by twin cities of large metropolitan areas facing each other. Residents of Ciudad Juarez, Mexico and El Paso, Texas drink the same water, breathe the same air and, to a large degree, share the same destiny (Hylton *et al.,* 2001).

The need for transborder cooperation across the U.S.-Mexico border follows from the growing global tendency for international boundaries to become zones of economic opportunity rather than simply buffers between nation states intended to restrict rather than encourage trade (SCERP, 1999). With this economic opportunity comes responsibility to address the stock and flow of resources in and out of the border area that affect the environment. Geography is a deciding factor in determining incentives to address environmental problems that differ along the border, such as upstream/downstream type impacts and shared effects to both countries. The border is distant from both national political capitals and various authors in the volume address the need for a change from centralized to regional decentralized political structure for decisions to drive environmental management with border players involved.

Herzog (1998) identifies a challenge for the twenty-first century focusing on sustainable development to "harness the economic potential of the border region without compromising either the quality of life for its growing population or environmental resources for future generations". Globalization, according to Herzog, involves more actors transforming the local border landscape and resulting in less local control and more environmental damage. Resources from outside the border area can lead to artificial increases in short term supply thus providing less local incentive to protect the resource. The influx of people as well as resources stresses the border. Outside financial flows and the physical importation of resources suggest that the local situation may not be in balance with respect to the costs and benefits of local economic decisions that impact the environment. Blaming globalization, however, ignores the fact that problems also stem from lack of formal identification of local property rights for environmental resources as well as from a lack of specific policy mechanisms that can help to internalize the scarcity value of environmental resources.

Even if neighboring countries did not trade, they would need environmental agreements for coordinated protection so long as they share the same environmental conditions. International trade with movement of people and products into a shared environment calls into question more variables and adds difficulty to coordinating protection of the environment. As an example, consider the manner in which trade revenues and taxes on Mexican maquiladoras might be channeled into financing border infrastructure that is lacking for protecting the border environment. Should all the citizens who benefit from the full blessings of free trade compensate the border region that pays the price in terms of the degraded environment and livelihood? Since the border is part of a larger, regional geographic area encompassing the economic activities the border supports, the resources to address border problems should come from that larger area served through trade. Widening the scope of financial resources from other areas pays recognition to the fact that border residents do not have the financial resources to cope with the environmental problems. The poorest region of the U.S. is along the border with Mexico. Still, minimum wages are 8 to 10 times higher and municipal budgets up to 50 times higher in the U.S. part of the border compared to its Mexican counterpart (SCERP, 1999).

The border must deal with the environmental impact of a constant flow of people, products and services that are destined for locations far from these cities (formally defined as beyond 100 km on either side of the international boundary line by NAFTA). For all of the volumes of transported flow, the U.S. Customs Service must monitor compliance with more than 400 laws and 34 international treaties, statutes, agreements and conventions on behalf of 40 federal agencies (Andreas, 2000).

Maintaining the flow of goods, people, information, capital and services across the border quickly, reliably and affordably has to be balanced with a concern for safety. Unfortunately, liberalizing economies, while facilitating the movement of products and workers also expedites passage for terrorists, small arms, drugs, illegal immigrants, pests and disease (Flynn, 2000). Many public health strategies aimed at managing the spread of disease require the identification and isolation of people, livestock and agricultural products that could place the general population at risk. Delays associated with intensified inspections along borders undermine the competitiveness of exports by supply chain disruption and raising transaction costs that include environmental costs associated with air emissions from mobile sources and congestion while passing through ports of entry (Andreas, 2000).

The tightening of border controls has happened at a time and place otherwise defined by the relaxation of state controls and the opening of the border, most notably through Mexico's entry into the General Agreement on Tariffs and Trade (GATT) in 1986 and NAFTA initiated in 1994. Noticeably left out of NAFTA are two of Mexico's exports: illegal drugs to North American consumers and migrant labor to U.S. producers (Andreas, 2000). Instead, tariffs on these smuggled goods are rising in the form of more intensive policing. The result has been the construction of a borderless economy and a barricaded border. The politics of opening the border to legal economic flows is closely connected to the politics of closing it to illegal flows. The enforcement challenge is the equivalent of finding a needle in a haystack; a haystack that keeps getting bigger and a needle that's becoming better at hiding (ibid.). U.S. imports from Mexico have doubled since the start of NAFTA in 1994 and most of this trade arrives via commercial cargo conveyances across the southwestern border. The more intensive and intrusive the inspection process, the longer the wait at the border. What is the optimal way to manage the flows of various kinds of imports? Varady *et al.,* and Halvey, Sciara, Martin and Lynch offer analyses in this volume of hazardous materials flows, border ports of entry management, transportation flows, labor flows and agricultural pest flows, respectively, that address binational and unilateral control at both the point of entry between the two countries and the point of origin where control might take place.

The Canada/U.S. border does not experience the problems common on the U.S/Mexico border of congestion, differences in language and units of measure, illegal flows of commodities and people and environmental ambient conditions. The U.S.-Canadian border is twice as long as the 1952 mile U.S.-Mexico border (Hylton, 2001). Besides a difference in standardized approaches on compliance and monitoring programs between Canada/U.S. that the Mexico/U.S. border does not share, a more fundamental difference is the distinct socioeconomic condition separating the neighbors on the southern U.S. border. The financial disparity between both countries and the scarcity of financial resources amongst U.S./Mexican border residents with low per capita income is profound. While there have been formal environmental agreements on both borders between the neighbors, the legal context and sovereignty issues have typically been handled at a lower level than the federal center. Until recently, this has been easier to carry out in Canada and the U.S., than in Mexico.

While there are differences between the southern and northern borders of the U.S., the northern border exhibits a greater attempt at cooperation on the part of the private sector, as well as local and national governments regarding transparent systems for tracking regional and global commercial flows. Regulators and enforcement officials can now conduct virtual audits of inbound traffic well before it arrives (Andreas, 2000). With tracking, greater security and accountability within transportation networks enables audits or targets for inspection well before any carrier arrives at the border. For example, to lower congestion at the border, U.S. Customs has begun experimenting with an automated clearance system that encourages carriers to provide advance customs documentation electronically. Revenue Canada, the Canadian customs agency, adopted a similar program in 1991 for single-load trucks. Companies that enroll in these programs and comply with their mandates receive immediate release of the cargo when their conveyances arrive at the border checkpoint. These systems are designed for high-volume, low-risk shippers, but might be adapted for people as well (ibid.).

Population in border cities continues to rise, especially in Mexico due to the economic engine at the border and presence of employment opportunities. Mexico experienced a peso crisis in 1994-5 that plunged it into its most severe recession in over half a century. The devalued peso lost over half its value in dollar terms. This translated into much lower production costs in Mexico. Maquiladora activity doubled from 1994 to 1998 encouraging high rates of internal migration from the interior of the country to the border for employment in the maquiladoras (Salas, 2001). The Ciudad Juarez-El Paso twin cities population of two million makes up the largest border community anywhere in the world. It has recently been growing at an unsustainable rate of 5% per year (Hylton *et al.,* 2001). While Mexico's border population is currently less than 6% of the whole country, in 25 years it is expected to be approximately 40% of the country's total population (ibid.). In 2000, the border region was estimated to have a population of approximately 11.8 million consisting of 6.3 million on the U.S. side and 5.5 on the Mexican side (Clement *et al.,* 2001).

This population growth started long before NAFTA and even before Mexico and the U.S. entry into GATT in 1986. Under Mexico's Border Industrialization Program, the maquiladora program initiated in 1965, certain corporations are permitted duty-free imports of raw materials, equipment, machinery, replacement parts and other items required for the manufacture or assembly of finished goods to be exported back to the country of origin (predominantly the U.S.). This program was designed to capitalize on availability of goods and inputs for production for both the U.S. and Mexico at the border, creating a clear interdependence of production among both countries. The U.S. could access low cost labor and low taxes in Mexico through establishing maquiladoras on the border. Empirical analyses suggest that concentration of firms at the border is due to better accessibility of both market to labor, logistical coordination and transport (Krugman and Hanson, 1993). The combination of the dynamics of population growth and changes border characteristics makes a geographic information systems (GIS) approach of analyzing different variables of importance in a visual mapping mode appealing.

The 25 U.S. counties and 38 Mexican municipalities of the border vary greatly in terms of economic and demographic structure and size (Clement *et al.,* 2001). The large twin cities, Tijuana-San Diego and Ciudad Juarez-El Paso differ from smaller communities in significant ways including transportation and distribution resources serving international traffic through the ports, as well as a large government sector with such activities as border enforcement, immigration and naturalization, and customs. However, all border communities face shortages of water and more recently energy resources such as electricity and natural gas. The increasing size of the border population serves both as a source of constraints on what can be done with the resource, and at the same time makes the resource more valuable over time. Rapid growth has not only overwhelmed the capacity of all municipalities to respond, growth in basic infrastructure such as water, wastewater, solid waste, and electricity has failed to keep pace.

Organization of the Book

This book includes six sections. The first section explores the critical linkages of institutions and policy with the border environment. The papers in this section provide an historical context for the provisions and terms of specific institutions and policies at different scales, local, binational and international. The authors offer empirical analysis of the institutions and policies that in theory and practice are thought to promote environmental cooperation. Papers in the second section describe socioeconomic conditions on both sides of the border in terms of people and resources. Papers in the third section present an analysis of scarce water resources in various border watersheds in terms of quality and quantity. Papers in the fourth section address air pollution, transportation, energy and hazardous materials. Papers in the fifth section address the management of biological resources, land and aquatic habitats along the border. The sixth section provides the editors' concluding thoughts and suggests directions for future research.

The *Law, Politics and Institutions for Environmental Mandates for the Border* section contains three papers. In the first paper, Mark Spalding discusses legal and political issues of policies and regulations established to solve environmental problems as well as policies to address environmental effects of production and transportation of the products impacting the border corridor. He highlights proactive ways to improve institutional response to environmental problems and address sustainable development.

The second paper by Nicole Carter and Len Ortolano provides an analysis of the performance of the environmental institutions set up with NAFTA to formally address environmental problems on the border that can be assessed based on their activities (capacity and responsiveness) to date. Funding of these institutions and their activities calls into question financial stability of local and imported support. They investigate the Border Environmental Cooperation Commission and the North American Development Bank. These NAFTA institutions were set up through a side agreement focused on the problems manifested by liberalizing trade. One needs a fundamental focus on monitoring cumulative impacts, along the border with a strong understanding of what constitutes a baseline of environmental quality, as well as the financial resources needed to carry out environmental projects. In this way, institutions can focus on improving the border environment rather than just responding to NAFTA fallout. This paper provides an interesting perspective on the accomplishments, limitations and adaptive management responses of binational cooperation.

The third paper by Roberto Sanchez discusses the Mexican perspective of binational efforts to solve border environmental problems before NAFTA and with NAFTA. He identifies gaps and strategies to improve joint activities by SEMARNAP and U.S. EPA to address border issues by focusing on local resources and participation. Local empowerment to address environmental problems is lacking and there is significant dependency on the federal and state financing and authority. A necessary step towards progress is to monitor and evaluate programs like Border 21 in order to better orient environmental management with continuity of players involved in workgroups such as the Paso del Norte Air Quality Group to be presented by Carlos Rincon in this volume.

Characteristics of the Border Community as an Influence on Environmental Policies section contains three papers. In the first, Chris Gianos applies a comprehensive geographic information system (GIS) database of socio-economic, demographic, and environmental resource characteristics of communities on the entire U.S.-Mexico border to analyze the impacts of various environmental projects. These projects are scheduled to be implemented by public resource management institutions addressing border environmental problems. The analytical method offers a new and useful way to integrate natural and social science information. Much of the scientific information and socioeconomic data is complex and in its original form not easily interpreted by other than specialists in one field. The data is often linked to a specific location and GIS helps in a policy arena to analyze and compare data in a map venue.

In the second paper Carlos Velez Ibanez and co-authors provide an empirical analysis of the colonias (shanty towns) on both sides of the border. These present specific challenges for environmental management to address different land tenure and population dynamics affecting investment in environmental infrastructure. The authors delineate the physical, political and cultural aspects of these marginal subdivisions with their varied residential population along with the constraints on formal channels for administering utility services and financing maintenance of them, as challenges to border environmental programs.

Phillip Martin provides an analysis of factors including income disparities between the two countries that promote the migrant population flow which add to environmental pressures on the border. Through identification of the factors, it is possible to analyze strategies for augmenting the migration. The primary incentive for illegal immigration is employment (U.S. Department of Labor, 1994). The devaluation of the peso further widened the U.S.-Mexico wage gap, increasing the incentive for Mexicans to migrate to earn dollar wages in the United States. Mexico has become dependent on exporting part of its unemployment problem just as many U.S. employers have become dependent on the cheap labor provided by Mexican workers. The legacy of the Bracero program was the institutionalization of large-scale labor migration from Mexico to the U.S. (Andreas, 2000). An immediate consequence of the Bracero program was that the promise of guaranteed employment unintentionally encouraged illegal border crossings. When the Bracero program ended, it was replaced by an informal process of illegal immigration for both rural agriculture and urban-based activities. Workplace enforcement of labor standards and employer sanctions are the instruments for reducing that incentive. Peso devaluation and recession exacerbated the wage differential between the U.S. and Mexico and fostered illegal immigration in the face of economic growth in the border region (Yucel, 2001).

The *Border Water* section of the book contains five papers. They address problems of sharing water quality and quantity along the entire U.S.-Mexico border from various perspectives. Two fundamental concepts recur: (1) water resources require adequate recognition of scarcity and value, and (2) free resources are degraded. In the first paper, George Frisvold and Margriet Caswell describe the history of formal border agreements on water quantity and quality issues and discuss the different institutions that focus on them. They apply a game theoretic framework with concrete results for future interactions over water between the two countries in a region with persistent poverty.

In the second paper, Helen Ingram and Suzanne Levesque provide an analysis of the Ambos Nogales area of the border (Arizona and Sonora states) that investigates the strategies to deal with shared water quality and quantity constraints. The specific characteristics of having a border between two hydrologically linked communities presents challenges to immediate solutions yet forces mutual efforts for scarce water management in the urban desert. Water is the vital resource for which binational efforts offers the potential for overcoming divides introduced by political boundaries.

In the third paper, Linda Fernandez focuses on economic incentives that foster protection of border waterways and other environmental resources through trade policy and institutions (under NAFTA). Empirical analysis of efforts to internalize and prevent waste in production and consumption of traded goods due to elimination of trade barriers is explored. Cotton and textile production is examined for the changes in trade policy and the resulting financial incentives that lead the U.S. and Mexico to address wastewater emissions in a shared border watershed.

In the fourth paper, Suzanne Michel provides a case study of the Tijuana River watershed with critical details of how wastewater, water transfers and stormwater drainage can affect the binational hydrocommons of Tijuana, Mexico and San Diego, California. The dramatic impacts of imported water resources changes the human and natural responses to local water resource quantity and quality management. The perception of availability of outside water leads to unlimited demand and excess use in the urban setting.

In the fifth paper, Jim Booker and Frank Ward take a forecasting approach to predict what kinds of instream flows and protection for aquatic habitat will result from different water quantities, institutions, and economic incentives at upstream and downstream points along the Rio Grande. Combining water flow and economic modeling leads to an informative integrated assessment for a binational watershed.

The *Air, Transportation, Energy and Hazardous Materials* section of the book contains five papers. The first two look at particular airsheds as well as an entire border scale of analysis that link flows of economic activities and air emissions from mobile and stationary sources to the stock of air at the border. The topic of air quality along the border is important for airsheds shared by the U.S. and Mexico that receive emissions from fixed sources such as industries and energy utilities plants, and mobile sources (vehicles) of pollution. The diffuse nature of such emissions requires cooperation and strategies for controlling and preventing such emissions. The paper by Carlos Rincon and Bob Currey provide an analysis of the *Paso del Norte* voluntary binational group for implementing air pollution control in the largest shared airshed on the border: five counties in Texas, two counties in New Mexico and two municipalities in Chihuahua, Mexico. The increase of economic activity on the border has generated political and social awareness and civil action that is often ahead of central government. This program is an excellent example of civic science. Here stakeholders in an air shed work in partnership with binational scientists to define goals and objectives and apply data into effective resource management.

Richard Halvey's paper straddles both air quality and transportation issues. It focuses on congestion at border ports of entry and exit from transport of people, products, and services, as well as pollution problems and plausible solutions. Halvey provides useful distinctions between four twin city ports along the border with comprehensive fleet data and transportation modeling linked to air quality measures.

Gian-Claudia Sciara offers an analysis that distinguishes NAFTA induced transportation effects from other influences in order to determine the infrastructure deficit directly related to international trade transportation along the U.S.-Mexico border. Transportation of the goods and the people is the key mobile source of energy use and pollution generated at border ports of entry and exit.

Martin Pasqualetti and Soll Sussman contribute a comprehensive perspective on current and future energy demand and supply alternatives that are truly binational in generation, transmission and distribution stages of energy use. Energy attracts new enterprises and new residents and can help shrink the socioeconomic chasm that separates the two countries. Border cities like San Diego have been limited in their ability to import power because they are not connected to the U.S. electricity grid so the opportunity to supply natural gas to fuel plants in Mexico that supply electricity to both sides of the border makes sense.

The topic of hazardous materials in production and transport along the border is a significant one. There is a serious threat and to public health and the environment from improper shipping and disposal of solid and toxic materials, including waste. In the interest of promoting waste management for existing disposal sites and pollution prevention for waste generators (industrial and others), it is helpful to investigate the strategy for binational monitoring of hazardous materials movements and enforcement of import/export regulations. Robert Varady, Patricia Romero Lankao and Katherine Hankins offer analysis of policy strategies to deal with interdependent aspects of hazardous materials management between the two countries. The production, transport and disposal of hazardous materials are addressed with an identification of key institutional processes and policies in both countries. The new federal administrations in both countries appear to favor decentralization which could help foster more financing and citizen participation in decisionmaking related to hazardous materials.

The last section contains four papers centered on *Management of Biological Resources and Habitat Protection* in binational context. Land and forest management is dealt with first, as it is central to addressing natural and human impacts on the environment along the border. Richard Minnich and Ernesto Franco offer a comparative analysis of fire management and forest sustainability on both sides of the border. Their spatial and dynamic investigation provides compelling suggestions for optimal fire prevention and suppression efforts, both physically and financially.

Another important topic is that of migratory species protection. Species take no account of political boundaries but face alarming rates of reduction in numbers and degradation of habitat on both sides of the border. The domain in which these migratory species live is characterized by open access to resources where the difficulty of monitoring and enforcing against rampant harvesting prevails. Mark Spalding provides a description of the ecological, legal, and institutional factors contributing to possible strategies to protect the migratory whale population between the U.S. and Mexico given current threats of harvesting, alteration of habitat through development of salt mining and commercial activities, and others. Environmental awareness for protecting threatened habitat translated into legal action for the whales. Much of the effort to marshal public opinion in the U.S. and across the world on behalf of the whales was the work of Mark Spalding who acted as a consultant for environmental groups that oppose the (salt) project in Laguna San Ignacio, Baja California (Feriss, 2000).

Peter Dutton, Laura Sarti, Rene Marquez and Dale Squires form a binational collaboration to provide a description of U.S.-Mexico cooperation on management of marine turtles on coastal land and at sea between California and Baja California. With ample detail of the turtle's life cycle as well as various factors affecting the quantity and habitat of Kemp's Ridley and leatherback turtles, the authors identify the plausible policy strategies on international, binational and local scales for marine and beach protection of the species.

Invasion of terrestrial and aquatic habitats by alien species destroys native ecosystems and inflicts economic damage running into billions of dollars annually. The topic of agricultural production and pest migration is a multi-billion dollar problem. The magnitude of trade between the U.S. and Mexico in agricultural products is substantial and represents the largest pathway for transferring both insect populations and human migrant populations across the border. Loretta Lynch provides research through an analysis of cooperative strategies to deal with "hitchhiker" pests on traded agricultural crops at the border, exploring specific policies that involve bilateral enforcement and monitoring efforts. The regulatory and economic infrastructure to control this possible threat involves international and local legal and market players. For the pest populations, the sanitary and phytosanitary standards of the GATT and its successor, the World Trade Organization as well as the product standards under NAFTA set rules for the agricultural trade that includes attention towards the spread of pests through passage on agricultural crops.

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PART I

LAW, POLITICS, AND INSTITUTIONS FOR A BORDER ENVIRONMENT

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Improving Institutional Response to Environmental Problems

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Introduction

For many, globalization and its combined engines of trade liberalization, economic restructuring and rapid growth are a threat to natural resources and the fabric of natural ecosystems. At the same time, such globalization is synonymous with the expansion of multinational corporations whose far-flung operations transcend national borders and allegiances. This creates a feeling of lack of control, or certainly of rapidly changing relationships between governments and the governed.

Industries along the Mexico-US Border, with their low-cost manufacturing and assembly sector location within easy, direct access to the world's largest consumer market are links in international supply chains. As such, the region has clearly begun to feel the significant growing pains associated with globalization. Numerous researchers have already mentioned, studied, and documented the myriad of serious impacts on the environment in the border region, many of which are the result of globalization in one form or another. We can divide these impacts into two main categories:

- Overuse or depletion of natural resources – land, water, biodiversity, loss of solitude
- Pollution (as a human and ecosystem health issue) – air, water, waste production, nuclear waste, food safety, noise

While some problems are localized, many are transboundary in nature. The main causes of the environmental problems are interlinked with the growth of urban populations as well as the constant development of new industry and associated activities. For example, with the expansion of the maquiladora industry, there has been an increase in industrial waste as well as an increase in human waste from population growth in the area. Unfortunately, the region has not yet focused on the proper management of its growth. The region needs an integrated ecosystem approach and rational land use planning, all coupled with incentives that will improve quality of life without resorting to the constant chase of absolute growth. Tradition border region policies intended to foster growth for growth's sake are doomed to repeat the failures of the past in which there are shortfalls in planning and infrastructure relative to that growth.

In some ways the border is no different, in terms of runaway growth, than any other parts of the Southwest. The same comments could be made about Los Angles or Phoenix. However the border is unique. It has interdependent, but asymmetric needs and desires. It also lacks the money and power and resources at the local level to deal with the problem – and this is what makes its version of the growth problem especially worrisome.

One area of confusion in the border growth debate is the word itself. "Growth" actually has meanings. Discussion about growth issues can proceed intelligently only when those two

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meanings are distinguished. The words assigned to those meanings are "expansion" and "development." Physical enlargement—more people, infrastructure, buildings, subdivisions, malls, etc., which may or may not benefit the community—is called "expansion." In contrast, "development" means betterment: living-wage jobs, increased income, greater savings and excellent quality of life.[2] There is plenty of room for improved management of the status quo to seek development and not expansion.

This paper briefly reviews the structural and environmental problems of the region, and attempts to list many of the federal agencies working on those problems, and note the difficult circumstances of the Indian Tribes in the region. This is followed by a more detailed analysis of the efficacy of the binational and trinational efforts to coordinate these disparate agencies and their work. The paper then closes with an attempt at suggesting how Mexico and the United States can improve their respective institutional responses to transboundary and border region environmental problems, as well as some thoughts on why this should be done. For those who seek an in-depth analysis of any particular aspect of this chapter, please note that much of it is drawn from the author's previous work, which is listed after the conclusion. The earlier writings support this more analytical piece without having to resort to repetition.

Structural Problems

In the border region we must ultimately address fundamental structural problems. The two sides of the border have different political systems, legal systems, tax policy and cultures. Generally speaking there are too many players at multiple government levels with conflicting goals and authorities, and too few existing cooperative projects. Most importantly there are no overarching plans to address the growth in the region. The result is unmanaged growth, pollution, and sprawl, which lead to overuse of water resources, air contamination, and damage and alteration to land resources.

We are operating with a lack of political will to reverse perverse subsidies[3] and with unsustainable assumptions and trends built into our economic structure, such as ever-expanding consumption. There is an almost complete lack of long-range planning, certainly a significant lack of ecosystem planning, and very little watershed analysis and management. Among other consequences, we risk political instability through failure to address degradation of fragile ecosystems as happened in Chiapas.

We are engaged in ongoing new construction of housing developments, paving over habitats. We construct new highways paying limited attention to public transportation or to urban sprawl, and we constantly add new economic development without regard to its impact on natural resources, or its cumulative impact on human health. Finally, developers, who were prevented from undertaking some new projects in the US are expanding to Mexico, which had previously been somewhat protected by limitations on foreign investment and especially by land ownership restrictions for foreigners along the coastlines and in the border region. All this development is happening amid shortfalls in financing for environmental infrastructure.

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[2] Paul Ganster, Alan Sweedler, and Norris Clement distinguish between these two concepts in their paper, "Development, Growth, and the Future of the Border Environment" in Ganster, Paul (Ed.) *The U.S.-Mexican Border Environment: A road map to a sustainable 2020* Southwest Center for Environmental Research and Policy/San Diego State University Press (2000).

[3] Improper incentives used in the blind search for economic expansion, e.g., water use fee waivers and other counter-productive subsidies.

Historically, environmentalists have opposed development, yet they have slowly begun to see that poverty often exacerbates environmental degradation and vice versa. Indigenous peoples in many countries cut trees in national parks and protected areas for use as firewood, clear rainforest for farmland, and so on. Impoverished colonias near border industrial zones are nightmares of untreated sewage, uncontrolled runoff, and land denuded of topsoil. We must find ways to alleviate poverty and its threat to the environment without harm to society, culture, or biodiversity. This effort will undoubtedly include an emphasis on sustainable development including long-term planing and public participation, and some grants or other financial assistance directed toward those in need.

As undeniable as poverty's environmental consequences may be, they pale in contrast to the problems caused by excess consumption, as demonstrated by a comparison of natural resources used and waste created in San Diego and Tijuana. Average water consumption in Tijuana is at the level the World Health Organization defines as necessary for human health. The average in San Diego is six times higher! Likewise, per capita waste generation on the US side is of a magnitude difference than Tijuana.

Environmental Problems

There are numerous environmental problems in the border region. They are not necessarily unique, but in some ways their causes and current barriers to solutions are unique to the border region. A listing of the region's environmental problems is set forth in Table A below. In summary, there are numberless contaminants produced in the region, including heavy metals and other hazardous materials, solid waste, excessive nutrients deposited into soil or water, as well as chemicals and particulates emitted into the air. These contaminants come from both point (identified, non-mobile) and non-point sources. The major point sources are individual industries, wastewater treatment facilities, petroleum and energy activities, and from legal and illegal disposal sites. The non-point sources include automobiles, storm water/urban run-off, and atmospheric deposition sources. In addition, there is ongoing loss and alteration of critical habitat.

Table A - Environmental Problems

Environmental Categories	Border Specifics
Water Quantity	• Communities and states fight over the scarce water supplies and other natural resources. • At current growth and consumption rates, the water supply in some communities is expected to be exhausted in 20 years. • There is a lack of proper water conservation, reclamation and prioritization of uses. • There has been a history of excessive and ill-planned diversion/diminution of natural water flows.
Water Quality	• Ground and surface waters are significantly contaminated. There is a related great and increasing need for municipal wastewater and industrial pretreatment. • There are some failures to upgrade wastewater treatment systems to comply with the Clean Water Act. • The Mexican side has struggled for over 50 years to provide sewage collection and treatment facilities for its exploding urban population. • There is extensive urban runoff, non-point pollution, as well as some runoff from the use of agricultural chemicals and pesticides.

Other Waste Problems (land-based pollution)	• There has been extensive dumping of heavy metals and toxic chemicals on land. • Only a portion of this waste is disposed of properly. There has been lax enforcement of Mexican environmental laws regarding dumping. • There is some evidence of illegal dumping on Indian reservations. • There are increased conflicts regarding siting of dumps, waste treatment or other operations in minority neighborhoods. • There are missed opportunities for recycling of maquiladora waste and byproducts.
Air pollution	• Air quality is being harmed by power generation in Mexico that does not use state of the art production methods or clean fuels. • There is long distance transport of air pollution. • The management of the El Paso/Juarez airshed basin has become crucial. • There has been lax enforcement of Mexican environmental laws regarding air pollution.
Climate Change Induced Problems	• In San Diego/Tijuana we can expect increasingly violent coastal storms with greater precipitation. • In the interior portions of the border region we can expect increasingly severe droughts. • There will be an impact on terrestrial natural resources. • There will be an impact on ocean fisheries - warmer water affects migration patterns.
Ecosystem/Habitat Destruction	• There has been extensive alteration of natural systems, including the coastal habitat and the diversion of rivers. • Improper attention has been paid to the location and size of ports of entry. • There has been construction in alluvial areas. • There is serious urban sprawl. • Habitat destruction causes in-migration and immigration and political instability. • There has been overuse of the environment as a sink for pollutants - uncontrolled dumping on land, in rivers, and into the surf - resulting in habitat deterioration.
Threats to Biodiversity	• Mexico and US are host to many endangered plants and animals. • There has been little funding in Mexico to administer natural protected areas.[4] • There has been lax protection of already designated conservation areas. • There are conflicts over protection of shared migratory species and their habitats.

Federal Agencies and Indian Tribes

The two federal lead agencies on border environmental issues are:

- US Environmental Protection Agency (EPA)
- Mexico's Secretaría de Medio Ambiente, Recursos Naturales (SEMARNAT)

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[4] Twelve countries contain 70% of the world's biological diversity, of these Mexico ranks fourth in the world after Indonesia, Brazil and Colombia. It boasts more than 10% of the world's birds, more than 10% of the world's mammals, and more than 10% of the world's plants. Furthermore, 32% of Mexico's terrestrial vertebrates and 40-50% of her plant species are endemic. This biological richness results from great habitat variation and diverse ecological regions, complex topography, climate, geology and geographical location. Ecosystems range from deserts to rainforests and mangrove swamps. (The World Conservation Monitoring Centre 1997)

However, technically they must work through the US Department of State and the Mexican Ministry of Foreign Relations. In addition to the lead agencies, there are a number of other Mexican and US federal agencies involved in border environmental issues:

United States	Mexico
Attorney General	Attorney General for the Environment (part of SEMARNAT)
Department of Agriculture	Secretariat of Agriculture
Department of Commerce	
Department of Defense	(Mexico's Navy has been involved in some water quality monitoring in the border region)
Department of Energy	Secretariat of Energy
Department of Health and Human Services	Secretariat of Health
Department of Housing and Urban Development	
Department of the Interior	(natural resources and Mexico's National Water Commission are part of SEMARNAT)
Department of the Treasury	Secretariat of the Treasury

Tribal natural resources are considered under US federal law and policy to be the property of the Tribes. In the contiguous United States, most Indian people live on or near Reservations that are held by the United States in trust for the Tribes. Although federally owned and ultimately subject to federal law, this trust land is not public land and is subject to different law and policy even though it may often be checkerboarded or abutting public land controlled by a federal agency such as the National Park Service, US Forest Service or Bureau of Land Management. Of critical significance are the facts that Tribal governments are the primary managers of Tribal trust land and Tribal natural resources located both on and off current Reservations, and that all federal agencies and departments must consult with Indian Tribes on a government-to-government basis before taking any action which affects Tribal members, lands or other resources.[5]

In Mexico, Tribes do not have the same recognition as in the US. Officially, only those persons who do **not** speak Spanish are considered to be indigenous. Tribes view this differently and are currently seeking autonomy in some form.[6] However, at present Indians and Indian land in Mexico is governed by federal, state, and local environmental laws. To make matters worse, the border splits some of these Tribes' traditional lands and thus there are communities affiliated with members of the same Tribes who live in the US and in Mexico.

Binational and Trinational institutions

The environmental administration and regulation in the border region is a confusing mosaic of international, federal, tribal, state, and local agencies and jurisdictions. It is often difficult to determine which agency is responsible for which environmental problems. Two very

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[5] Tribal natural resources attorney and consultant Marta Burg provided this information.

[6] At the time of this writing, President Fox has convinced the Mexican Congress to consider a bill regarding the rights of indigenous peoples in Mexico and together with the Congress has invited and allowed the Zapatistas from Chiapas to participate in the Congressional debate.

different political systems meet at the border. Mexico is highly centralized and thus there are few direct governmental and administrative counterparts across the border.[7] To make matters worse, transborder cooperation is not always a high priority. As we can see from the sections above, there are many federal government actors in the border region. When one adds to this, tribal governments, state agencies, local, and municipal agencies in the border region the potential for confusion becomes overwhelming. This is not to mention the non-governmental organizations or the academic or the private sectors. While all these other sectors are important, Table B focuses on binational and trinational institutions that may bring all these actors together. This is followed by a discussion of their relative success to date in doing so.

Table B: Binational and Trinational institutions

Institution and Date	Description
The International Boundary and Water Commission (IBWC) 1944	The principle binational agency with authority over territorial limits, water allocation, wastewater treatment, sanitation, and water quality.
The La Paz Agreement 1983	Established a framework for cooperation on specific environmental pollution problems. Formal workgroups comprised of federally appointed governmental and academic experts target their policy recommendations toward water, air, contingency planning and emergency response, hazardous waste, enforcement cooperation, and pollution prevention.
Integrated Border Environment Program (IBEP) 1992-1994	Proposed strengthening enforcement of environmental laws, increased cooperative planning, completion of expansion of wastewater treatment facilities, and the development of a computer tracking system on the transboundary movement of hazardous wastes.
Good Neighbor Environment Board (GNEB) 1992	Advises the President and the Congress concerning environmental and infrastructure issues and needs within the states contiguous to Mexico.
North American Free Trade Agreement (NAFTA) 1994	The NAFTA is the first trade agreement which contains provisions to deal with environmental issues which arise in the context of trade relations and disputes: 1. NAFTA protects certain Multilateral Environmental Agreements from trade challenge (art. 104). 2. NAFTA prohibits reducing environmental standards to attract investment (arts. 104, 906(2), and 1114). 3. NAFTA sets general, multilateral rules on Sanitary and Phytosanitary Measures (SPSs) and other Standards Related Measures (SRMs) (arts. 712, 902 and 904). 4. NAFTA promotes the upward harmonization of environmental policies and standards (arts. 713, 714, 905 and 906). 5. NAFTA provides for improved consideration of environmental issues in its trade dispute resolution procedures (arts. 723 and 914).

[7] Mexico has recently begun a slow, painful process of decentralization.

The Commission for Environmental Cooperation (CEC) 1994	The CEC is a trinational organization whose members are Canada, Mexico and the United States, created under the North American Agreement for Environmental Cooperation (NAAEC) to address regional environmental concerns, help prevent potential trade and environmental conflicts and to promote the effective enforcement of environmental law.
The Border Environmental Cooperation Commission (BECC) 1994	Created to assist border communities and other sponsors in developing and implementing environmental infrastructure projects, and to certify projects for financing consideration by the North American Development Bank or other sources.
The North American Development Bank (NADBank) 1994	Capitalized in equal shares by the United States and Mexico to provide $3 billion in new financing to supplement existing sources of funds and leverage the expanded participation of private capital. The BECC/NADBank institutions are limited to three types of environmental infrastructure development: water supply and treatment, waste water treatment and disposal, and solid municipal waste [and related matters].
The Border XXI Program 1996	A binational effort which brings together the diverse US and Mexican federal entities responsible for the shared border environment to work cooperatively toward sustainable development through protection of human health and the environment, and proper management of natural resources in both countries. It is the follow-on to the IBEP.

While the IBWC sometimes takes a long-term view, this is usually lacking.[8] The IBWC builds infrastructure and not local capacity. It has not until very recently fostered public participation, transparency or accountability. The IBWC does not use any measurements of qualitative outcomes such as the sustainable development criteria now in use by the BECC. Instead, everything has been focused on quantitative outcomes such as millions of gallons per day treated. In other words, the IBWC has little potential to better the quality of present and future generations in the border region in its current structural form. In the future, the IBWC will either exercise its unused authority to lead or it will move into a strong support role. A support role might make use of the organization’s best qualities and resources, which include its engineering capabilities and its role in crafting binational agreements known as minutes.

In an examination of the La Paz Agreement and its workgroups (as constituted from 1983 to 1993), we find that they rarely take a long-term view. This said, the La Paz Agreement does create the potential for an institutional framework for long-term binational federal government cooperation on border environmental issues. However, in doing so it leaves out many stakeholders, and does not build local capacity. It does not serve to foster public participation,

[8] For the purposes of this paper, we will assume long-term is something akin to the Native American requirement that thinking take into account the needs of seven generations. At a minimum, thinking beyond a single presidential term in office would be an improvement.

and is not a transparent structure that can be held accountable for its actions. Finally, the La Paz workgroups, during their first ten years, did not use any measurements of qualitative outcomes which, for example, would include transparency and public participation into the mix when undertaking binational cooperation. In other words, the La Paz Agreement and its workgroups, like the IBWC, have little potential to better the quality of present and future generations in the border region in its current structural form.

Because the IBEP lacked any implementation plan or resource commitment, it was widely criticized as nothing more than a plan to plan. It was also considered too "top down." Obviously, as such, IBEP did not take a long-term view. It did not build local capacity or foster transparency or public participation. Despite these criticisms, a recent San Diego State University study of the IBEP indicates many of its programs and activities have proceeded and proved useful for the border communities.

The GNEB is attempting to take a long-term view including the use of long-term indicators of human and ecosystem health. It has been unsuccessful to date in building local capacity, but has begun to foster public participation. It is effective at calling for and reporting on the transparency and accountability from the various other border institutions and government agencies working on border issues. While the GNEB's deliberate, but important development of consensus results in a more diplomatic message, it is the only real multi-stakeholder approach regarding border issues. The 25-member board is comprised of representatives from federal, tribal, state, and local government, non-governmental organizations (NGOs), academia, private organizations, and the community.

It is too early to tell what will be the NAFTA's impact on border environmental infrastructure, or border infrastructure in general, although we can assume it is going to have a significant impact in pollution from manufacturing, energy, and transportation sectors. This said, it is possible to look to the NAFTA trade agreement and its two environmental side agreements (which created the CEC, BECC and NADBank) to discern one set of attempts to address regional environmental problems and resolve the question of how to liberalize trade while simultaneously improving environmental performance. All three countries have varying levels of enforcement and success in dealing with pollution and natural resources issues. As a result of the injection of environmental protection issues into the debate over the NAFTA, during the last five years the three nations have embarked upon a joint effort to deal with environmental issues at the same time as they liberalize trade. The NAFTA environmental provisions discussed above are set for the foreseeable future. It thus takes the long-term view. The trade agreement part of the package does little else toward promoting environmental protection. However, examined together with its environmental institutions (see below) it is on balance as positive a package as was politically possible in its day.[9]

Very few commentators perceive the three NAFTA environmental institutions for what they are: limited first steps toward broad North American cooperation on environmental issues. As such they are working toward that lofty goal of actual cooperation and partnership in a slow but sure fashion. In other words, within their mandate, we see less conflict and more collaboration as a result of the creation of institutional structures, which require that the nations work together. For example, the over 50 BECC/NADBank projects certified to date exceed the number of projects and people served in all preceding efforts in the border region.

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[9] See generally, Audley, John J., *Green Politics and Global Trade: NAFTA and the Future of Environmental Politics* Georgetown University Press, 1997.

The CEC has undertaken a number of border-related activities. Under its Article 13 investigation report authority, the CEC seized the opportunity to look at the San Pedro River watershed uses and sources of contamination. Its conservation program's Bight of the Californias project will test the CEC's usefulness to promote binational clean up of non-point and point sources of marine pollution and habitat modification in the coastal area near San Diego and Tijuana. The CEC has also been actively involved in the development of a transboundary environmental impact assessment agreement. At present, with the exception of BECC/NADBank projects, there is no requirement for a binational impact assessment. The lack of such a requirement has lead to such famous border disputes as Carbon I&II and Sierra Blanca. As an ongoing exercise which will test the CEC's dispute resolution procedures for a border issue, the San Diego-based Environmental Health Coalition brought an Article 14 "Public Submission" regarding the abandoned *Metales y Derivados* battery recycling facility in Tijuana. This Submission is slowly working its way through the Article 14-15 process.

The CEC does an excellent job of taking the long-term view, including the use of long-term indicators of human and ecosystem health. The CEC staff and the CEC's Joint Public Advisory Committee strive for public participation. Something far from easy when its public is North American in scope. Some of its training and education efforts have built local capacity. While at times difficult, the dispute resolution mechanisms provide a spotlight to encourage transparency and accountability.

The BECC and the NADBank have done little to take a long-term view. While they have helped in some ways to ensure that projects build local capacity, they are still acting on a project-by-project basis to build infrastructure. As noted above, the BECC has done an outstanding job at fostering public participation both locally and at the border-wide level. In doing so, and in making project certification files open to the public, it has also made a positive contribution to transparency and accountability. The NADBank still needs to take some steps to follow in the BECC's path. Together however, through the BECC certification criteria and the NADBank's financial evaluations, they have adopted real measurements for qualitative outcomes rather than simply quantitative outcomes.

As a five-year plan, Border XXI looked beyond single congressional appropriation cycles, but falls short of taking the long-term view. This said, it is attempting to put in place the use of long-term indicators of human and ecosystem health. It is still federal government-focused and has not really succeeded in building local capacity or in fostering public participation (except during its drafting). It has, however, made the work of the La Paz workgroups more transparent and thus more accountable.

How to Improve the Institutional Response to Transboundary Environmental Problems

The principles of sustainable development, foresight, pollution prevention, public participation, environmental education, and integrated environment management should guide regional efforts to protect the ecosystems of the border region. The border region allows for the enrichment of existing models for binational cooperation in a workable geographic, environmental, and institutional basis. We can define the shared ecosystems in terms of existing conditions and inventory actions to date. In this way, we can address all sources of environmental degradation, identify priorities for additional needed short- and long-term actions, and identify and evaluate institutional and administrative measures to address current problems.

Because of the importance of environmental impacts upon economic activities, public health, watershed resources, ecosystem health, and social benefits, including cultural values, we need to be proactive and preventative:

- We know what the environmental problems (and infrastructure needs) are at the border (see Table A above).
- The technology for public and private solutions and improvements exist, whether we call it sustainable technology, natural capitalism,[10] sustainable development or thinking outside the box.
- Especially in context of the CEC, BECC and NADBank, we have created institutions with sustainable development criteria to implement solutions.[11]
- The obstacle then is getting government officials at all levels to both accept and create incentives for new thinking. Our challenge is to find ways to overcome structural and philosophical obstacles to the solutions.

The border region has scientific, economic, and ethical value to both Mexico and the US. Thus a unified effort to address the region's environmental problems is crucial if we wish to maintain those values.

First, the border is scientifically and naturally defined by its watersheds and thus constitutes a unique ecological region. The watershed approach is preferred by science. It is also a more natural approach taken by Tribes for centuries. In other words, identifiable watersheds are one of the reasons we talk about the border area as a region.[12] The ecological and human health of this region is linked to the health of the nation as a whole. To preserve these defined ecosystems and their elements of natural capital, we should clean up the border and prevent the spread of human and environmental harms to areas outside the region. This will become especially important as climate change increases the risk of introduction of more tropical disease vectors such as mosquito-borne Dengue, which are predicted to migrate northward to the border region as it warms.[13]

Second, the border region is a trade zone of national concern. US interests own a significant majority of maquiladoras and other business investments in the region. In other words, this is a region of economic importance to the nation which should be "managed" accordingly. The low wage production center at the border benefits **all** US consumers. However, the tax base of border communities is too small for current needs, much less for the provision of infrastructure for projected growth. The result is that border communities are unable to generate enough in tax revenues to support the governmental entities that implement and manage environmental infrastructure systems for potable water, sewage collection, wastewater treatment, or solid waste management. This socioeconomic problem thus manifests itself in domestic and

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[10] Increased resource productivity; industrial ecology and/or closed-loop production in which every output is either returned harmlessly to the ecosystem as a nutrient, like compost, or becomes an input to manufacturing another product; and shifts from selling to leasing durable, reusable, non-toxic products, owned by the manufacturer throughout their lifecycles. Interestingly, such environmentally wise moves increase profitability while reducing the risk of exposure to environmental liabilities.

[11] For a more full discussion of this see: Spalding, Mark "The NAFTA Environmental Institutions and Sustainable Development on the U.S.-Mexico Border" chapter for *Shared Space: Rethinking the U.S. Mexico Border Environment* published by the Regents of the University of California (2000)

[12] For a detailed discussion of the border watersheds and their importance, see the GNEB Fourth Report to the President and Congress (September 2000)

[13] National Assessment Synthesis Team *Climate Change Impacts on the United States* Overview Document (January 2001) at pages 102-7.

transboundary environmental and health problems. Unfortunately, NAFTA will not solve the environmental problems of the border region because of unequal geographic distribution of benefits or harms. Benefits are broad and universal, while the burden or costs are local.

Third, there are clear ethical reasons to value the region. Most of the counties on the US side of the border are the poorest in the US with the worst health and mortality statistics. Thus, the Border States and Tribes have very special needs. While the communities on the Mexican side are relatively wealthy in relation to the interior of Mexico, there is certainly room to improve the quality of the lives of our neighbors and important trading partners. To the degree that the US benefits from production in the border region, while Mexico or US Hispanic minorities suffer environmental harm, an environmental justice – or human rights and the environment – argument can be made in favor of directing assistance to the region. Finally, a justification for foreign direct assistance to Mexico is that stability in Mexico is good for the US and its economy.

While normally capital is a necessary, but not sufficient condition, the ultimate barrier to the success of the border environmental institutions is financial. While imperfect, the thee NAFTA environmental institutions have developed criteria and guidelines that lead to much more positive outcomes than their predecessors. As such they provide a good financing mechanism to put money where it is needs. What these institutions need is more financing earmarked to long-term planning focused on an ecosystems approach. For example, reasonable estimates for border environmental infrastructure in the three areas of the BECC/NADBank mandate are between $8 and $10 billion. At best the NADBank can only leverage $1 to $2 billion. More grant funds for project design, capacity building, planning, etc. are crucial. Thus, there is a need to pull the nation together to support the Mexico-US border region as was done in the Great Lakes (also a binational example), the Hudson River Valley, the Chesapeake Bay, or the Everglades. To illustrate, using the Everglades as the most recent example, the nation as a whole has committed $7 to 8 billion to attempt to restore the Everglades,[14] which constitute only a third of the state of Florida. In addition to the restoration commitment is over $170 million for annual operations and maintenance. The Everglades restoration happened because a cross-section of society, first in Florida, and then nation-wide saw it in their interest to act. Environmentalists called for the nationwide support to protect the countless endangered species that call the Everglades home, meanwhile Florida's powerful sugar industry and water utility agencies have joined in support of the legislation once they were satisfied they would benefit as well.

Likewise the border region must be part of a national effort. The US should not wait for a crises to spend US tax dollars in the region. A means to raise funds should be developed. Other infrastructure used for the national benefit is supported by special taxes, such as the gas tax for road infrastructure (including border crossing infrastructure), and airport taxes for air transportation infrastructure. If such a fund could be created, then a coordinated effort must be made to ensure rational use of funds that lead to regional planning using an ecosystem approach. Assuming both the funds are raised and the plans are made, the mechanism of the BECC criteria

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[14] In the hope of recovering millions of acres of endangered wetlands, coral reefs and wildlife habitat, thus saving the Everglades National Park, the restoration aims to revamp the water flows within the 100-mile Everglades system and capture more fresh water and distribute it in ways to revitalize ecosystem. The project includes eliminating 240 miles of levees and canals, building above-ground reservoirs and underground aquifers, and developing new wetlands.

for certification and the NADBank financial evaluations should ensure the efficient spending of the funds raised are use to improve the quality of life of those who live in the border region.

In addition to addressing border region finances, everyone in the border region communities needs to become better informed regarding current circumstances. Only an informed community can begin to identify its priorities and effectively participate in the public policy process. Because Mexico severely lags in waste emissions data collection and public dissemination of industrial waste management information, it is difficult to know the harms done to the environment, who the culprits are, or the opportunities for solutions such as improving systems efficiency, or waste-matching. For example, as a result of limited funding and a severe lack of information, it is difficult for environmental officials to assist companies in complying with environmental regulations or to enforce Mexico's strict anti-pollution laws.[15]

For decades the border's environmental institutions have engaged in an uphill battle in their efforts to put in place infrastructure as fast as population and commercial development were growing, or as sprawl extended systems far and wide from original plans (particularly in larger border communities). One small but important aspect of this may be changing. Recent elections in the United States and Mexico have affected the political context of the border area, and each respective administration will be looking for guidance regarding sustainable development for the region and, hopefully, more managed growth.

For many years there has been complicity by the Mexican government in its corrupt failure to govern land use, maintain urban limit lines and control growth in the face of unscrupulous developers. Mexico has some of the best planners and urban settlements specialists in the world. One only need look to the work of IMPLAN in Tijuana and Matamoros, for example, to confirm this. However, likewise, one need only look at the lack of implementation of the ideas of IMPLAN in Tijuana to see the disconnect between ideas and reality. While the border will undoubtedly continue to be a magnet for population and business, it is now hoped that in the Fox Administration there will be a anti-corruption, pro-democracy regime that will enforce the rule of law and thus limit unplanned growth, unauthorized settlements and polluters that act with impunity.

The US, meanwhile, has exercised a form of neglect. Neglect that can only be partly excused by US frustration with Mexican corruption and lax controls. As such it has provided minimal support for the region, allowing its public infrastructure and natural capital to decline. With a new administration led by a former border state governor boasting a close relationship with President Fox, perhaps there is hope that the border region will get the support it needs and deserves. The US should engage in a dialogue that addresses border region capacity and training, and encourage cross-border exchanges of expertise and skill. The US should also ensure federal, state, and tribal programs for protecting the border region's ecosystems are adequately staffed and funded at all levels.

A long-term strategy is necessary to address the root cause of the unsustainable nature of the border region's growth. The US government should engage the Mexican government and the private sector in pursuit of new economic mechanisms that will address environmental and social needs without excessive dependence on larger and larger federal grants. Mexico and the US should support the development of a successor Border XXI type plan for federal-state-local-tribal cooperation that builds on the experience of the 1996–2000 period.

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[15] This, however, is an area of change. Mexico's 1988 General Law of Environmental Equilibrium and Protection was amended in 1996 to include a very basic pollutant release and transfer register (PRTR) to track some industrial emissions.

Conclusion

There are many environmental problems to be addressed in the Mexico-US Border region: air, water, and land-based pollution; overconsumption of water and other natural resources; and loss of biodiversity. The negotiation of NAFTA brought these border environmental issues to the forefront of public attention. The NAFTA, its two side agreements and the Border XXI document incorporate the concepts of conservation and environmental protection. Thus the institutional structures as implemented allow for innovative initiatives to resolve border environmental problems. In particular, the BECC's project certification criteria are to be highly applauded. Overall, the BECC and the NADBank have had a limited but positive effect on binational environmental cooperation in the region. Finally, the various workplans of the CEC's programs reflect positive objectives applicable to the border.

Of course, some will continue to label border environmental institutions as failures and claim they are not doing anything constructive. The reactive nature of all these border environmental institutions constitutes the basic problem. They are not designed to be proactive and, consequently, cannot prevent environmental degradation from unsustainable development. Unless they are radically redesigned or supplemented with a much broader planning and regulatory enforcement structure, they will never do more than treat the symptoms of the disease of unsustainable development.

The driving force behind the booming US-Mexican border economy is low-cost labor. The resulting social and environmental degradation in the border region would argue that an alternative is needed. However alternatives are very hard to come by. The border region by some estimations has already exceeded nature's ecosystem services carrying capacity. The environment and local natural resources can no longer continue to support so many industries, increasing numbers of people and their respective wastes. Assembly plants are ecologically ill-located in the binational zone that is bereft of water, energy and most natural resources needed in manufacturing. However at present they, and agriculture, predominate as the sole economic engine in some parts of the region. In short, a complete rethinking of the type and intensity of economic activity and human settlement in the binational zone must be undertaken.

I advocate for an upward harmonization of environmental regulations, and increasing opportunities to do more to consolidate and expand joint work on issues of environmental protection and conservation on which there is consensus. On one hand, increasing fragmentation or compartmentalization of US-Mexico relations may limit leverage in linking environmental protection to trade liberalization. On the other, unilateralism will decrease.[16] We can expect better outcomes from a more interactive, reciprocal relationship on environmental issues between the US and Mexico. The slow opening and democratization of Mexico's political system will support this, and it will require the NGO community continue to take a greater lead in innovation and in finding workable solutions. The final result will be a steady improvement of environmental conditions/indicators.

Undoubtedly, the border region's many environmental problems will remain at the forefront of public attention for some time. However, until the region has focused on the proper management of its growth, the main causes of the environmental problems will continue to be the accretion of urban populations and industrial development. While the NAFTA environmental clauses and institutions allow for more innovative initiatives to resolve border environmental problems, the reactive nature of all border environmental institutions constitutes the basic

[16] However, the golden rule will still applies – the nation with the most gold rules. In other words, "who decides" and "who pays" are inextricably linked.

problem. The persisting degradation in the border region makes it clear that a more holistic alternative must be found.

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Impact of Two NAFTA Institutions on Border Water Infrastructure*

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ABSTRACT

Environmental concerns surrounding the signing of the North American Free Trade Agreement (NAFTA) led to an agreement establishing the Border Environment Cooperation Commission (BECC) and the North American Development Bank (NADBank) to promote water, wastewater, and solid waste infrastructure projects in the U.S.-Mexico border region. The creation of these organizations represents a unique cooperative attempt to address environmental infrastructure needs of a transboundary region through a trade agreement. The development assistance provided by these organizations is innovative because of its focus on producing debt-financed and user-fee-supported projects that are developed with public participation.

Because BECC and NADBank are significant components of the governments' efforts to address environmental infrastructure needs in the region, their performance is significant in determining how well government assistance has addressed the region's environmental problems. Between 1995 and 2000, BECC and NADBank helped develop forty water and wastewater projects via BECC's certification efforts and technical assistance for project development and NADBank's financing packages and capacity-strengthening for water and sewer service providers. Although these projects represent significantly more investment in environmental infrastructure than had been made in previous years, they only covered in six years of operation about 13% of the water and wastewater infrastructure needed for the region between 1994 and 2003. Beginning in late 2000, BECC and NADBank expanded the range of environmental infrastructure projects that they would support through certification and financing.

* An earlier version of this chapter titled "Working Toward Sustainable Water and Wastewater Infrastructure in the US-Mexico Border Region: A Perspective on BECC and NADBank" appeared in the International Journal of Water Resources Development (December 2000).

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Decades of rapid industrialization and population growth along the U.S.-Mexico border have strained the water and wastewater infrastructure capacity of this transboundary region, thus contributing to a degradation in environmental and human health. Negotiations for the North American Free Trade Agreement (NAFTA) in the early 1990s brought public attention to environmental problems of the border. In 1993, U.S. President William Clinton and Mexican President Carlos Salinas de Gortari announced an $8 billion initiative to address the pressing environmental problems in the area one hundred kilometers on each side of the international boundary. This area, referred to as the "border region," grew in population from 6.6 million in 1980 to an estimated 12 million in 2000 (Ham-Chande and Weeks, 1992; Southwest Center for Environmental Research and Policy, 1999). A $3 billion component of the $8 billion environmental initiative was the creation of two binational organizations—the Border Environment Cooperation Commission (BECC) and the North American Development Bank (NADBank). These two organizations have worked together to promote sustainable development of the border region by supporting water, wastewater, and solid waste infrastructure projects.[1] NAFTA-related environmental concerns also led to a side-agreement creating the Commission for Environmental Cooperation (CEC) for handling environmental legal disputes between the United States, Canada, and Mexico.

In this chapter, we analyze BECC's and NADBank's accomplishments in the area of water and wastewater infrastructure during the period from their initial operation in early 1995 through December 2000. These organizations represent significant components of the two governments' cooperative attempt to address the environmental problems of the shared border region. The analysis is limited to what BECC and NADBank call "water pollution" and "wastewater" projects.[2] Water pollution projects can include, but are not limited to: (1) potable water treatment; (2) water supply systems; (3) water pollution prevention; and (4) projects to improve or restore quality of water resources. Wastewater treatment projects can include: (1) wastewater collection systems; (2) wastewater treatment plants; (3) water reuse systems; and (4) systems for treatment and beneficial use of sludge. Our assessment is based on data collected from February to December 1997, and periodically from 1998 through early 2001. We gathered data from personal interviews with municipal, state, and federal officials in Mexico and the United States and with BECC and NADBank staff. We also collected data through reviews of BECC files, participation in public meetings, observations as a participant in the U.S. Environmental Protection Agency (EPA) Region IX Border Water Group, and research in Mexican and U.S. border communities.

Evolution of Border Water Cooperation

Binational attention to the region's water resources started in the mid-1800s because a number of rivers define and cross the international boundary. The U.S. and Mexican governments first formally attempted to address border sanitation problems through the International Boundary and Water Commission (IBWC). A 1944 binational treaty established the

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[1] NADBank also arranges financing for community adjustment projects for communities with significant job losses due to changes in trade patterns as a result of the trade agreement.

[2] BECC and NADBank classify water projects as environmental projects because the two organizations interpret "environment" as including both the natural and human environment.

IBWC to manage all international water projects and water resource disputes involving the two countries' shared border, including disputes over territorial limits and water allocation. Since the 1970s, rapid industrialization and population growth in the border region created problems that were beyond IBWC's original mandate and resources. Only a few IBWC projects directly addressed the urban water infrastructure and treatment needs of the growing border communities. Moreover, critics claim that IBWC has been ineffective because of its slow, secretive, top-down approach (Vanderpool, 1997; Spalding and Audley, 1997; Ingram, 1996; Ingram et al., 1995).

The failure of IBWC to address growing environmental concerns resulted in other attempts at binational cooperation. The 1983 Agreement on Cooperation for the Protection and Improvement for the Environment in the Border Area (the "La Paz Agreement") established a framework for addressing a comprehensive range of environmental issues, including water. In response to concerns that NAFTA would result in rampant growth and aggravate existing environment problems in the border region, BECC and NADBank were added to the mix of institutions working on border water issues. The agreement creating BECC and NADBank recognized IBWC's continuing role in border wastewater projects, and thus it required BECC and IBWC to cooperate in the planning, development, and implementation of border sanitation projects and other environmental activities.

BECC and NADBank's Approach to Assistance

BECC and NADBank were designed to play an active role in fostering environmental infrastructure to protect public health and the environment within the border region. Located in Ciudad Juàrez, Chihuahua, BECC's primary roles are to provide technical assistance to border communities developing projects and to certify environmental infrastructure projects in the border region for financing consideration by NADBank and other sources. NADBank, in San Antonio, Texas, facilitates financing for the implementation of BECC-certified projects and provides financial and managerial guidance for border communities with projects. This division of functions was intended to avoid a conflict of interest: the entity involved in fostering project development (BECC) is different from the organization involved in financing (NADBank) (Varady, 1996).

BECC and NADBank are unique as international development organizations not only because of this bifurcation of responsibilities but also because of their approach to development assistance. They focus on promoting "sustainable development" as the concept is presented in the Brundtland Commission's Report to the World Commission on Environment and Development: development that meets the needs of the present without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development, 1987).[3] BECC and NADBank's involvement in individual projects is guided by the agreement creating the two institutions, which states that environmental infrastructure projects should be operated and maintained through user fees and subject to local or private control.

[3] Through its High Sustainability Development Program, BECC acknowledges projects that satisfy binationally accepted indicators of sustainable development.

Project Certification: Border Environment Cooperation Commission

The purpose of BECC is "to help preserve, protect and enhance the environment of the border region in order to advance the well-being of the people in the United States and Mexico" (U.S. Department of State, 1993). To carry out this agenda using its $3 million annual budget (appropriated by the U.S. and Mexican Congresses), BECC does not develop or manage individual projects. Instead, it promotes and certifies projects. Border water and sewer service providers develop their own projects and propose them for BECC certification. BECC's criteria for certification are intended to assure investors and border communities that projects meet requirements in the following topical areas: human health and environment, technical feasibility, financial feasibility and project management, community participation, and sustainable development (See Table 1). In short, BECC provides technical assistance to ensure that the projects it promotes benefit the border region.

In addition to providing technical assistance, BECC also coordinates the activities of numerous public organizations engaged in efforts to enhance water and sewer services in the border region. In order to coordinate the development of water and sewer projects, BECC has created coordinating committees involving an array of agencies at various levels of government. These committees typically include members from the following: EPA, *Comisión Nacional de Agua* (CNA, Mexico's federal water agency), U.S. Department of Agriculture, U.S Public Health Service, IBWC, state utilities, state governors' offices, state environmental agencies, and municipal authorities, and local steering committees.

BECC's staff developed the certification criteria based on guidelines set forth in the agreement creating BECC and NADBank and using extensive public input. Sixty-nine members of the public submitted comments on the 1995 draft of BECC's criteria. The criteria were revised and adopted in September 1995. BECC later revised the criteria adopted in 1995 in order to reflect the knowledge gained from operating experience. In 1996, a draft of BECC's new criteria was presented for public comment. Based on our 1997 review of BECC files, the 1996 draft received approximately forty-six public comments. After responding to these comments, BECC adopted a final set of criteria in November 1996.

BECC's certification criteria, particularly the community participation requirements, increase the transparency of border water and wastewater project development. For example, the certification criteria require project applicants to have a comprehensive community participation plan that consists of forming a local steering committee, meeting with local organizations, allowing public access to project information, and holding at least two public meetings. The service provider (typically a water and/or sewer utility) responsible for a project must submit a report documenting both the implementation of this community participation plan and public support for the project. BECC's promotion of public participation in project development and decision-making represents a significant change from IBWC's closed approach. Moreover, extensive public participation is different from typical decision-making processes in Mexico and within international development organizations. Based on an analysis of public participation in BECC, two researchers at the University of Arizona, argue:

> ... by stressing community participation BECC provides groups from both sides of the border with new resources for mobilization. BECC has not only encouraged the emergence of new groups, but [also] it has created new spaces for debate, facilitated the

exchange of ideas and information, and improved access to data and funding sources (Lemos and Luna, 1999).

The public also participates in BECC’s own operations. Applications for certification are reviewed by BECC's staff, which makes recommendations to BECC's Board of Directors and distributes project information for public review and comment. A binational Advisory Council, which consists of border residents, also advises the Board of Directors. The Advisory Council is intended to provide an avenue for public input into BECC activities and certifications. The decision process of the Board of Directors also has a public component. After reviewing project applications, the Board votes on certification at a meeting that is open to the public.

Notwithstanding BECC’s procedural requirements, public participation has not been problem free. In Mexico, limited information and constraints on resources available to border communities have limited the extent of citizen participation in planning for water and sewer projects. Based on their analyses of a project in Nogales, Sonora, Lemos and Luna (1999) argued that BECC should “strictly enforce its mandate for public involvement in project certification.” Other analysts, such as Mumme and Sprouse (1999), have noted that compliance with public participation following BECC certification is problematic because BCC has no mechanisms to enforce those requirements.

Project Financing: North American Development Bank

Once BECC's Board of Directors votes to certify a project, the project is eligible for a NADBank financing package. Despite its name, the North American Development Bank does not operate like the World Bank or other traditional development banks. Including the word "development" in the name of the North American Development Bank helped the Clinton administration sell NADBank to the public (Browne, 1996). But to sell NADBank to Congress, the administration limited the federal allocations that the Bank would receive, and it eliminated features that resembled foreign assistance. Ostensibly at least, a traditional development bank transfers resources from wealthier nations to poorer ones. In NADBank's case, however, the United States, with an annual gross national product (GNP) of over $6 trillion, contributed the same amount to capitalize NADBank as Mexico, whose GNP was roughly 4% of the United States' GNP in 1994 (Browne, 1996).

As of December 2000, NADBank had a capitalization of almost $3 billion dollars—$349 million in paid-in capital and $2.55 billion in callable capital. NADBank is authorized to use its paid-in capital to make direct loans to communities and to guarantee payment of a community's non-NADBank loans (in order to encourage investments by other lenders). The Bank's callable capital is money that the U.S. and Mexican federal governments pledged to make available in the unlikely case that a large number of NADBank borrowers fail to repay their loans. Because NADBank must preserve its capital and cannot borrow in the tax-exempt bond market, it lends primarily at market-based interest rates.

NADBank can leverage its limited resources into substantial financing for environmental infrastructure projects by creating financing packages that combine NADBank loans with loans and grants from other government entities and private investors. NADBank provides loans to fill financing gaps that are not covered by other sources. Loans made or guaranteed by NADBank are for specific projects, not general programs. The projects must be certified by BECC and be financially self-sustaining; i.e., fees collected for water and sewer services must both cover operation and maintenance costs and up to twice the cost of repaying creditors.

The capital structure of NADBank allows it to lend to utilities that otherwise have difficulty accessing financing from commercial markets, (e.g., NADBank can loan to small utilities borrowing one or two million dollars or less). NADBank also offers other financial services, such as loan guarantees and "gap purchases" of bond issues. In a gap purchase, NADBank buys the portions of a bond offer that are not quickly bought by private investors. NADBank assists in the financing of projects by acting as an investment banker, a source of financial advice, and a coordinator of grants and loans from multiple sources.

Management of Border Environment Infrastructure Fund Grants

In 1997, NADBank signed an agreement with the U.S. Environmental Protection Agency (EPA) that gave NADBank responsibility for managing that agency's Border Environment Infrastructure Fund (BEIF), which receives appropriations from the U.S. Congress (NADBank, 1997a). Grants from the fund can be used for border water and wastewater projects that are either in the U.S. or in Mexico, but projects in Mexico must benefit the United States. BECC and NADBank’s existence has permitted this groundbreaking use of U.S. funds for projects affecting the region’s shared environment regardless of the project’s location

EPA maintains final oversight over the use of BEIF grants. Using a set of project selection criteria and affordability guidelines, NADBank analyzes if a project is eligible to receive BEIF grants. The guidelines differ somewhat for U.S. and Mexican projects. U.S. projects are eligible for assistance if the project cost per household exceeds 1.7% of the median household income (NADBank, 1997b). CNA determines which Mexican projects are eligible for BEIF support by using Mexico's Municipal Poverty Index (NADBank, 1997c). BEIF grants for projects can be used for construction costs to make a project affordable for a community. They can also be used to ease a community's adjustment to higher user fees over time; eventually, however, operation and maintenance costs must be covered by user fees.

For projects that qualify for BEIF assistance, NADBank determines the size of the grant for a project using factors such as: the socio-economic characteristics of the area; and the water and sewer utility's current debt burden, other available sources of funding, and ability to assume debt. As of December 2000, NADBank had used criteria linked to the affordability of projects to approve $249 million in BEIF grants. For Mexican projects, CNA and state sources generally match BEIF grants.

Assistance for Capacity-Building Activities of Service Providers

Because of BECC and NADBank’s focus on improving the environment of the border region, the two institutions are concerned about the operation and benefits of the projects they support. Believing that sound planning and management of projects were essential for producing environment protection, BECC and NADBank created two programs that strengthened the capacity of border water and wastewater utilities. One of these, a grant program for technical assistance called the Project Development Assistance Program (PDAP) was established by BECC in 1997. The program, which assists utilities and other types of service providers with the development of water and wastewater projects intended for BECC certification, is funded by a $22.5 million grant from the U.S. Environmental Protection Agency. Examples of activities funded through PDAP grants include: preparing municipal master plans, technical feasibility studies, and preliminary design documents; and conducting mapping and surveying, environmental assessments, financial feasibility studies, and public participation programs. By December 2000, PDAP support used on certified projects and projects pursuing certification totaled $16.7 million. BECC also operates a management training program which trains Mexican utility operators on how to enhance their capacity to meet local environmental infrastructure needs.

A second grant program, the Institutional Development Cooperation Program (IDP), assists public utilities in achieving effective and efficient operations by reinforcing their institutional capacities thus creating a stronger financial foundation that will support the development of future infrastructure (NADBank, 1997d). NADBank established this program using a portion of the earnings on its paid-in capital. As of December 2000, NADBank had used IDP to assist sixty-four communities with a total of ninety-three projects, and it had committed a total of $6.6 million worth of IDP funds (NADBank, 1999). The types of activities funded include: updates of the user registries and development of utility management systems, surveys of the water distribution systems and related information systems, and water loss and repair studies. In 1999, NADBank initiated as part of its IDP effort a Utility Management Institute, which trains the border region's water and sewer utility professionals in long-term utility organization, administration, finance, and management (Lehman, 1999).

Between 1997 and 2000, PDAP and IDP were particularly important in the improved development of projects for small U.S. border municipalities, and the programs were critical to the development and financing of Mexican projects. For example, IDP grants assisted local branches of Mexican state utilities to improve billing and collection systems, update user registries, and install working meters. Capacity-building for utilities was significant because it helped to ensure that environmental infrastructure investments in the border region were not wasted because of lack of maintenance and technical, financial, and management expertise. In part because of BECC and NADBank's insistence on local control of projects, local branches of the Mexican state-level water and sewer utilities became involved at unprecedented levels in project development and implementation. The capacity-strengthening activities funded through PDAP and IDP helped these local branches to assume expanded roles in facility construction and operations. By investing to strengthen the capacity of border utilities, BECC and NADBank hoped to ensure the long-term integrity of projects they certified and financed.

BECC and NADBank's Project-Specific Accomplishments

BECC and NADBank were not created to solve the water and wastewater problems of particular border communities. Rather, they have a mandate to support the development and financing of environmental infrastructure projects in the entire border region. To gauge what they have accomplished for the border region, we first present data on BECC certifications and NADBank financing packages completed by December 2000. We then compare the financing packages for the projects to the estimated financial need for water and wastewater infrastructure in the border region.

BECC began accepting project applications in May 1995. As of December 2000, fifteen Mexican water and wastewater projects and twenty-five U.S. projects had earned BECC certification. More U.S. projects were certified than Mexican projects because, in general, U.S. projects were smaller and easier to certify. In most cases, U.S. projects were well-developed before reaching BECC; often they had been developed with assistance from federal or state subsidy programs or in response to health and environmental regulations. Moreover, U.S. service providers more easily fulfilled BECC's criteria than their Mexican counterparts because they had previous experience with similar requirements. Many federal and state grant programs and permits involved conditions that overlapped with BECC's certification criteria.

By December 2000, twelve of the fifteen Mexican projects listed in Table 2 had requested funding for construction. The other three projects received IDP or PDAP funds, but they did not request further financial assistance. All but one of the twelve NADBank-financed projects received a BEIF grant. And a total of $102 million worth of BEIF grants were allocated to Mexican projects. Although NADBank had only issued $7.26 million in loans, that number was expected to increase because loan packages for three of the projects were still being negotiated as of December 2000.

Table 3 provides a breakdown of BECC-certified, NADBank-financed projects in the United States. In contrast to the situation in Mexico, a relatively small fraction of the twenty-two U.S. projects receiving NADBank support involved loans. This occurred because U.S. communities had easier access to capital markets and state grant programs (compared to Mexican communities), and they were able to secure loan financing at better rates than NADBank could offer. However, the twenty-two U.S. communities are similar to those receiving NADBank assistance in Mexico in that nearly all of them took advantage of BEIF grants.

NADBank's financial activities for water and wastewater projects in the border region can be summarized as follows. As of December 2000, the Bank had approved about $249 million in BEIF grants and five loans totaling $10 million. In addition, three other loan packages were being developed. The total value of the financing packages that NADBank had participated in was $927 million. Only one project with NADBank financing—Brawley's water project—was complete by December 2000. Nineteen were under construction, and twelve were in bidding and design phases. BECC and NADBank are working with another twenty-one communities to develop infrastructure projects for future certification and financing.

As mentioned, NADBank had not made many loans for border projects, especially in the United States. For eighteen of the twenty U.S. projects with NADBank financing packages, NADBank's participation consisted of only BEIF grants; *i.e.,* no NADBank loans were involved. Its loans represented only 3% of its paid-in capital.

Although NADBank did not participate as a significant lender in many of the financial packages that it coordinated, the packages included other debt-financing mechanisms. Before investigating NADBank's lending further, we summarize the different levels of investment needed in water and wastewater infrastructure for the U.S. and the Mexican portions of the border region.

Public Expenditures Needed for Border Water and Wastewater Infrastructure

During the NAFTA negotiations, various groups published estimates of the public expenditures needed for the border region's water and wastewater infrastructure between 1994 and 2003. We reviewed estimates by the U.S. Department of Commerce ($8.7 billion), the U.S. Department of Treasury ($3.8 billion), the U.S. Council of the Mexico-U.S. Business Committee ($5.3 billion), and the Sierra Club ($7.0 billion).[4] We selected the Sierra Club's estimates for the

[4] For details on this, see Carter (1999).

analysis presented herein because those estimates were the most detailed and well-documented, and they included water and wastewater infrastructure expenditures for both conveyance and treatment. Table 4 summarizes the Sierra Club's estimates of public spending needed for the border region's water and wastewater infrastructure.

Because of the distinct economies of the two countries, the Sierra Club's estimates do not provide a complete picture of the need for border water and wastewater infrastructure in Mexico compared to the United States. One billion U.S. dollars spent on infrastructure in Mexico builds considerably more capacity for water and wastewater treatment, water distribution, and wastewater collection than one billion dollars spent on infrastructure in the United States. This difference is useful in interpreting the public spending needs estimated for each country in Table 4. It suggests that the need for facilities is significantly greater in Mexico than in the U.S.

Another difference between the infrastructure deficit in Mexico and the U.S. relates to the size and character of the communities with the greatest unmet needs. In Mexico, the shortfall in water distribution, sewage collection, and treatment is most urgent in large urban areas. Wastewater in Mexican border municipalities is particularly problematic because of the substantial fraction of total wastewater that is linked to industrial development. Mexico's "Border Industrialization Program," which was initiated in 1965, sparked economic development in Mexico's urban centers in the border region. This program granted the Mexican side of the border region a special economic status that permitted foreign-owned industries to own and operate assembly plants in Mexico. At these plants, referred to as *maquiladoras,* Mexican laborers assemble imported parts and materials. Finished goods are exported with only the value added in Mexico being taxed. By 1990, over two thousand maquiladoras directly employed five hundred thousand workers, primarily low-income laborers that relocated to the border from the interior of Mexico (Corcoran, 1997). The Mexican government initiated the Border Industrialization Program to alleviate unemployment, to relieve population pressure on Mexico City and other metropolitan areas, and to provide a source of foreign currency. The program was not accompanied by investment in infrastructure to support either the industrialization or the expanding Mexican border population.

Growth in Mexico's border municipalities resulted in increased demand for urban infrastructure, but the means to finance water distribution, sewage collection, and treatment projects in Mexico did not improve. Wastewater generated in urban centers, such as Mexicali and Tijuana, far exceeded the capacity of treatment facilities, resulting in raw waste being discharged into rivers and ocean waters. By the early 1990s, only 34% of the Mexican sewage collected along the border received any treatment (General Accounting Office, 1996). All thirty-nine Mexican border municipalities, including fourteen municipalities with populations over one hundred thousand, needed major investments in water and sewer systems and treatment facilities.[15] In addition to this lack of municipal treatment capacity. Many low-income migrants to Mexico's border municipalities built homes on vacant land that lacked public service. In the early 1990s, 18% of urban households in Mexican border municipalities lacked potable water, and 40% were not connected to sewage collection systems (Betts and Slottje, 1994).

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[5] A Mexican municipality consists of a city plus the surrounding less-densely settled area, and thus the municipal government is comparable to a consolidated city-county government.

In contrast to the need in Mexico which was greatest in large urban centers, the need for water and wastewater infrastructure in the U.S. border region during the 1990s was most urgent in small municipalities and "colonias." The U.S. General Accounting Office defines colonias as "rural, unincorporated subdivisions along the U.S.-Mexico border, in which one or more of the following conditions exist: substandard housing, inadequate roads and drainage, and substandard or no water and sewer facilities" (General Accounting Office, 1990, 1). Of the more than four hundred thousand people in the U.S. who lived in colonias in 1990, 85% lived in Texas border counties. In Texas, colonias generally lacked adequate water and wastewater disposal facilities for their residents because colonia developers (before 1989) were not required to provide water and wastewater services. The State of Texas responded to its growing colonia population through legislation restricting the development of new colonias and the creation of a program to subsidize the construction of water and sewer systems in Texas colonias. The three other border states also had colonias, but the scale of the problem was not as large as it was in Texas. California's colonia population was 32,000; Arizona's was 15,000 and New Mexico's was 14,600 (General Accounting Office, 1990).

Colonias are not the only communities needing assistance in the U.S. border region. Many small U.S. border municipalities also require improvements in their water and sewer facilities because of their growing populations. In 1990, three of the ten fastest growing metropolitan areas were located in Texas along the border (Texas Legislature, 1996). Although the border economy grew substantially from 1970 though the 1990s, U.S. border residents were among the poorest in the nation. In 1990, Webb and Starr Counties along the Texas-Mexico border were among the ten poorest of all U.S. counties, and Laredo, Texas (in Webb County) was the poorest city in the U.S. (Texas Legislature, 1996). The combination of rapidly expanding populations and a high proportion of low-income residents made it difficult for small U.S. border municipalities to finance needed improvements to their water and wastewater facilities. Many small municipalities struggled to operate and maintain their systems, much less to expand them. As a result of their limited budgets, small border municipalities often postponed maintenance of systems, thus exacerbating the stress on their water and sewer systems caused by their increasing populations.

In the early 1990s, only 7% of the U.S. border cities and towns had populations above fifty thousand (BECC, 1996). Large U.S. border municipalities generally possessed adequate technical, financial, managerial, and administrative staff to maintain well-functioning water and sewer systems and to finance expansion and construction projects (although they often needed assistance in addressing the needs of adjacent colonias). Consequently, twenty-two of the twenty-five U.S. projects certified by BECC as of December 2000 were serving less than 50,000 border residents.

BECC and NADBank's Experience in Providing Needed Financing

As mentioned, BECC and NADBank were part of a larger scheme—the $8 billion environmental initiative for the border region announced by Presidents Clinton and Salinas in 1993. Although BECC and NADBank were not the only organizations addressing the shortfall in water and wastewater infrastructure in the border region during the 1990s, the data on estimated need in Table 4 provides a basis for putting the impact of BECC and NADBank's activities on the border region in perspective.

This is done in Table 5, which indicates that U.S. projects certified by BECC and financed by NADBank packages covered 18% of the estimated U.S. need. In contrast, Mexican projects covered only 9.7% of the estimated public need in Mexico. Although BECC-certified and NADBank-financed projects (as of December 2000) address only 13% of the total estimated need for the border region, the eleven Mexican projects and twenty-two U.S. projects represent an unprecedented number of border region projects in development. In their six years of operation between 1995 and 2000, BECC and NADBank worked on eight times more border wastewater infrastructure projects than the IBWC did in its almost sixty years of work on border sanitation issues. Since the first binational wastewater treatment plant in 1951, IBWC has spent less than $1 billion (in 2000 dollars) on construction of wastewater facilities in the border region; this money was spent on the Nuevo Laredo, Nogales, and South Bay (in San Diego) treatment plants and facility planning for the New River/Mexicali treatment facilities .

The significance of BECC and NADBank's contributions to border projects is exemplified in a colonia-related project that was certified in 1999 and received financing in 2000. NADBank played the role of "dealmaker" by providing key funding for water and sewer hookups for colonia households benefiting from a Texas' program that subsidized water and sewer systems in colonias.[6] The Texas subsidy program—the Economically Distressed Areas Program—did not provide funding for household connections. Using BEIF grants as a start, NADBank attracted money from other sources. The final NADBank financing package enabled colonia households in seven communities to connect to water distribution lines and wastewater collection lines that had been constructed through the Economically Distressed Areas Program. Without NADBank's financing package for household connections, the state's investment in the distribution and collection systems would have failed to provide many colonia residents with needed water and sewer services. In February 2001, NADBank approved another BEIF grant to assist with household connections and water and wastewater improvements for fifteen colonias outside Laredo, Texas. BECC certified the Laredo project in September 2000.

Much of what BECC and NADBank can accomplish within their mandates is shaped by the funding for border infrastructure. For the last three years, the U.S. Congress has provided less than the EPA's request for border environmental funding. Instead of providing the $100 million requested for 2001, EPA's border funding is $75 million with $9.5 million of this earmarked for specific projects (U.S. Congress, House, 106th Legislature).

Obstacles and Opportunities for NADBank's Lending

Although NADBank has played a significant role in projects through BEIF grants, it has experienced difficulty lending in the United States because water and sewer service providers can obtain less expensive debt-financing elsewhere, e.g., from State Revolving Funds and municipal bond markets. In general, U.S. utilities did not seriously pursue NADBank's participation in projects until after NADBank began administering BEIF grants. U.S. utilities were encouraged by the BEIF grants because these grants were earmarked for border communities, and the utilities could easily access the grants. Prior to BEIF, the main subsidies for U.S. border projects (with the exception of funding for colonia projects) were for international wastewater projects through

[6] Telephone interview conducted by Nicole Carter with a representative of the Office of Texas Secretary of State representative, 31 March 2000.

the IBWC. These projects received direct allocations from the U.S. Congress. Obtaining funding for these projects required political clout, and most border communities, with the exception of the City of San Diego, were not politically powerful.

NADBank's participation in Mexican projects has been limited for reasons related to the institutions for delivering water and wastewater services and projects. State water and sewer utilities and their local branches provide water and sewer service to Mexican border municipalities.[7] To satisfy the BECC certification criteria, local branches of state utilities must take responsibility for developing and implementing their own projects. But most of these local branches had not had extensive experience with planning or building water and wastewater projects. Moreover, because of difficulties in establishing and collecting user fees and upheavals in utility staff due to changes in state political administrations, local branches often lacked the financial and managerial capacities needed to satisfy BECC criteria (Carter, 1999). Managers of state utilities and their local branches were usually either appointed by state governors or selected by appointees of state governors. Their selection was based more on their political ties than their skills and knowledge of water and sewer utilities. In Mexico, the fourteen certified public projects were undertaken by utilities working to overcome these impediments, often relying on assistance from BECC and NADBank.

The context of project financing in Mexico provided NADBank with both opportunities and impediments. NADBank was able to loan more for Mexican projects than U.S. projects because Mexican utilities had fewer financing options than U.S. utilities. Mexican state utilities are denied access to foreign capital. Because of provisions in the Mexican Constitution, only the Mexican federal government can borrow in a foreign currency or with foreign creditors. Moreover, state water and sewer utilities could not work with the municipal governments to raise funds through municipal bonds (a common means of financing water and wastewater projects in the U.S.) because a municipal bond market did not exist in Mexico as of 2000.

Mexican utilities and communities were also constrained in their ability to raise funds using taxation. In the 1990s, tax collection in Mexico remained centralized, and the federal government maintained control of over 80% of the federal revenue (Mendoza Berrueto, 1996). Under a revenue-sharing scheme, the federal government disbursed to each state a portion of the remaining 20%. In principle, Mexican border states could offset their water and sewer financing problems by raising state taxes. However, the political feasibility of state governments raising revenue via state taxes was severely limited. State governments ran the risk of losing federal disbursements if they increased their tax revenues.

Another possible source of financing was the *maquiladoras,* which were among the largest water and sewer users in Mexico's border municipalities. These plants were also a driving force behind the border population boom. *Maquiladoras,* however, contributed little to financing public infrastructure. Their profits accrued largely outside of Mexico, and their payrolls were so low that payroll taxes were relatively insignificant. A 1990 study of eighty *maquiladoras* in Nuevo Laredo found that together these companies paid only $279,000 in payroll taxes that year—hardly enough to pay for the social services needed by their workers, let alone the cost of infrastructure construction (Barry et al., 1994). As a result of the tax system, the *maquiladoras*

[7] We identified one exception to a state utility providing municipal water and sewer service. A municipally-owned utility—Junta de Aguas y Drenaje—serves the municipality of Matamoros, Tamaulipas.

are not significantly contributing to the infrastructure that they and their workers use and are actually being subsidized by the governments' investments in infrastructure.

Debt financing was expensive through Mexican government entities such as the *Banco Nacional de Obras y Servicios Públicos* (BANOBRAS, National Bank of Public Works and Services). Nonetheless, competition for BANOBRAS loans is high because a BANOBRAS loan was one of the few available financing options. BANOBRAS lent at an interest rate a few points higher than the interest charged by the Mexican Treasury; in 1999, BANOBRAS was lending at 35.6% (General Accounting Office, 2000).

As a consequence of the limited and expensive options for project financing available to Mexican water and sewer utilities, NADBank's loans for Mexican projects at interest rates between 25.5% and 27.1% were attractive (General Accounting Office, 2000). NADBank's loans for the Ciudad Juárez and Naco projects constituted, respectively, 15% and 11% of the financing packages. Because the interest rates for loans in Mexico (including NADBank's) were high, border water and wastewater projects required significant subsidies both from NADBank and Mexican federal and state sources in order to be affordable to border communities.

In early 1999, NADBank developed a mechanism that allowed financing of Mexican public sector projects in a manner consistent with the Mexican Constitution's prohibitions on sub-federal entities borrowing in foreign currencies and from foreign entities. NADBank established a limited-purpose financial institution that channels NADBank financing to environmental infrastructure projects sponsored by Mexican public entities. In late 2000, NADBank began a pilot initiative—the Value Lending Program—using $50 million of the Bank's paid-in capital. The program, which was still under development in May 2001, will lend for water, wastewater, and solid waste projects at lower rates than the NADBank's regular lending program. The reduced rates will make debt-repayment more affordable for low-income border communities.

Reality of User Fees for Debt Repayment and Facility Maintenance in Mexico

In order to repay loans, utilities need a revenue stream from their operations. BECC's financial feasibility criteria and NADBank's financial packages require repaying loans through user fees. BECC and NADBank were required to overcome decades of problems related to user fees when they attempted to apply their requirements to Mexican border projects. A vicious cycle of poor service quality and deferred maintenance had evolved among Mexican utilities. The explosive growth of border municipalities contributed to a decline in the quality of urban water and sewer service. Rapidly expanding demand exceeded systems' capacities. Users failed to pay their bills because of the poor service quality and for a variety of other reasons discussed below. Without these user fees, water and sewer utilities could not adequately operate and maintain their facilities, and utilities became dependent on subsidies from state and federal sources for both construction and maintenance activities. Systems quickly degenerated; for example, a $50 gate for the wetland lagoons used to treat Mexicali's sewage was not replaced when it failed, thus cutting treatment efficiency of the lagoons in half.[8] As of December 1995, thirty (33%) of the ninety water treatment plants that had been built in Mexican border states were no longer operating, and many of those that were operating were not at their maximum treatment capacity or efficiency (Navarrete Martínez, 1996).

[8] Interview conducted by Nicole Carter with a representative of EPA Region IX Water Group, 25 November 1997.

User fees were inadequate because they were too low and collection was poor. Collection rates often dipped below 40% (Technical Director of BECC, interview, 14 March 1997). Utilities had trouble collecting fees because, for many years, cutting domestic water service was interpreted as unconstitutional; the Mexican Constitution protects access to water as a fundamental right (Ingram et al., 1995). In the mid- and late-1990s, the Constitution was reinterpreted to allow water service to be cut for nonpayment; the rationale is that only service is cut—not the right to water.[9] By the late 1990s, utilities in many border states possessed explicit legal authority to cut water service for nonpayment of user fees. Low fee collection rates also developed out of a commonly held belief in Mexico in the right to free water and free public services.[10] This belief, combined with the failure of utilities to collect user fees aggressively and to take action to stop illegal connections to water lines, yielded an informal rule among customers: it is acceptable not to pay water and sewer fees. Another reason collection rates remained low was that local branches of state utilities had not been forced to face hard budget constraints or to operate efficiently; utilities consistently relied upon state and federal subsidies for construction and maintenance.

Water and sewer rates charged customers were often below the amount necessary to cover operation and maintenance costs, much less to repay debt. As one BECC director explained it, increasing rates was "political suicide" for anyone in politics or with political aspirations because rates affect every voter connected to the water and sewer system.[11] As a consequence, low user rates persisted.

Mexican border residents have a limited ability to pay for water and sewer service; one estimate is that 51% of Mexico's border residents in the early 1990s lived below the poverty line (Betts and Slottje, 1994). Before BEIF and other grants were available to decrease the amount a service provider would need to borrow, the user fee increases that were required to repay NADBank's loans would have substantially increased the monthly water and sewer bills of low-income customers. These dramatic increases would have indeed amounted to political suicide and would not have been affordable for most border communities.

By carefully combining loans and grants, NADBank developed financing packages with user fees set so that they were affordable for community members, but nonetheless sufficient to provide revenue for operation and maintenance and debt repayment. NADBank works with the community to develop a least cost financing package for the community. The increases in water and sewer rates that NADBank supported in its financing packages appeared to be affordable for low-income customers. The water and sewer rate increases represented real annual increases of 10-15%. Although this is a significant jump, these higher rates did not exceed 2.3% of the household income based on a single, minimum-wage earner (Carter, 1999). One rule of thumb commonly used by international development banks is that households can afford to pay up to 5% of their income for water and sewer services (Wright, 1997). By using grants to cover construction costs, NADBank's financing packages reduced the loan amount so that repaying the debt was manageable for the community. Proposed rate increases were made politically acceptable because the increases were often characterized as being forced by BECC and

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[9] Interview conducted by Nicole Carter with BECC's Public Outreach Coordinator, 14 March 1997.
[10] Interview conducted by Nicole Carter with BECC's Technical Director, 14 March 1997.
[11] Interview conducted by Nicole Carter with BECC's Technical Director, 13 February 1997.

NADBank, and the increases were associated with specific projects to improve and expand water and sewer services.

Results from BECC and NADBank's insistence on using fees to finance maintenance and debt repayment are exemplified in a project for Ciudad Juárez. BECC would not certify the wastewater treatment project proposed by the local branch in Ciudad Juárez—*Junta Municipal de Agua y Saneamiento* (JMAS)—until a new rate schedule was devised and implemented. JMAS not only instituted a rate increase of 10% for average residential customers in 1997, but it also increased its water and wastewater fee collection rate from 40% in 1995 to 90% in 1998 and developed an advanced system for managing customer complaints.[12]

In 1996, in order to foster customers' willingness to pay and to temper the politically liabilities of user fee increases, BECC revised its certification criteria to require a public meeting to discuss user fee increases. In some communities, these meetings successfully strengthened public support for increases by clarifying the reasons for the increases and providing assurances that the additional money collected will go to improving local water and sewer service.[13]

Uncertainties in the Future of BECC and NADBank

Although BECC and NADBank contributed to unprecedented levels of border infrastructure investments, the future roles of the two organizations are uncertain. Beginning in Spring 2000, NADBank began investigating the possibility of extending its activities geographically beyond the 100 kilometers of the border region and beyond the current scope of water, wastewater, and solid waste infrastructure. The Bank initiated this effort in order to expand the use its credit resources. In late November 2000 after receiving public input on proposals for an extension of its mandate, NADBank's Board of Directors decided that the Bank should expand its scope beyond the current water, wastewater, and solid waste projects into activities within the current provision of the Bank's charter. In response, BECC decided to certify projects of the following types: industrial and hazardous waste projects (to the extent that the waste presents a pollution threat to water or soil); water conservation projects; water and wastewater hookups for housing; and recycling and waste reduction projects. BECC is also considering (on a pilot basis) projects related to air quality, public transportation, and clean and efficient energy, as well as projects that improve municipal planning and development and water management (BECC, 2000). As of May 2001, BECC had not received any applications for projects falling under the new project types that could be certified.

Beginning in August 2000 and continuing into 2001, Mexican President Vicente Fox (who took office in December 2000) demonstrated interest in changing the focus and responsibilities of BECC and NADBank. Fox proposed expanding NADBank beyond its focus on border environment infrastructure; under his proposal, NADBank would be a $20 billion bank financing a broad range of North American development projects (*Los Angeles Times,* 18 August 2000). The expanded Bank would be part of Fox's ambitious plan to form an economic block similar to the European Union in North America. NADBank would manage an "economic

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[12] Interview conducted by Nicole Carter with BECC's Technical Director, 14 March 1997; Interview conducted by Nicole Carter with Director of Sanitation for JMAS, 17 December 1997.

[13] Interview conducted by Nicole Carter with Director of Sanitation for JMAS, 17 December 1997; Telephone interview conducted by Diana Cardenas with a representative of a U.S. non-governmental border organization, 26 Februar 1998.

convergence fund" aimed at accelerating Mexico's economy, thus facilitating the integration of the three countries. BECC's relationship to the expanded NADBank was not discussed; however in Mexico during early 2001, there was some discussion of moving some of BECC's project development responsibilities to the NADBank (Kelly et al., 2001).

Numerous border non-governmental organizations have expressed concern regarding the changes being proposed by the Fox administration (Kelly et al., 2001; Arizona Toxics Information et al., 2001). They argue that BECC and NADBank still have numerous border water and wastewater issues to address before expansion into other development concerns can be considered and that the two institutions are not equipped to deal with the full spectrum of water issues much less to expand into other areas of development in North America. For example, the Mexican and U.S. border population is projected to increase from 12 million in 2000 to 15 million in 2010 and 19 million in 2020 (Southwest Center for Environmental Research and Policy 1999, 7). This growth will only exacerbate the previously discussed shortfalls in water and sewer infrastructure. Moreover, providing water for the region's growing urban population and industrial sector is increasingly in conflict with the use of water for regional agriculture and instream uses, including species habitat conservation, especially during years with low precipitation in watersheds affecting border water supplies. Neither BECC nor NADBank (nor IBWC) are structured to manage or assist communities in planning the exploitation of their water supplies, which fundamentally affects the water systems being constructed in this post-NAFTA era. BECC and NADBank are limited to construction-based projects and project-by-project development assistance. Neither of these organizations is involved in regional planning, and deficiencies in regional planning are the core of numerous water-related problems including those that stem from the booming border populations. Many border non-governmental organizations argue in spite of these shortcomings BECC and NADBank have significantly contributed to efforts addressing the environmental infrastructure needs of the region, and what these organizations need is not an expansion into other development areas but increased support for their environmental infrastructure efforts.

Conclusions

In recent decades, the border region has experienced dramatic population growth and industrialization due largely to trade patterns end economic policies. The governments of Mexico and the United States created BECC and NADBank in association with NAFTA to improve and protect the environment of the border region. The two organizations contribute to environmental protection by actively promoting well-crafted water, wastewater, and solid waste infrastructure projects. Between 1995 and 2000, BECC certified forty water and wastewater projects, and NADBank developed financing packages for thirty-one of those projects. These projects represented a significant increase in infrastructure investment in the border region. However, these projects are only the first step in addressing the water and wastewater infrastructure needs of the region. As of December 2000, NADBank financing packages covered only 13% of the water and wastewater infrastructure investment needed between 1994 and 2003, and NADBank's financial participation in projects was overwhelmingly through grants, not loans. BEIF grants constituted 97% of NADBank's financial participation in projects.

During their first six years of operation, BECC and NADBank did not address a substantial fraction of the financing needed for water and wastewater infrastructure, but they succeeded in promoting debt-financed, and user-fee-supported projects developed with public participation. The technical assistance and utility strengthening activities sponsored by BECC and NADBank are expected to contribute to the long-term viability of these projects by strengthening utilities so they cannot only complete the projects but also maintain them and plan for future investments. Even with the progress made under BECC and NADBank, many additional water and wastewater infrastructure investments will have to be made if citizens of the border region are to enjoy basic water supply and wastewater collection services.

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Table 1. BECC Certification Criteria

Topical Area	Subject of Certification Criteria
General Criteria	· Project Type · Project Location · Project Description and Work Tasks · Conformance with International Treaties and Agreements
Human Health and Environment	· Human Health and Environmental Need · Environmental Assessment · Compliance with Applicable Environmental and Cultural Resource Laws
Technical Feasibility	· Appropriate Technology · Operation and Maintenance Plan · Compliance with Applicable Design Standards
Financial Feasibility and Project Management	· Financial Feasibility · Fee/Rate Model · Project Management Capacity
Community Participation	· Comprehensive Community Participation Plan · Report Documenting Public Support
Sustainable Development	· Adherence with Sustainable Development Principles · Institutional and Human Capacity Building · Conformance with Applicable Local and Regional Conservation and Development Plans · Natural Resource Conservation · Community Development

Source: BECC, 1996.

Table 2. NADBank Financial Packages in Mexico (as of December 2000, in millions of U.S. dollars)

Mexican Community	Population (in thousands)	PDAP and/or IDP	NADBank Loan	BEIF Grant	Total Project Cost
CONSTRUCTION COMPLETED					
Matamoros, TAM (private project)	23	0.20	no participation	no participation	no participation
UNDER CONSTRUCTION					
Ciudad Acuña, COAH	113	0.28	-	21.18	80.35
Ciudad Juárez, CHIH	1,100	0.33	4.58	11.08	31.16
Mexicali, BC	635	0.32	-	20.62	57.36
Naco, SON	6	0.19	0.18	0.42	1.62
Nogales, SON	215	0.87	being designed	being designed	39.00
Piedras Negras, COAH	133	0.09	-	12.83	57.42
Reynosa, TAM	474	0.08	-	8.09	83.40
Tijuana, BC	113	0.30	2.5	16	19.52
UNDER DESIGN					
Palomas, CHIH	7	0.19	-	1.88	5.18
Región Cinco Manantiales, COAH	30	-	being designed	-	17.50
San Luis Rio Colorado, SON	170	0.64	-	5.93	13.50
Tecate, BC	66	0.25	being designed	3.72	7.81
Tijuana, BC (Ecoparque)	NA	0.04	no participation	no participation	no participation
REDEFINED					
Ensenada, BC	250	0.25	no participation	no participation	no participation
MEXICO TOTAL	*3,335*	*4.03*	*7.26*	*101.75*	*413.82*

Sources: BECC and NADBank 2000; NADBank 2000.

Table 3. NADBank Financial Packages in Mexico (as of December 2000, in millions of U.S. dollars)

U.S. Community	Population (in thousands)	PDAP and/or IDP	NADBank Loan	BEIF Grant	Total Project Cost
CONSTRUCTION COMPLETED					
Brawley, CA	27	-	0.97	-	24.80
Douglas, AZ	14	0.50	no participation	no participation	no participation
El Paso, TX (NW Reclaimed Water)	90	-	no participation	no participation	no participation
UNDER CONSTRUCTION					
Alton, TX	6	0.05	-	0.26	14.47
Calexico, CA	26	0.04	-	6.5	11.30
Donna, TX	20	0.24	-	3.49	21.62
El Paso, TX	47	0.63	-	14.9	37.82
El Paso County, TX (Lower Valley)	40	0.33	-	17.5	98.35
El Paso County, TX (on-site treatment)	1	-	no participation	no participation	no participation
Heber, CA	3	0.29	-	1.08	3.38
Mercedes, TX	15	0.24	1.87	0.9	11.16
Roma, TX	21	0.20	-	5.6	34.18
San Diego, CA	1,200	-	-	17.2	99.59
Somerton, AZ	6	0.08	-	1.07	3.44
Westmorland, CA	2	0.05	-	1.98	4.41
IN BIDDING PROCESS					
Berino, NM	0.5	0.22	no participation	no participation	no participation
Del Rio, TX	42	0.04	-	14.18	36.50
Heber, CA	NA	0.07	-	2.53	4.34
Laredo, TX	4	0.26	-	6.23	21.58
UNDER DESIGN					
Brawley, CA	NA	0.32	-	6.39	13.56
Nogales, AZ	220	0.14	-	39.5	46.10
Patagonia, AZ	1	0.22	-	0.77	1.26
Sanderson, TX	1	0.05	-	0.35	3.60
Texas Plan for Hookups	23	0.02	-	6.36	8.82
BEING REDEFINED					
Somerton, AZ	NA	0.25	no participation	no participation	no participation
U.S. TOTAL	*1,810*	*4.24*	*2.84*	*146.79*	*500.28*

Sources: BECC and NADBank 2000; NADBank 2000.

Table 4. Sierra Club's Estimates of Public Spending Needs for Water and Wastewater Infrastructure in the U.S.-Mexico Border Region for 1994-2003 (in billions of U.S. dollars)

	U.S.	Mexico	Total
Water	1.07	0.94	2.02
Wastewater	1.68	3.33	5.01
Total	**2.75**	**4.27**	**7.03**

Source: Sierra Club, 1993.

Table 5. Impact of BECC and NADBank's Activities Through December 2000 on Estimated Water and Wastewater Need in the U.S.-Mexico Border Region for 1994-2003

	U.S.	Mexico	Total
Estimated Need (hereafter Need)[a]	\$2.75 billion	\$4.27 billion	7.03 billion
Cost of Public Projects with NADBank Financing Packages from 9/1996 to 12/2000 (hereafter Cost)[b]	\$500 million	\$414 million	\$914 million
Cost as % of Need	18%	9.7%	13%
% of Need Covered by NADBank-financed projects Each Year[c]	4.2%	2.3%	3.0%
NADBank Debt Used for Project Financing[d]	\$2.84 million	\$7.26 million	\$10.1 million
NADBank Debt as % of Need	0.10%	0.17%	0.14%
NADBank Debt as % of Cost	0.6%	2%	1%

[a] Need figures are from Table 4.

[b] Cost figures are for the public projects shown in Tables 2 and 3.

[c] This calculation is made using the years between the financing of the first project in September 1996 and the end of the analysis in December 2000—4.3 years.

[d] NADBank debt figures are from Tables 2 and 3.

Acronyms

BANOBRAS	Banco Nacional de Obras y Servicios Públicos
BECC	Border Environment Cooperation Commission
BEIF	Border Environment Infrastructure Fund
CEC	Commission for Environmental Cooperation
CNA	Comisión Nacional de Agua
EPA	U.S. Environmental Protection Agency
GNP	Gross National Product
IBWC	International Boundary and Water Commission
IDP	Institutional Development Cooperation Program
JMAS	Junta Municipal de Agua y Saneamiento
NADBank	North American Development Bank
NAFTA	North American Free Trade Agreement
PDAP	Project Development Assistance Program

Binational Cooperation and the Environment at the U.S.-Mexico Border: A Mexican Perspective

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The border region between Mexico and the United States is one of the most environmentally stressed areas in the world. The U.S. and Mexican governments have created a series of binational plans and projects to solve some of the region's most pressing environmental problems. Binational efforts range from a general agreement to solve transboundary pollution signed in 1983 to plans seeking a solution to environmental problems and the creation of binational institutions focusing on urban infrastructure related to these problems. However, until now there has not been an evaluation of the achievements and limitations of binational cooperation. This evaluation is long overdue since after 17 years of binational cooperation, border environmental problems have not significantly improved, and Mexico and the United States are preparing to launch a new environmental plan for the border region.

An evaluation of binational cooperation is a task beyond the scope of this paper. The paper reflects on the reasons why binational cooperation has achieved only limited success in solving border environmental problems. The basic argument of the paper is that binational actions have not responded to the needs of the border communities. Two factors help explain this distance between actions and reality. First, binational actions have been designed more as a response to political pressure from media attention to environmental problems at the border, and from groups in the United States, than a comprehensive long-term strategy to meet the needs of the border communities. Second, the managerial approach used in the design of binational actions has provided a fragmented perspective of environmental issues, isolating problems from the structural causes behind them and their social and economic consequences. This paper suggests in conclusion that there is an urgent need for a new approach in binational cooperation to help border communities find sustainable solutions to their environmental problems.

The paper is divided in two sections. The first part presents a brief summary of the major driving forces for environmental change along the U.S.-Mexico border. The second part presents a perspective of binational cooperation on border environmental issues, seeking to explain the obstacles created by political pressures and the managerial approach to a comprehensive long-term environmental action plan for the U.S.-Mexico border.

The Driving Forces for Environmental Change at the U.S.-Mexico Border

Environmental problems in the Mexican border communities have deep historical roots and cannot be attributed to a single cause, but rather to a combination of factors related to fast urban and population growth during the last five decades, together with rapid industrialization since the 1970s. These two driving forces for environmental change at the U.S.-Mexico border are the result of complex social processes at the local, national, and transnational levels. Historically, much of the border communities' uneven urban growth was due to imbalances in federal policies, which promoted rapid economic growth in the region (by funding highways, energy facilities, communications links, and industrialization) without making parallel investments in social infrastructure (housing, public services, and so on).[i] The border's

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accelerated population growth, which began in the late 1950s, peaked during the 1960s and 1970s due to the constant flow of migrants through the border area en route to the United States (Lorey, 1990). Shortfalls in housing and public services intensified, and slums areas became a common component of the urban space.

That unbalanced growth of the Mexican border cities had important environmental consequences. Water supply, distribution, and quality have historically been a major environmental problem with severe social impacts, such as health, standard of living, and income (Mumme, 1988). Other problems like collecting and treating sewage created severe hazards for large number of the inhabitants of the border cities, and in some cases like Nogales and Tijuana, with transboundary consequences. Deficiencies in public services were particularly evident in the recollection and disposal of solid waste.

Industrialization associated with transnational processes since the early 1970s was characterized by the appearance of *maquiladoras*. Most of the *maquiladoras* are subsidiaries or subcontractors of transnational corporations and the logic of their relocation to the border area has to be understood within the international distribution of labor fostered by transnational capital. Sklair (1989) explains this process as a coming together of the interests of the transnational corporations and some key elites in the countries of the Third World. For him, this merge of interests establishes three types of transnational processes: economic (the relocation and operation of plants to Third World countries), the political (the emergence of a transnational capitalist class), and the cultural (the culture-ideology of consumerism) (Sklair, 1994). The first two of these processes help explain the arrival of the *maquiladora* in Mexico and their disproportionate power in governance at the U.S.-Mexico border.

Growth in the *maquiladora* boomed at the U.S.-Mexico border during the 1980s. This explosive growth diversified the local economies and created a large number of jobs, but it also exacerbated urban problems along the border. The strong demand for labor in the *maquiladora* attracted new waves of migrants to the region. As newcomers augmented the pressures on the housing stock and the network of public services, and as the city governments continued to be unable to keep pace with the cities' urban growth, the gap between the demand for and the availability of services widened year by year. This process continues today.

Several factors help explain this impact of the *maquiladora* on border communities. Newcomers to the border who are employed in stable but low-paying jobs have difficulty finding affordable housing with basic services because of the city's substantial accumulated deficit in the supply of such housing. Without an alternative, workers must resort to substandard, often self-built, housing in *colonias* lacking electricity, sewerage, paved roads, and so on. A characteristic of Mexico's border communities is the extent of such urban marginalization.[ii]

Although *maquiladoras* are not responsible for providing housing and public services for their workers, it is important not to forget how closely the growth and operation of the *maquiladora* industry is linked to urban growth. Further growth of the *maquiladora* sector is likely to attract more migrants from northern and central Mexico to the border, augmenting the demand for housing and services and widening the gap between supply and demand.

The increasing industrialization that accompanied the growth of the *maquiladora* sector also created an unequal competition for physical and human resources—flat urban land, public services, communications, and skilled and unskilled labor—between economic sectors and between economic actors and social groups (Gonzalez-Arechiga and Ramirez, 1991).[iii] This competition aggravated the uneven distribution of public services within the cities.

Municipal planning

The Mexican border cities' inability to keep pace with the demand for urban infrastructure has also been due in part to the local governments' lack of economic resources. In Mexico's centralized political system, the resources provided to the municipalities are minimal. On average, only 4 percent of the annual federal budget reaches the municipalities, and only 14 percent goes to the state governments (Zepeda, 1992). Most municipalities in Mexico have barely enough resources to pay the salaries of local government employees. For example, over 72 percent of all municipal public expenditures in Tijuana in 1995 were administrative expenses; only 10.1 percent went to support public works (INEGI, 1996). Municipal resources for public works finance small-scale projects, such as street repair. Tijuana, like other municipalities along the border, depends on federal resources for the construction of major public works (housing, public services, roads, and so on). Since the beginning of the economic crisis in the early 1980s, federal government spending on public services has been limited overall, and the border municipalities are not high on the federal agenda.

Planning efforts in the Mexican border communities have been limited. Urban growth has been unregulated and chaotic, aggravating the challenges of underdevelopment (Alegria, 1992; Herzog, 1989). Moreover, the urban plans have not been enforced consistently. Topographic conditions in several border cities present additional obstacles to urban growth. Flat areas for low-cost urbanization are few. Hence, low-income groups and recently arrived migrants are often forced to create zones of incomplete urbanization on hillsides, living in extremely precarious housing that is prone to washouts, mudslides, and other natural disasters (Bocco et.al., 1993). For these residents, natural disasters are just one more element in their marginalization and in the inequities they suffer in the distribution of the benefits of the city's economic growth. However, these are not the only sectors of the border population that are affected by a failure in urban planning. Even well-urbanized areas that are home to the city's middle- and high-income groups are located in risk-prone zones.

The incomplete enforcement of urban planning schemes has also facilitated the indiscriminate location of industry throughout the urban areas, with impacts on urban structure and on daily urban life (Sanchez, Alegria, and Castro, 1994). Areas of incomplete urbanization, settled by *maquiladora* workers or migrants, soon grew to surround industrial areas that originally lay outside of the urban area. Other plants opted to locate within the existing city but outside the industrial parks.

This indiscriminate location of industry in border cities has environmental consequences. There has been an increasing number of environmental emergencies originating in the industrial site at Tijuana, Mexicali, Nogales, Ciudad Juarez, Reynosa, and Matamoros. Such emergencies arise from improper management of hazardous substances or from accidents due to human errors or equipment failures. Industrial emergencies are a particular concern for the border communities because of the widespread distribution of industrial plants throughout the cities, the shortage of information regarding what kinds of hazardous substances are housed in each plant, and the limited local resources for training and equipping emergency staff to deal with these kinds of events. Mexico's new environmental legislation (1996) incorporates some "right-to-know" provisions, but to date, inventories of hazardous substances in the Mexican border cities are very incomplete or nonexistent.

This same lack of knowledge extends the environmental health risks of *maquiladoras.* Because *maquiladoras* are considered light industry, they were long believed to have little or no environmental impact. But since the late 1980s, a growing number of studies have documented the use of hazardous materials in *maquiladoras* and the lack of safety controls in the handling of these materials inside and outside the plant (Denman, 1997; Cedillo et.al., 1997; Moure-Eraso et.al., 1994; Simon, 1997; La Dou, 1991). *Maquiladoras* have for years been unable to document that they are handling their hazardous wastes in accordance with the law (Sanchez, 1990). These range from solvents containing organic compounds to acids and heavy metals (Acosta et.al., 1994). These studies also suggest that there are problems in the way these substances are handled inside the plants. Despite recent efforts, Mexico's federal and state-level environmental agencies have not yet been able to provide a comprehensive solution to this problem. To date, there are few data on which to base an assessment of the amount of pollution generated by the border's industry and its environmental and social repercussions.[iv]

Environmental pollution caused by hazardous substances and hazardous wastes is in fact a national problem in Mexico. Unfortunately, there are few resources available in federal or state budgets with which to bolster enforcement of environmental regulations. Mexico's economic crisis and the resulting cuts in federal expenditures have taken a toll on the enforcement of environmental legislation. There is also only very limited documentation available on hazardous waste generators, including accurate descriptions of the types, volume, and form of emissions from each source, and on the final disposition of hazardous wastes. These obstacles hinder effective protection of the border environment and public health, and they undercut efforts to deal with environmental emergencies whose origins are to be found in border industries.

The Mexican Border Cities Today

Fast industrialization has been a major factor in the modification of the urban structure, the urban economy, and daily urban life. The Mexican border cities grew historically as centers of trade and services, and industrialization transformed them into centers of industrial production during the last three decades. Flows of people and goods were traditionally directed toward the downtown area and the international border, where trade and service activities were concentrated (Alegria, 1992; Herzog, 1989; Sanchez, Alegria and Castro, 1994). Transport routes and roads were designed to parallel demands of the urban economy.

The rapid growth of industry over a widespread area in a relatively short period of time has altered the flow of people and goods in the urban area. Goods now flow from the border to the industrial areas and vice versa. People flow from different parts of the city to the industrial areas. The development of new shopping malls outside the downtown areas also contributed to changing the historic flow of urban traffic. Transport routes have adapted to the new demands of the urban economy, but the construction of roads to service heavy traffic to the industrial areas has been slow, difficult, and expensive. Frequent traffic jams create severe obstacles for urban activities and are a major source of air pollution. Fast industrialization has introduced a new range of pollution emissions of volative organo-chlorate compounds (VOCs)—used as solvents in painting, woodworking, and other industrial activities in *maquiladoras*—contribute to ozone contamination in the lower atmosphere.

Inefficiencies in public transportation, an extensive market for relatively inexpensive (hence, older and more polluting) cars, and the influence of the U.S. "car culture" together account for the high number of private cars in Mexican border cities. Statistics from Mexico's Motor Vehicle Registry show that in 1994 almost 77 percent of all motor vehicles along the border were private cars (INEGI, 1996). The real number of cars might be 10 to 15 percent higher than the official count, considering that many of the cars driven by people living in Mexican border cities are not registered in Mexico.[v] Many of these vehicles are old and in poor condition, with high fuel consumption and no emissions controls. Mexico requires that new cars and trucks be equipped with catalytic converters, but this law has been in effect only since 1991. The diesel engines that power most of the buses and heavy trucks trafficking servicing the industry and exports (22 percent of all vehicles in 1994) often emit high levels of contaminants.

The added volume of transient vehicles due to the area's high number of border crossings also contributes to air pollution. The U.S.-Mexico border is the busiest border in the world. Many of these crossings are by car. Stalled vehicles contribute further to the border's air quality problems.

Air quality is affected not only by the lack of controls on industrial and automobile emissions, but also by the large volume of suspended particles coming from areas of incomplete urbanization. Air pollution sources include: fixed sources (power plants, industrial plants, kilns for brick and tile making); mobile sources (cars and trucks); particulate matter (windblown dust carried from unpaved roads and eroding areas, the burning of solid waste, aggregate mining and construction, and crop burning in the rural areas). The strange blend of underdevelopment and economic growth that characterizes border cities explains the combination of these pollution sources. On the one hand, fast and often chaotic urban growth is responsible for the removal of vegetation, for soil erosion, and for the urbanization of risk-prone areas. This has aggravated the deficiencies in urban infrastructure, exemplified by the number of unpaved roads and by the solid waste problems mentioned above. These sources are responsible for the high concentrations of particulate matter. On the other hand, increasing economic growth, transport and industrialization greatly increased the volume of this pollution (World Bank, 1994).

Air pollution is also a transboundary environmental problem particularly acute in the border areas of Tijuana-San Diego, Mexicali-Calexico, the Two Nogales, and Ciudad Juarez-El Paso. Because these twin cities share the same air basin, emissions on one side of the border can affect the air quality on the other side. Emissions of particulate matter, which is a serious problem on the Mexican side of the border, frequently travel from south to north. Ozone and sulfur dioxide emissions, meanwhile, generally travel from north to south (although in some areas this flow is from south to north). Although the monitoring of air quality in Mexican border cities has been limited until recently, Tijuana and Mexicali have established a net of monitoring stations which will help to provide a better picture of how air pollutants flow within the cities and across the border.[vi]

Border cities' uneven growth and lack of services have further aggravated water pollution problems. Shortfalls in constructing, operating, and maintaining public services are to blame for part of these problems. Despite efforts to increase the coverage of the municipal drinking water and sewage systems, significant number of inhabitants in the Mexican border communities have not adequate access to these services. Efforts to expand these systems between 1970 and 2000 were not able to keep pace with the increased demand from a growing population.[vii] Because of inadequate maintenance, the municipal systems are subject to line breaks in many parts of the cities, including well-urbanized areas.

In the case of sewage, spilled and uncollected raw sewage represents an important source of bacterial pollution. Sewage spills occur because the increase of wastewater generated by the expanding population exceeds the capacity of the existing pipes (Sanchez and Lara, 1993). The combination of uncollected raw sewage in slums and low-income neighborhoods spills in other parts of the city, and gaps in the distribution network for potable water go far toward explaining the high incidence of water-borne diseases in Mexican border communities. Untreated sewage also poses a constant threat of contaminating surface and groundwater resources.

Industrialization has also introduced a new problem into the operation of sewerage systems. The illegal discharge of hazardous wastes into municipal systems or open waterways adds to the environmental problems and health risks created by underdevelopment and deficiencies in urban infrastructure. Currently there are no comprehensive and systematic water quality programs in any of Mexico's border cities that could clearly identify hazardous waste pollution. However, this illegal practice has been documented in several Mexican border cities. Sewage samples in Mexicali, Tijuana, Nogales, and Matamoros have been found to include pollutants, especially organic compounds, that tend to be associated with the border industry (Perry et al., 1990; Sánchez and Lara, 1993). This illustrates the importance of multimedia analysis in the study of border environmental issues.

Sewage problems have an important transboundary dimension. Spills of uncollected raw sewage have flowed across the international border for years. As I mentioned above, this was one of the environmental problems that prompted Mexico and the United States to sign the La Paz Agreement to control transboundary pollution along the border in 1983 (Sanchez, 1988). It is also an issue area in which the two governments have cooperated in their search for a solution to the problem. The best example is Tijuana's sewage problem. Much effort has gone into controlling this problem over the past two decades, including the construction of a municipal sewage treatment plant, the expansion of sewage networks, a defensive catchment system just across the border in San Diego, and the construction of the new binational sewage treatment plant next to these facilities. Despite these efforts, the problem has not been solved and the operation of the binational plant has run into problems due to the presence of industrial pollutants in sewage coming from Tijuana. It is worth noting that the binational plant does not alleviate all sewage treatment problems in Tijuana. This city is currently seeking to create additional treatment capacity to keep pace with its future increases in sewage flows.

Fast urban growth has severe consequences for the supply and distribution of water in the Mexican border communities. Almost all Mexican border communities face water supply problems (Sanchez, 1997). In some areas (Tijuana, Nogales, and Ciudad Juarez) water is a major constraint on population growth. The distribution of drinking water has also been a major problem. A significant percent of the population in Mexican border communities are not connected to the city's drinking water system. These people are forced to depend on secondary sources of drinking water, such as street vendors. Poor maintenance of the potable-water distribution network leads to pipe ruptures and spills.[viii] Most of the low income neighborhoods throughout the border cities with connections to the Municipal drinking water system suffer shortages in their supply several times in a year, in which cases they turn to secondary sources of drinking water (Varady and Mack, 1995; Sanchez and Lara, 1993). Secondary sources are not subject to quality controls, and the cost per liter of water from a secondary source is in average three to four times that of water provided through the municipal system (Ingram et al., 1995). Unfortunately, and despite the fact that water distribution is a national problem in Mexico, very few studies have examined this issue from a social point of view. Such a perspective requires assessing the impact of imbalances in water consumption on income distribution, health, and standard of living among the various social groups.[ix]

Deficiencies in other publicly provided services also have important environmental consequences in border cities. Municipal solid waste is one of the most visible environmental problems. Mexican authorities estimate that the country's border communities generate 0.749 kilograms per person per day of solid waste (World Bank, 1994). On average, only 46 percent of this waste is collected. The remainder is left on the streets, dumped on open land or in waterways, or burned in open fires in the urban area, presenting a major public health risk to border inhabitants. Even collected waste is an environmental threat because it is deposited in landfills that lack coverings, linings, and leachate control, and thus threaten the quality of surface and groundwater.

The rapid expansion of the *maquiladora* sector over the past twenty years, together with the lack of financial resources for strengthening environmental protection, may very well have increased the amount of pollution that is attributable to the mismanagement of hazardous waste. Not only has the *maquiladora* sector grown rapidly, it has also diversified its operations and integrated them vertically (Gonzalez-Arechiga and Ramirez, 1991). There is now a wide range of products that are assembled or manufactured at the border. This industrial diversification is paralleled by a similar diversification of and increase in the hazardous substances that are used in industrial processes (Sanchez, 1991; Sklair, 1994). Despite federal efforts to increase control on hazardous wastes, and despite the fact that growing numbers of *maquiladoras* are complying with environmental legislation, there is still evidence of mismanagement (Newman, 1996).[x] Such evidence includes the discovery of illegal hazardous waste dumpsites within and outside of urban areas, and wastewater samples showing concentrations of volatile organo-chlorate compounds (VOCs), heavy metals, and other pollutants frequently used by border industry (Simon, 1997; Liverman et.al., 1999). Environmental problems related to the use of hazardous substances or the mismanagement of hazardous waste are not limited to the *maquiladora* sector. They are present in the domestic industry as well. However, the *maquiladora* is by far the dominant industrial sector along the border.

Mexican legislation and the U.S.-Mexico Binational Agreement currently require that all wastes from *maquiladora* plants must be returned to their country of origin, that is, the country from which the raw materials were temporarily imported. (More than 95 percent of such imports to the border *maquiladoras* comes from the United States.)[xi] However, this requirement might change in the near future. Under the North American Free Trade Agreement (NAFTA), *maquiladora* plants are expected to be operating as domestic industry by 2001, and they will no longer be required to return their wastes to their country of origin. Although an agreement has been reached between the *maquiladora* and the U.S. and Mexican governments to maintain the current status and avoid double taxation, it is not clear what will happen with the provision regarding the return of hazardous waste. Mexico's very limited capacity to dispose of hazardous waste should be regarded as a major bottleneck to improved environmental protection in the border region.

In summary, the Mexican border communities are marked by two important characteristics. The first is their inability to keep pace with the demands of its fast-growing population and accelerated urban expansion. These shortfalls have resulted in large areas of incomplete urbanization, and they have generated severe environmental problems. The second is the cities' rapid industrialization during the last two decades, which has diversified the urban economies but also modified the urban structures—their daily urban life—and introduced a new set of environmental problems. These two phenomena have been the major driving force for environmental change along the border.

These characteristics have created a peculiar situation. The same factors that give rise to opportunities for economic growth also present obstacles to balance growth. Any examination of the obstacles and opportunities regarding future development opportunities along the border should take into consideration the diverse range of interactions among economic activities, social issues, political factors, and environmental problems. These interactions generate a number of conflicts due to the diverse range of federal, local and transnational interests and actors involved in governance. These actors often respond to interests beyond the local needs of the border, like those associated with the industrialization process (Sklair's transnational capitalist class). Mediating among these interests to solve environmental problems is a difficult task, but any effort in this direction should recognize that the future of the border is intrinsically associated with its industrialization process.

Binational Cooperation

Binational cooperation has gone through different stages and it includes a diversity of programs and actions. Binational cooperation can be divided into two generations for analytical purposes. The first generation covers the early years from 1983 and the La Paz agreement to the attention and influence of NAFTA on the border environmental issues that led to the creation and implementation of the IBEP. The second generation evolves after NAFTA with the creation of BECC, NADB, and Border XXI.

The formal departure of binational cooperation is the U.S.-Mexico Binational Agreement for the Control of Transboundary Pollution, signed by the two countries in 1983. This agreement is known as the La Paz agreement, and it provides a broad framework for binational communication and cooperation to control environmental pollution in the border region (Liverman et.al., 1999). The agreement is managed by the U.S. Environment Protection Agency (EPA) and Mexico's Environmental Agency, SEMARNAT in coordination with the International Boundary and Water Commission (IBWC). It has five annexes that established binational actions to specific environmental problems. Annex 1 establishes a partial control to sewage spills from Tijuana to San Diego. Annex 2 fosters binational cooperation to establish emergency response plans in the sister cities along the border. Annex 3 controls the transboundary movement of hazardous waste. Annex 4 focuses on the control of SO_2 emissions from the copper smelters in Arizona and Sonora. Annex 5 creates monitoring efforts for air pollution in El Paso/Ciudad Juárez and Tijuana/San Diego.

Subsequent efforts to present an integrated approach to manage the border environment led to the creation of the Integrated Border Environmental Plan (1992-1994). The creation of the Border Environmental Cooperation Commission (BECC) under NAFTA in 1994, brought high expectations that this commission could assume a coordinated role on border environmental issues (Spalding and Audley, 1997). However, BECC's jurisdiction is restricted to establishing the investment priorities for the North American Development Bank (NADB) and other financial institutions to be used for the construction of urban infrastructure, including those with a strong impact on the environment. Despite its limited mandate, one positive result of BECC during its first years of operation has been the increase in public participation in the certification process of projects (Varady et.al., 1997). For the first time, local authorities, NGOs, environmental groups, professional associations, and other groups participate in a binational forum dealing with decision making processes (limited as it currently is) that affect the growth of their communities (Lemos and Luna, 1999).[xii]

Border XXI is the most recent major initiative by the two governments to control border environmental problems (1996-2000). Border XXI was presented as a follow-up plan of IBEP with the goal of promoting sustainable development in the border area. Binational cooperation was expanded under this plan from 6 to 9 working groups, and the number of binational projects increased from 71 to 114. Border XXI ended at the end of 2000, and a new plan for binational cooperation is expected in the near future.

The first generation of binational cooperation

Binational cooperation during its early years can be characterized by an agenda dominated by few environmental issues. The five annexes of the La Paz agreement illustrate the limited perspective of environmental issues in the early years of binational cooperation. Out of the five annexes only three focused on solving specific environmental problems and only two have been successful (Mumme, 1992).[xiii] The La Paz agreement created six binational working groups that meet regularly each year on the following issues: air, water, hazardous waste, cooperation enforcement, pollution prevention, and contingency planning. The work of these working groups led to an exchange of information and a better understanding of their counterpart. But most concrete actions and investment were concentrated on sewage issues (the Tijuana problem mentioned above, the expansion of the binational treatment plant in the two Nogales, the New River in Mexicali, and the construction of the treatment plant in Nuevo Laredo), and the provisions under Annex 3 and Annex 4 mentioned above.

The fragmented perspective of binational cooperation on border environmental issues did not address the driving forces of problems, even in those issues related to sewage. Nor did it consider the social, economic, political and environmental consequences of its actions, or the consequences of its lack of –actions – beyond the exchange of information and the rhetoric of cooperation – on other critical environmental issues (hazardous waste, environmental health, pollution prevention, natural resources). Binational cooperation adopted a very limited technical interpretation of border environmental problems.

There are two issues that help explain the severe limitations of binational cooperation mentioned above. First, there is the impact of political pressure on binational cooperation. Binational actions have been particularly susceptible to influence from a diversity of political pressures. For example, the impact of groups in San Diego demanding the control of sewage spills from Tijuana since the early 1980s that became a major factor in the creation of the La Paz Agreement, its Annex 1 (Sanchez, 1988), and the IBEP.[xiv] This issue continues to be among the top priorities for the United States as reflected by investment on border environmental issues (see tables 1 and 2 below). Despite the rhetoric discourse of a broad approach to border environmental issues, both governments used a case-by-case approach to respond to those political pressures as it is illustrated in the priorities of binational actions.

The second issue is the lack of international experience on the part of EPA and SEDUE, its Mexican counterpart at that time. The La Paz Agreement was a learning process for both agencies, and they did not have the structure to provide comprehensive responses to international issues. Their response was to provide a technical solution to transboundary environmental problems with the minimum of resources. On the U.S. side, binational actions were coordinated by EPA's International Activities office in Washington that was staffed with only a handful of people, although it had some additional technical support from region VI and region IX. The situation on the Mexican side was even worse. Furthermore, only a handful of people were engaged in binational cooperation, but Mexico just began dealing with environmental issues when the La Paz Agreement was signed. Staff at SEDUE had no experience on environmental issues, and they relied on their U.S. counterparts for technical expertise. Mexico did not have an environmental legislation until 1988, and some of the norms, like those dealing with hazardous waste, were not enforced until 1989.

These two interrelated issues, the political pressure to find fast solution to specific border environmental issues and the lack of experience on international activities in EPA and SEDUE, created severe limitations on binational cooperation. Problems were treated under a very narrow technical approach on an *ad hoc* basis. Binational cooperation was also a very secretive process centered on federal agencies, with no public participation or involvement from the state governments or local authorities along the border. The lack of transparency and accountability in binational cooperation facilitated the restricted approach followed by the two federal governments.

NAFTA brought significant changes to the binational cooperation on border environmental issues. The media attention to the border area brought to light a number of environmental issues that have not been addressed by binational cooperation, as well as some of their social, economic, and political consequences. The two governments were forced to respond to rising political pressure from NAFTA critics focusing on the deteriorated state of the environment along the U.S.-Mexico border and the limited success of binational cooperation. The United States and Mexico presented the IBEP in 1991 as a new comprehensive approach to border environmental issues. The IBEP provides a new name to binational cooperation, but without any significant changes in the program's format, approach, or priorities (Mumme, 1992). The IBEP committed $845 million dollars to the solution of border environmental issues, but most of those funds were already committed as part of the binational cooperation under the La Paz Agreement. The additional funds, particularly those coming from Mexico, were invested in activities that had no clear relationship to critical border environmental problems beyond sewage.

The demands from Environmental NGOs (ENGOs) in the United States, Mexico, and Canada for transparency in the NAFTA negotiations introduced minor changes in the operation of binational cooperation. For the first time the two governments held public hearings about the IBEP before it was enforced. There is no evidence that comments from the public were taken into account. There was no further public participation beyond those hearings.

The IBEP served its political purpose. It was a fast response from the Mexican and the U.S. federal administrations to the criticism on NAFTA. But it did little to expand or improve binational cooperation. The IBEP disappeared quietly after the U.S. Congress approved NAFTA.

The recent years of binational cooperation

The second generation of binational cooperation began with the changes introduced by NAFTA and the creation of the so-called NAFTA environmental institutions, the Border Environmental Cooperation Commission (BECC) and the North American Development Bank (NADB). The broad attention to environmental issues in the NAFTA debate introduced significant changes in the binational cooperation.

On the U.S. side, EPA became involved in international trade negotiations for the first time and strengthened the international activities and capacity of the agency. EPA began to provide more attention to the U.S.-Mexico border by expanding the activities and staff from IX and VI working on border issues as well as opening liaison offices in San Diego and El Paso and at the U.S. Embassy in Mexico City. It also committed several millions of dollars to binational cooperation (see tables 1 and 2 below).

Changes on the Mexican side covered a broader range of issues. The Mexican government became aware of the domestic and international importance of environmental issues that led to a restructuring of its environmental institutions. It created the National Institute of Ecology (INE) and the Environmental Attorney Office (PROFEPA) as decentralized units of the environmental agency (Mumme and Sanchez, 1992). These changes strengthened environmental research and enforcement. It also began expanding its staff and resources under the pressure to

Table 1. Binational cooperation and the U.S.-Mexico border

	up to 1995		up to 1998	
	Projects	% of invs.	Projects	% of invs.
Air	11	1.29	13	2.5
Water	19	97.94	31	95.3
Drinking water	12	.94	21	
Sewage	7	97	10	
Hazardous waste	11	.4	19	1.05
Coop. enforcement	13	.2	8	.26
Pollution prevention	12	.2	13	.3
Conteng. planning	5	.18	7	.1
Natural resources		4	0	
Environmental info.			5	.32
Environmental health			14	0
Total	71	100	114	100

Source: U.S.-Mexico Border XXI Program: 1998 Implementation Plans. EPA 160-R-98-003. 1998

Table 2. Binational cooperation on water issues at the U.S.-Mexico border

		up to 1995	
	Number of projects	**Investment**	**%**
Total water projects	19	353,711,378	100
Sewage	**7**	**350,300,000**	**99**
Water	12	3,411,378	1
		up to 1998	
Total water projects	31	92,523,300	100
Water	21	1,576,300	1.7
Sewage	**8**	**21,500,000**	**23.24**
Support BECC	1	10,000,000	10.8
Support NADBANK	1	60,000,000	64.84

Source: U.S.-Mexico Border XXI Program: 1998 Implementation Plans. EPA 160-R-98-003. 1998

Table 3. Binational cooperation at the U.S.-Mexico border

Participation in environmental projects

	up to 1995	up to 1998
Total projects	71	114
U.S. federal	100%	89.5%
U.S. state	40.8%	57%
U.S. local	**18.3%**	**27.2%**
Mexican federal	88.7%	76.1%
Mexican state	18.3%	24.6%
Mexican local	**14.1%**	**12.3%**

Source: U.S.-Mexico Border XXI Program: 1998 Implementation Plans. EPA 160-R-98-003. 1998 demonstrate a clear commitment to environmental protection. Mexico expanded the staff involved in binational cooperation.

Binational cooperation benefited from all the changes in the United States and Mexico. The border area began to obtain more attention together with recognition of the importance and extent of its environmental problems. The creation of BECC and NADB brought also some additional financial resources that have supported border communities in their plans to expand their urban infrastructure with a direct impact on the environment (drinking water, sewage, solid waste). BECC also enhanced public participation in the discussion of projects submitted to this institution for certification. However, it is worth remembering the limitations of these institutions. BECC has a very restricted mandate oriented only to certified projects. Its impact in improving border environmental issues is very limited. The operation of BECC has not been free of controversy, ranging from the mismanagement of resources to questions about its legitimacy to represent the interests of border communities.[xv] NADB has been the target of severe criticism during the first five years of its operation due to its high interest rates and slow funding of projects.

Binational cooperation also expanded the number of binational working groups from six to nine, adding new groups on natural resources, environmental health, and environmental information, as well as contributing to the expansion of binational projects from 71 in 1995 up to 114 in 1998 (see table 1 below). These changes became part of Border XXI, the new binational plan seeking solution to border environmental problems (1997-2000). Participation of state and local governments also increased under border XXI. But perhaps one of the most significant changes in the most recent years of binational cooperation is the commitment and cooperation that have developed between EPA and SEMARNAP during the last six years. The binational working groups developed a broader and dynamic communication among them. Developing a better understanding and trust between parties is a fundamental requirement for successful cooperation efforts.

Binational cooperation has also made available more data and information on certain border environmental issues.[xvi]

Despite these benefits, there are also limitations in the binational cooperation process. Funding under Border XXI has significantly declined between 1995 and 1998. The U.S. funding declined from $361,717,617 dollars until 1995 to only $96,880,426 until 1998 (EPA, 1998). There are no figures available for Mexican funding, but the Mexican government has made periodic budget cuts in all areas of the federal budget (including cuts on environmental protection) since its severe financial crises in early 1995.

The Managerial Approach

Binational cooperation has shown signs of development during the recent six years. Environmental agencies in Mexico and in the United States have expanded the areas and number of projects of binational cooperation with some positive results. Despite this development, binational cooperation has failed to improve environmental conditions along the border. I mentioned above that this is due in part to the managerial approach followed by binational cooperation on border environmental issues.

Several scholars have pointed out the limitations of a managerial approach. Gibbs and Jonas (2000) highlight the detachment of environmental management from its political and economic dimensions. They highlight the divorce between local environmental policymaking process and the broader issue of governance and regulation of local economies. "The danger of such a view is that it treats the 'environment' as a relative self-contained and closed system, the constituent elements of which can be monitored, modeled and, subsequently, regulated with little interactions with 'external' economic and political system" (305).[xvii] For Carley and Christie (1993), environmental management is a social and political process and not only a technical exercise.

By the same token, Redclift (1994) states that environmental managerialism begins with the problems and attempt to resolve them in a more *ad hoc,* piecemeal fashion. The problem with this approach, Redclift mentions, is that "environmental managerialism pays attention to neither conceptual framework within which we understand 'environmental problems' nor the international economic framework in which these problems are manifested" (644). As Gibbs and Jonas above, Redclift also highlights the separation of the environment from its social and economic dimension. For him, the environment is considered after growth and development objectives have been set and environmental managerialism does not propose alternative development where ecological and social factors are balanced. Instead, environmental management is only a set of technical reactive responses to specific circumstances. He also stresses the need to recognize the distributive effects of development and to have environmental management assume redistributive functions. "The emphasis needs to lie not with 'compensation' for environmental damage, as it does at present, but with establishing environmental objectives that reduce the poverty and vulnerability of the poor to natural disasters or health hazards" (644).

The above criticisms to environmental managerialism apply to binational cooperation on environmental issues at the U.S.-Mexico border. Binational actions under the La Paz agreement, IBEP, and Border XXI have been a set of technical reactive responses. The impact of political pressure mentioned above triggered these technical responses. This is particularly evident in the case of sewage related problems in the Mexican side where most of the investment in border environmental issues has concentrated (see tables 1 and 2). Each environmental issue was considered in isolation from other environmental issues (no multimedia analysis) and detached from its social, economic, and political dimension (causes and consequences of these issues). The design of binational environmental projects departed from the physical manifestations of the problems and did not address the social processes behind them. As a result, binational actions achieve only temporary solutions to long-term problems. The problem of sewage spills from Mexican cities to the U.S. side of the border is a good example. The complexity of these social processes is due not only to the transboundary nature of the environment at the U.S.-Mexico border and the significant cultural, social, political, and economic differences between Mexico and the United States, it is also related to the dynamic interaction of these different components.

The fragmented perspective of a managerial approach has created the following problems in binational environmental cooperation at the U.S.-Mexico border:

- There is still little coordination among federal agencies involved in border environmental issues in the two federal governments, and between federal and state agencies.
- Environmental issues are still considered technical problems treated on an *ad hoc* basis in isolation from their social, economic, and political dimension and with little consideration to their social and economic consequences.
- There is no multimedia analysis, which aggravates even further the fragmented perspective of environmental issues.
- There is little public participation in the implementation of binational projects.

- There is no clear strategy under Border XXI to provide a comprehensive response to border environmental issues. Funding of binational activities is still concentrated in supporting sewage-related projects. Other critical environmental issues (environmental health, hazardous waste, pollution prevention, air quality) have little funding (see tables 1 and 2).
- Binational cooperation is a process dominated by federal agencies with little participation of state and local governments. It fosters dependency on federal actions and provides little empowerment of local communities.

Based on the summary of binational projects at the U.S.-Mexico border published by EPA (1997), tables 1, 2, and 3 provide a good summary of the limitations of binational cooperation mentioned above. Tables 1 and 2 show an increase in the number of binational working groups and projects between 1995 and 1998, as well as a decrease in U.S. funding during the same period. These tables also demonstrate that despite the diversity of binational projects on critical environmental issues, funding has concentrated on sewage projects. Thus, 97.9 per cent of all U.S. funds invested in binational projects until 1995 were concentrated on the construction of sewage treatment plants. The rest of the sectors received the remaining 2.1 per cent. The figures for 1998 are similar to a great extent.

Table 3 also shows the participation of federal, state, and local governments in the United States and Mexico in binational cooperation. The table illustrates almost a complete control of the process by the federal government until 1995. The situation improved by 1998, particularly on the U.S. side of the border, where binational projects had more state and local involvement. However, it is still a process heavily centered on the federal governments. Table 3 also shows that dependency on federal actions is stronger on the Mexican than on the U.S. side of the border.

Conclusions

The failure of binational actions to address environmental issues within a comprehensive context of development for the border area explains current inability to solve a large number of environmental problems. Binational environmental cooperation has been a self-contained and closed system not coordinated with other sectors involved in the growth and development of the border area (e.g., industry, trade and services, urban growth, health) at the federal, state and local levels. It has been a set of technical responses in an *ad hoc* fashion as the five annexes in the La Paz Agreement clearly illustrate. A similar approach was used in IBEP and Border XXI where the binational projects with concrete funding were designed as *ad hoc* technical responses. As mentioned above, this fragmented perspective of the environmental problems creates fragmented solutions that do not address the driving forces of the problems or their social and economic consequences. Binational cooperation requires a new approach seeking alternative strategies for development according to the needs of the reality of the border communities.

Endnotes

[i] This pattern was maintained during the 1980s. For example, federal public investment in Baja California between 1983 and 1987 was concentrated in the development of energy facilities (45.7 percent), and transport and communication infrastructure (22.2 percent). Investment in urban growth and environmental protection was only 10.9 percent during the same period (Zepeda, 1992: 36).

[ii] For example, some studies suggest that few *maquiladora* workers with less than three years of residence in Nogales and in Tijuana have access to adequate housing or public services. While access increases with their term of residency in the city, the proportion of *maquiladora* workers with such access remains below the comparable figures for workers in non-*maquiladora* sectors (Sánchez, 1990a).

[iii] Despite the *maquiladora* sector's contribution to the strengthening of the border's economy, because Mexico lacks a plan for orienting industrialization, this sector has not developed the anticipated backward linkages with local industries. The *maquiladoras*' failure to establish ties to local suppliers has meant a failure to realize potential opportunities for regional and local development.

[iv] Mexico's federal and state governments have only limited and incomplete inventories of pollution sources.

[v] Some of these vehicles are registered in the United States and owned by holders of U.S. resident alien cards who live in the Mexican border cities. Others have expired U.S. registrations.

[vi] For air quality data from these monitoring stations see CICA home page on the World Wide Web: http://www.epa.gov/oar/oaqps/cica/airq_e.html.

[vii] This assessment is based on data reported by the Mexican National Census of Population.

[viii] Old pipes break due to lack of maintenance or to excessive water pressure in a system trying to deliver water to consumers in new urbanized areas. On average, close to 30 percent of the water intended for consumers in Mexican border cities is lost in this way.

[ix] Residents using a non-municipal water supply consume significantly less water (an average of 10 gallons per person per day) than the level recommended by the World Health Organization. Moreover, low quality controls of these sources of water often causes gastrointestinal diseases. Ironically, residents with lower incomes pay more for their water and suffer a higher exposure to water-related diseases than residents with mid-range or high incomes. Because of rapid and incomplete urbanization, these problems affect even those individuals with stable jobs and incomes (as workers in the *maquiladora* sector).

[x] According to the U.S. EPA, more than 6,000 tons of hazardous waste were returned to the United States in 1992. This was a significant increase from only 658 tons in 1987 and 3,183 tons in 1990 (EPA, Region 6 Hazardous Waste Tracking System. June 17, 1993 [as reported in *EnviroMexico.* Vol. II, Issue 2, 1993]). Nevertheless, it is still a small part of the annual volume of hazardous waste generated by the *maquiladoras.* Mexican federal environmental authorities estimate that the border industries generate close to 60,000 tons of hazardous waste per year, out of a national total of approximately 5 million tons annually in 1992.

[xi] *Ley Federal de Protección al Ambiente y el Equilibrio Ecológico. Mexico. 1988; U.S.–Mexico Environmental Agreement. Annex III*; 1986; EPA–SEDESOL, *Hazardous Waste Management and Maquiladora Industry Manual* (Washington, D.C., November 1992).

[xii] Previously, local groups have been "consulted" on border environmental issues. For example, the IBEP, and more recently the Border XXI framework, carried out hearings in most border cities with a period to receive public comments. But the decision making process on the design and content of those programs was maintained by the two federal environmental agencies. Public participation in this context

is more a matter of form than substance. Decision making process in other federal agencies dealing with border environmental issues, particularly the IBWC, did not considered public participation until recently (Sanchez, 1993).

[xiii] Annex 1 concentrated on solving the transboundary pollution created by sewage spills coming from Tijuana and affecting San Diego. This annex has led to a series of binational actions mentioned above, but after 17 years of cooperation and millions of dollars spent on it, only partial solutions have been achieve so far to this issue. Annex 3 helped control the legal and illegal movement of hazardous waste across the border. Annex 4 established controls that led to the control of SO2 emissions in the copper smelters along the Sonora and Arizona border.

[xiv] Binational actions have been particularly susceptible to be influenced by political pressure. The best example is the influence of groups in San Diego demanding the control of sewage spills from Tijuana since the early 1980s that became a major factor in the creation of the La Paz Agreement and its Annex 1. This issue continues to be among the top priorities for the U.S. as reflected by investment on border environmental issues (see Tables 1 and 2 above).

[xv] Several senior staff from BECC has resigned under allegations of mismanagement since this institution began its operations.

[xvi] See U.S.-Mexico Border Program, "United States—Mexico Border Environmental Indicators, 1995" (http://www.epa.gov). For data on the tracking of hazardous waste that cross the border see the data base Haztracks http://www.epa.gov/earth1r6/6en/h/haztracks/haztracks.htm)

[xvii] Missing in this consideration is the social system. In the United States, the detachment of the environment from the social system explains the emergence, strength, and diversity of the environmental justice movement. In the case of developing countries like Mexico, the linkage between the environment and the social system has been addressed in terms of the relationship between poverty and the environment. However, this relationship is broader than just issues of poverty as illustrated by the diversity of complex interactions between social processes and the environment mentioned above as driving forces for environmental issues at the U.S.-Mexico border.

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PART II

CHARACTERISTICS OF THE BORDER COMMUNITY

Characteristics of Border Communities

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When faced with a shortage of affordable housing caused by a very rapid increase in population, people improvise. Along the U.S.-Mexico border this improvisation has led to colonias. A colonia often begins as farmland that is subdivided into numerous lots and sold to people who are attracted by promises of low monthly payments. When people buy a lot for a house, that is all they are buying. They need to build their own house and generally do so with whatever materials are available. These new communities, called colonias, initially lack infrastructure, such as electricity, phones, paved roads, drainage, and access to clean drinking water. Colonias exist on both the United States and Mexican sides of the border, and conditions can be equally bad regardless of location. Though exact figures are difficult to come by and vary widely, it is safe to say that there are hundreds of thousands of Americans and over a million Mexicans living in thousands of colonias.

Colonias are often offered as a symbol of how much needs to be accomplished along the border. A documentary on PBS called *The Forgotten Americans* that aired in December 2000 introduced many to these communities by offering a close look at the Americans that live in third world conditions. Not only does the PBS documentary present a powerful image of a problem that needs to be addressed urgently, but it also points to an inherent difficulty in addressing this problem; conditions along the border vary greatly. For instance, one of the nations richer counties, San Diego, which lies along the western edge, stands in stark contrast to the County of Starr, Texas, the nations poorest county (Katz, 1999). On the Mexican side, too, there is a wide variety of communities and conditions.

Reliable border data about colonias do not exist, which makes it extremely difficult to compare conditions in colonias to general border conditions. The shortage of data also creates problems when we try to broadly assess the effectiveness of institutions such as BECC, NADBank, Border XXI, and the IBWC, all of which have the potential to improve conditions along the border by improving infrastructure in colonias. This chapter looks at the border broadly to show how border communities differ from one another and from their respective nations as a whole. In some cases it is not a question of how areas differ but how they are similar. A community on one side of the border often shares familial, economic, and environmental ties with a community on the other side. Moreover, it is difficult to generalize about a region inhabited by over 10 million people and stretching over 2,000 miles.

We are using a series of maps in this chapter to look at the characteristics of the border broadly. The advantages of this approach are twofold. First, this approach helps convey the big picture of conditions along the border region. Secondly, by looking at the border broadly, consistent data become available allowing us to introduce additional information into the equation. We conclude this chapter by examining how the types of data presented here can be used to help address some of the problems the border faces.

Characteristics of border communities are examined using a variety of indicators to convey a sense of what the border is like as well as to highlight some of the environmental

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challenges the region faces. By using counties[1] as units of analysis it is possible to get a sense of some of the differences that define the communities of interest while holding the number of geographic units at a manageable level. Additionally, examining counties allows for the inclusion of both urban and rural regions. The most complete of the existing border studies deal only with established urban areas. Studying counties, however, allows for the inclusion of rural areas and, it is hoped, more colonias as well.

The border region is typically defined as 100 kilometers north and south of the international marker. This definition is difficult to operationalize on the U.S. side because the U.S. border includes small portions of counties that just fall into the 100-km zone, such as Orange County, California, and are not at all typical of border counties. Fortunately, the U.S. counties are large enough so that those counties on the border comprise the vast majority of the 100-km zone. Therefore, the only counties included in this study are those immediately adjacent to the border. On the Mexican side, however, there is a large number of small municipalities, particularly in Nuevo Leon and Coahuila, so that looking only at those municipalities on the border would leave out quite a few municipalities falling into the 100-km zone. To simplify matters while still offering the detail needed, we are including all municipalities that fall within the 100-km region in Mexico. The border states defined in this way comprise the vast majority of the border's population.

First, general population distribution along the border is studied along with the prospects of future growth. Next, we look at the ethnic characteristics along the U.S. side of the border. Unfortunately, Mexico does not offer comparable information. Our focus then shifts towards socioeconomic conditions. We examine income distribution and educational level to obtain a better understanding of two factors strongly associated with socioeconomic status. Finally, we study the environmental infrastructure because of its importance in the border region.

The data used in this section come from the U.S. Census and the National Institute for Statistics, Geography and Information Processing (INEGI). The data for the United States come from the 1994 and 1996 U.S. county profiles (U.S. Dept. of Commerce 1994, 1996). The data for 1990 come from the 1994 profile, and the more recent data for 1995 come from the 1996 profile. Much of the county profile information, including all of the 1994 information, is based on the decennial census of 1990. The U.S. Census Bureau updates information in some categories on a yearly basis, and that information is used here for figures other than those for 1990. All of the infrastructure information in the United States is derived from the 1990 census. Most Mexican information comes from the XI Censo General de Poblacion y Vivienda, 1990 (INEGI, 1990). The 1995 population figures are from a limited census conducted in 1995 (INEGI, 1995).

Population Distribution

Population distribution along the border varies by large degrees. Some portions of the border are sparsely populated, while others are densely populated. The 1990 population of border counties included in this study amounts to 9,968,013 persons. The most populous region of the border is located near the western edge of San Diego County, where in 1990 the population amounted to nearly 2.5 million. On the Mexican side, Tecate, Ensenada, and Tijuana add nearly a million people. Over a third of all border residents live in this small region. In general, more people tend to live on the eastern and western edges of the border. Map 1 depicts

[1] The word "county" is often used here as a generic term and is meant to apply to both counties in the United States and municipalities in Mexico.

the population for 1990 in both countries. This map offers a good description of two important issues with regard to population distribution.

The first thing that becomes apparent in the map is how closely population distribution is correlated between the two nations. When there is a large number of people in a county on one side of the border, the same is most often true of the other side. These relationships may originate from a single community that was later separated by the border. There are still small cities separated by the border that share familial, economic, and social ties with residents living and working in both countries (Hebard, 1999). These communities offer an example of how larger communities can develop. Small towns of one hundred years ago have in some cases grown into large metropolitan regions. The two nations are closely linked in terms of development. Municipalities often grow in response to the population growth in counties as people migrate looking for economic opportunities. In short, when there is a large community on one side of the border, there is a large community on the other side, too.

The second thing apparent in the map is that large regions of the border have very few inhabitants. Particularly along the New Mexico and eastern Texas regions, excepting El Paso-Juarez, there are large areas of land inhabited by small numbers of people. Here many counties have populations numbering well under 10,000 people. Taken as a whole, the vast majority of people living in the region are concentrated in roughly a third of the border region. As population continues to expand, some of these areas are likely to develop, but as map 2 shows, growth is occurring primarily in the more populous regions.

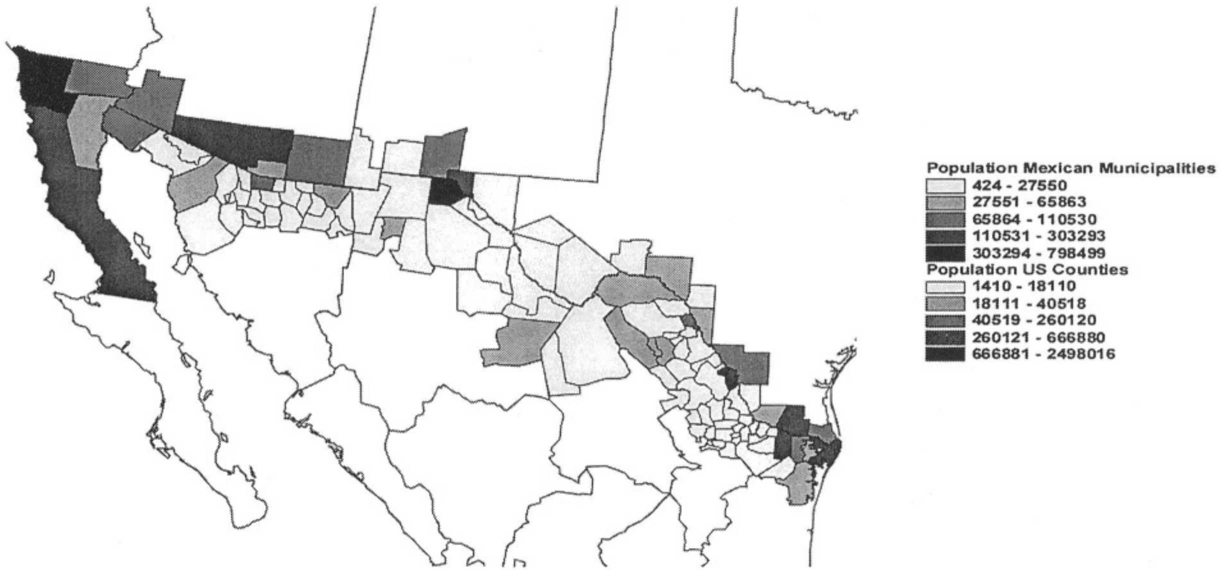
Map 2 shows the net changes in population from 1990 to 1995. In five years, population increased to 11,544,196, which is an increase of nearly 1.6 million people. What is most striking about population growth is how concentrated it is in developed regions. Much of this growth is spurred by migration. On the U.S. side, people move to warmer climates where good economic opportunities may also exist. On the Mexican side, migration is primarily economic in nature. On the basis of its analysis of population trends, the Southwest Center for Environmental Research and Policy expects the present growth rates to continue and finds that if migration continues at the present rate, the border population will more than double by 2020 (1999).

These rapid increases in population create concerns about conditions along the border and our ability to protect the environment and health of those living in the region. If, as projected, population does more than double in the next twenty years, infrastructure will have to keep pace. Problems with the supply of drinking water and the treatment of waste will have to be overcome, or serious consequences will ensue. An examination of the characteristics of people living in counties along the border can help us begin to establish an understanding of factors that may play an important role in the distribution of resources to cope with this growth.

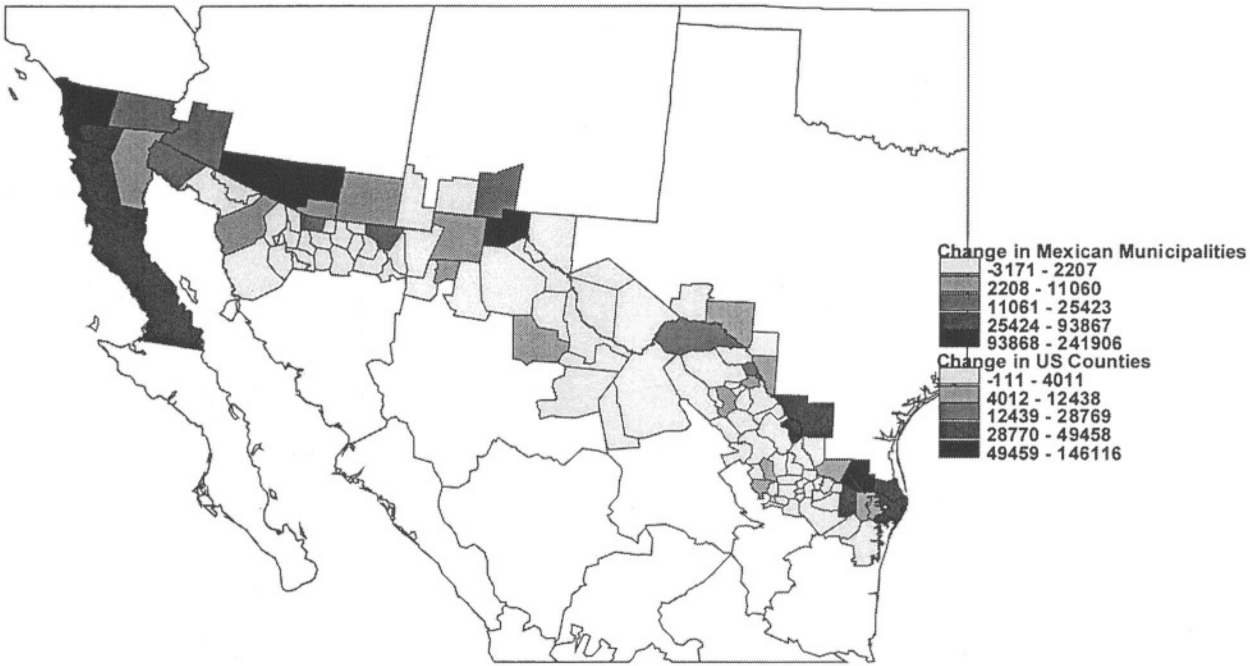
Racial and Ethnic Distribution in the United States

With the exception of the “other” category, the dominant groups in the border region are white and Hispanic. No other group exceeds ten percent in any of the counties. In 1990 forty-one percent of all border residents were of Hispanic origin. In well over half of the counties the majority of the residents are of Hispanic origin. Map 3 shows the distribution of people of Hispanic background. Concentrations of Hispanic residents are highest towards the eastern portions of the border. Some counties are made up almost entirely of Hispanics. In Starr, Texas, 97 percent of the residents are of Hispanic descent.

Map 1
1990 Population Distribution Along the Border



Map 2
1990-95 Population Change Along the Border



It is interesting to note that two of the counties with the fewest number of Hispanics also have higher per capita incomes. Pima and San Diego, the counties with the two highest per capita incomes, also have a smaller number of Hispanics. When per capita income and the percentage of Hispanic residents are correlated against one another, we get very striking results ($r=-.881$, $p<.01$). As the percentage of people identifying themselves as Hispanic increases in a county, the per capita income tends to drop. Income and Hispanic origin are, therefore, strongly negatively correlated.

Income

Financial information is gathered in different ways by each of the two nations. The United States makes income information available as per capita income. This type of information is treated differently in Mexico. The Mexican census gathers income information in ranges related to the minimum wage. For a municipality, it is possible to determine what percentage of residents earn less than the minimum wage, what percentage earn one to two times the minimum wage, what percentage earn three to five times the minimum wage, and what percentage earn more than five times the minimum wage.

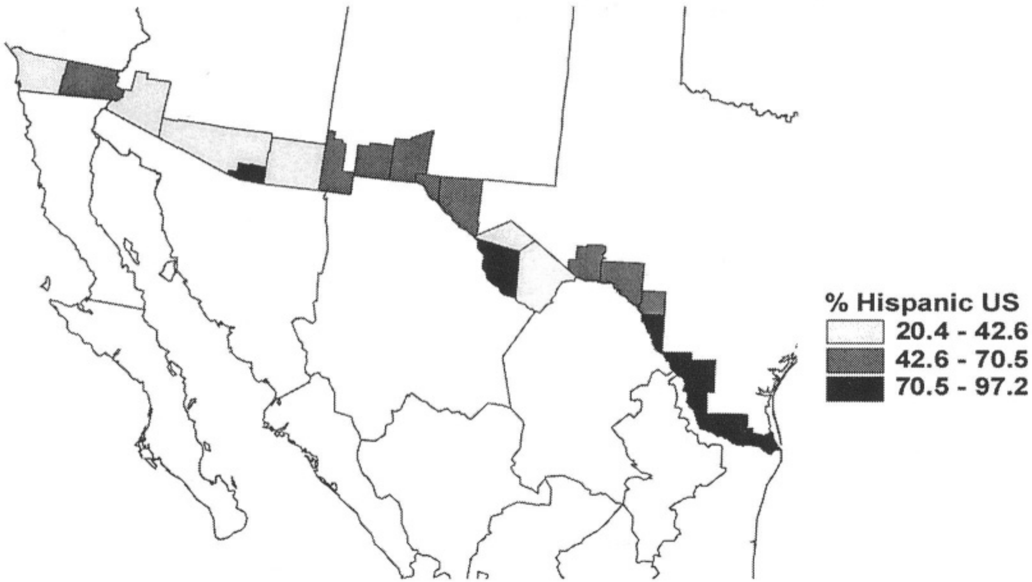
In 1990 the average per capita county income along the border was $8,555. This figure is calculated so that all counties are weighed equally, and it is not adjusted for population differences. When we adjust it for population differences, the per capita income along the border amounts to $12,698. Each of the counties along the border falls below the national average of $18,172, while San Diego, with an average per capita income of $16,220, is substantially above the rest of the counties (U.S. Census, 1994). Counties like Starr, Texas, with the per capita income of $4,152, lower the border's average. On the whole, per capita incomes are very low along the border, although there are substantial differences between different counties.

In Mexico, on the contrary, the average income in the 96 municipalities along the border is higher than the national average (INEGI, 1990). Only 12 percent of employees along the border made less than the minimum wage compared to 27 percent for all of Mexico. Moreover, 42 percent of employees along the border earned one to two times the minimum wage compared to 41 percent nationwide. Furthermore, 36 percent along the border earned three to five times the minimum wage with only 25 percent in all of Mexico earning the same amount. In the top category, 11 percent of employees along the border earned more than five times the minimum wage compared to 8 percent in the nation as a whole. Workers along the border earned more than the national average in all four of these categories.

Map 4 shows income distribution across the counties for 1990. For the United States, categories are based on per capita income. Mexican income data show the percentage of residents with earnings within a particular category. The analysis focuses on the highest income groups, those earning more than five times the minimum wage. The map shows the percentage of people in a single municipality earning more than five times the minimum wage.

Income varies substantially along the border. It tends to be highest in the western, most highly populated, regions. In the United States, there is a rather striking decline in income from west to east. Income drops from county to county in an almost linear manner. In Mexico, on the contrary, income distribution is more varied along the border. While there are more people earning five or more times the minimum wage along the western portion, there are similar pockets scattered along the entire border region. Unlike what we saw with population distribution, the communities on each side of the border do not appear to be as closely related

Map 3
1990 Hispanic Population Distribution US



with regards to income distribution. Higher incomes on the Mexican side do not necessarily reflect higher incomes on the U.S. side.

Education

In both countries, educational information is based on the number or percentage of people having certain levels of education. Educational information in the United States reflects educational levels of people 25 years and older, and percentages are calculated by the U.S. Census. In Mexico, educational groupings include: *primeria, secundaria, escuela preparatoria,* and *instruction superior.* If we translate these terms in the American context, we will get: elementary school, junior high, high school, and college (Garcia, 1999). All figures in this section are for 1990. The latter two categories are discussed and summarized in this section.

Mexican information is released in counts, and in order to calculate percentages so that comparison across municipalities of different sizes is possible, we must convert to percentages. The INEGI releases the number of individuals with a particular level of education as well as information about age distribution. With the age groupings used by the INEGI we know only how many people are 18-34 years of age. When calculating educational information we are forced to include all people over 18 years of age. As a result of this age break, individuals still in school are also included.

Overall levels of education are higher in the United States. Seventy-four percent of U.S. border residents have a high school or better education, while 20 percent have a four-year or better college degree. Nationwide, 77 percent have a high school or better education, and 21 percent have a college education. In the Mexican border municipalities, 25 percent have a *primeria* level education, 17 percent have a *secundaria* level education, 27 percent have *escuela preparatoria,* and 9 percent have *instruccion superior.* For the sake of comparison, in Mexico as a whole we find that 22 percent have a *primeria* level education, 14 percent have a *secundaria* level education, 25 percent have *escuela preparatoria,* and 9 percent have *instruction superior.* Levels of education among Mexicans living in the border region are slightly higher than national levels.

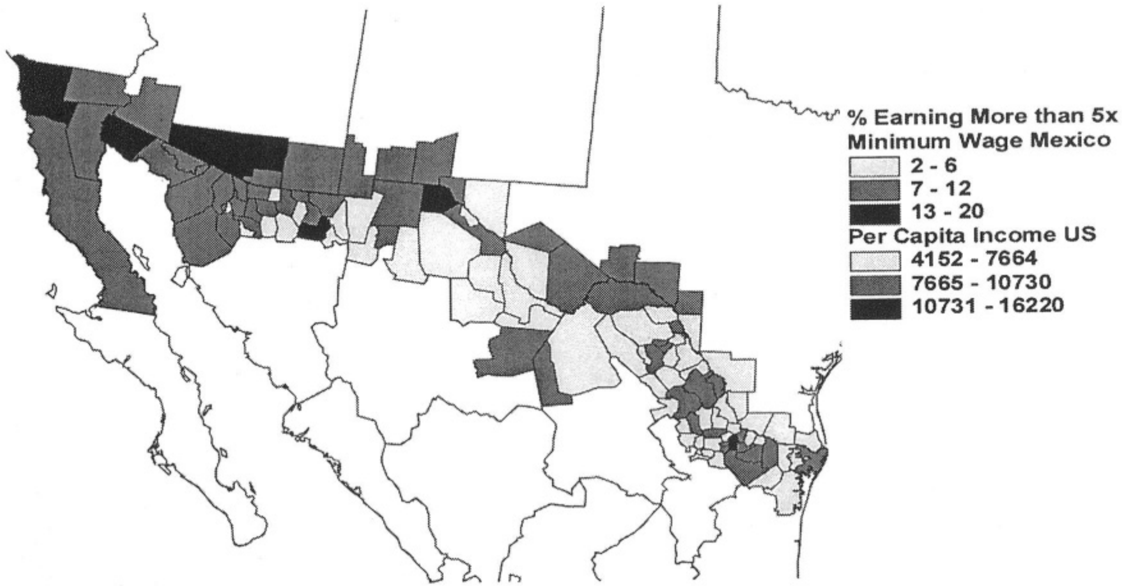
Map 5 shows how different regions fare with regard to higher levels of education. In the United States, we have looked at the distribution of the people with college degrees, and in Mexico we have looked at those who have education at *escuela preparatoria* level or better. We can see that this map is very similar to map 4, income distribution. The areas with highest education levels fall along the western portion of the border, with a few exceptions. Visually, there appears to be a strong correlation between education and income.

What we can see in the map is supported statistically by a very strong correlation in the United States between income and the percentage of the population with a college education ($r=.74$, $p<.001$). There is a negative correlation between Hispanics and college degrees, as was the case with higher incomes ($r=-.7$, $P<.001$). In Mexico, we find the same relationship between those with higher levels of education and those earning more than three to five times the minimum wage ($r=.59$, $p<.001$).

Environmental Infrastructure

Environmental infrastructure is extremely relevant to the border region because of its rapid population growth and limited financial resources available to cope with the effects of the growth. The study of environmental infrastructure is concerned with treating problems caused by large numbers of people living in close proximity to one another. Primarily, the concern is

Map 4
1990 Income Differences



directed towards treating and mitigating the effects of air and water pollution and towards the handling of solid waste. The specific infrastructure includes wastewater collection and treatment, solid waste disposal, and systems for providing clean drinking water (US-GAO, 1996). Infrastructure is particularly important at the border where rapid population growth has quickly exceeded the capacities of existing infrastructure in the region.

It is important to note differences between regions under examination. Infrastructure varies greatly in urban and rural regions. It is not practical to construct sewers in rural regions, while they are a virtual necessity in urban areas. As far as drinking water is concerned, wells are common in rural regions because it is not reasonable to lay large amounts of pipe for a single user. The border contains both sorts of regions, and this will play an important role in determining the desirable types of infrastructure. While what is desirable can vary, what is undesirable is much more universal. The residents who do not have an immediate source of clean water or any sort of wastewater disposal, be it a sewer or a septic tank, are of interest for our investigation since lack of infrastructure is highly undesirable.

The data used in this section come from the U.S. Census and from the INEGI. The U.S.data come from the deciannual census of 1990 (U.S. Dept. of Commerce, 1990). The Mexican information comes from the XI Censo General de Poblacion y Vivienda, 1990, and the Conteo de Poblacion y Vivienda, 1995 (INEGI, 1990, 1995).

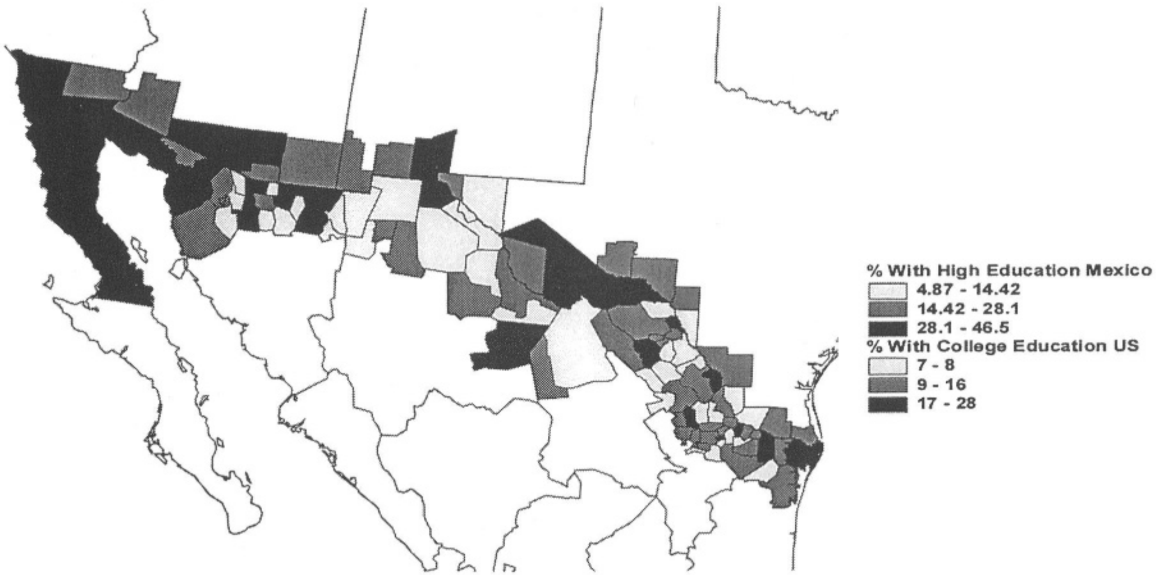
Wastewater

Wastewater treatment options for households vary widely. Options range from desirable, including sewer hookups and septic tanks, to undesirable, such as drainage to the ground, a ditch, or a waterway. Sewer hookups are desirable on condition that sewer lines lead to treatment plants. Desirable options decrease the risk of disease and help to protect drinking water. Undesirable options can have the opposite effect. We are interested primarily in those households confronted with undesirable options because of the negative impact this may have on people.

What is appropriate for wastewater disposal in urban regions differs from what is appropriate in rural settings. While urban communities can share the cost of creating and maintaining a sewer system, matters become more complicated in rural areas. Septic tanks or cesspools, for example, are often found in rural settings. These treatment options are typically paid for and maintained by the resident with little or no government assistance. It is easy to lay the responsibility for treatment of wastewater upon an individual when sewer systems or drainage is not available; after all, the households could install a septic system. The treatment of wastewater becomes a collective issue, however, when the failure to treat wastewater has a negative impact on others. The inability of an individual to treat his wastewater has an impact on others. Lack of infrastructure causes serious concerns in rural regions since untreated wastewater can lead to serious health and environmental problems (Ellman and Robbins, 1998).

Information on household wastewater disposal collected by the U.S. Census falls into one of the three categories: connection to a sewer, a septic tank or a cesspool, or other. It is assumed that the category of “other” includes the least desirable options. According to the U.S. Census, “other means would generally be a privy, a chemical toilet, or facilities in another building” (U.S. Dept. of Commerce 1999). The officials go on to say that other category is most applicable in Alaska. Most U.S. households in the border region are connected to a sewer, 87 percent, or a septic tank, 13 percent, depending on what is more appropriate for the area. Rural

Map 5
1990 Education Distribution



counties have considerably more residents utilizing septic systems. A very small portion of border residents resort to the "other" category, with eleven counties having less than one percent of people using other methods. The county with the largest number of households using other methods, 8.2 percent, is Hudspeth, Texas. Nationwide, 75 percent of residents are connected to a sewer, 24 percent to a septic tank, and 1 percent use other methods. The 1990 Census leads us to believe that treatment of wastewater is not a major problem along the U.S. side of the border. It is likely that there are those who would disagree with this assumption, but the data the U.S. Census has released support this conclusion. The population growth along the border may have led to an increase in the number of people using other sources, but updated figures will be unavailable until the release of the 2000 Census data. Therefore, our analysis of wastewater infrastructure will focus on Mexico rather than the United States.

The INEGI gathers more information about wastewater disposal than the United States because it is a more important issue in Mexico, where infrastructure is more limited. The INEGI's categories include drainage to a sewer, drainage to a septic system, drainage to the ground, a river, or a lake, and no drainage. The methods used can vary greatly from place to place. It is important to note that even when there is drainage to a sewer system, the waste may not be processed because of inadequate treatment facilities. Fifty-two percent of households in the border region have drainage systems connecting to some sort of public system compared to 52 percent nationwide. Eleven percent have a drainage system connecting to a septic system, in contrast to 9 percent nationwide. Less than 1 percent have drainage systems that drain wastewater to the ground, a river, or a lake, while 3 percent have this kind of drainage system nationwide. And finally, 32 percent of households have no drainage system at all compared to 34 percent nationwide. Municipalities bordering the United States are very similar to the rest of Mexico when it comes to disposing of wastewater from households. However, there are individual municipalities that do not fare as well.

Map 6 shows the percentage of Mexican households without drainage systems. Results vary considerably across municipalities, but western portions appear better off. In many municipalities less than half of residents have some sort of drainage system in their homes. If households have some sort of drainage system, that system most often leads to a sewer or a septic system. In a study of wastewater, it is important to bear in mind that the wastewater from a large number of households with no drainage system does end up somewhere. Lack of any sort of drainage system is a very important issue given the large number of households involved.

The regions on the Mexican side of the border have the most pressing problems with wastewater, and it is worthwhile to take a closer look at wastewater conditions there. In 1990 over 800,000 households of the border's 2.7 million population lacked any sort of wastewater drainage. While there are some who fall into the "other" category in the United States, the numbers are very small according to the Census. In addition, because of the scale used in the United States, some of those people in the "other" category may well have acceptable methods of treating their wastewater. Looking solely at the differences in 1990 between the population size of municipalities and the proportion of households lacking drainage, we have come up with results that are somewhat unexpected. As the population of a municipality rises, the proportion of households with no drainage decreases ($r = -.24$, $p < .05$). The 1995 figures reveal nearly identical results, ($r = -.22$, $p < .05$). More populous areas are less likely to lack drainage. One possible explanation is that larger populations create greater potential for health problems if drainage is insufficient, and these areas are, therefore, more likely to have some type of household level drainage. Still, a large number of households lack drainage in these areas, and while the proportion of households lacking drainage may be lower, the absolute number is generally higher. It is also important to underscore that household waste from a drainage system may not lead to treatment facilities.

More directly relevant to our study is the question concerning ways in which infrastructure has kept up with rapid population growth in particular areas. During the period when INEGI's 1990 and 1995 censuses were conducted, the number of households with no drainage dropped, so that about 2 percent of households appeared to gain access to drainage systems during the 1990-1995 period. This could indicate either improvements in household level infrastructure or problems with measurement. It is difficult to determine exactly what occurred. Therefore, rather then focusing on the degree of change, we will emphasize the type of change: an increase or decrease in the percentage of households with drainage. Here we find that areas with positive rates of population growth have experienced a decrease in the number of households lacking drainage. Taken as a whole, municipalities that made improvements in the proportion of households having some type of drainage had an increase in population of 921,402 people, while municipalities experiencing increases in the number of households lacking drainage had an increase of only 29,614 residents. The border's population grew significantly in the period between 1990 and 1995, and while serious shortfalls in infrastructure persist, there appear to be improvements in household infrastructure during this period.

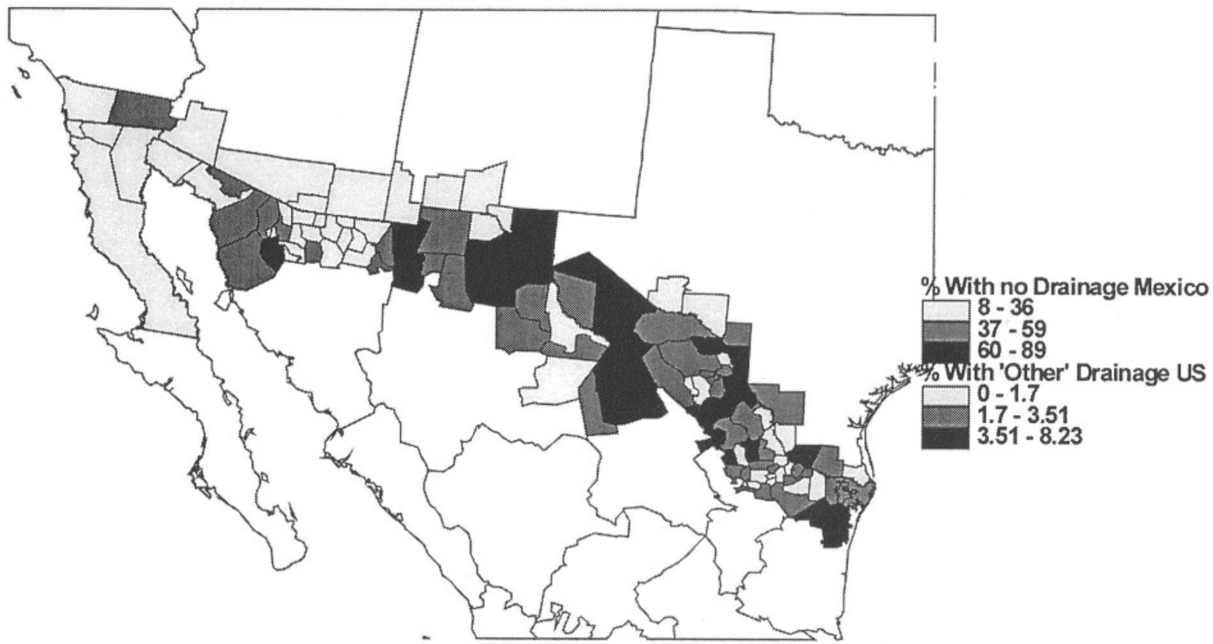
Drinking Water

As is the case with wastewater treatment, options for obtaining drinking water can vary. In some instances, indoor plumbing allows residents to obtain water from a well or a public water system. In other cases, residents obtain water from a public hydrant near their homes or they have to transport water from distant locations. To have a connection to a well or a public system does not always guarantee that water will be available. In Ciudad Juarez, there is an insufficient water supply, and water is not available all 24 hours a day. Problems are particularly acute in summer, when supplies are lower and demand is higher (Chavez, 1999). This is not an isolated case; similar problems with insufficient water supply exist in Nogales (Ingram, Laney, and Gillian, 1995).

Water quality is also an important issue, particularly in Mexico. Problems with the treatment of wastewater lead to contaminated drinking water. Drinking water becomes a serious concern when residents need to rely on delivery methods that are at best inconvenient and expensive, and at worst dangerous. While residents may be able to get safe drinking water, this can be a time consuming and expensive chore (Ingram, Laney, and Gillian, 1995). Residents must have water delivered, or they need to gather water in containers and transport it to their homes. In both cases, storage of water can cause concerns when residents use containers, not designed for storing water, that may not have been properly cleaned.

In this study, we have examined methods for delivering water to households with an emphasis on undesirable delivery options called "other" in the United States, and "no piped water" in Mexico. The U.S. Census classifies "other" sources as springs, cisterns, streams, lakes, or commercial bottled water (U.S. Dept. of Commerce, 1999). The INEGI's coding of "no piped water" means that residents do not have immediate access to water either in their homes or from a nearby public hydrant. Both options are undesirable. Focusing on the methods of water delivery has some obvious limitations, chief among them being that there is no measure of the availability or quality of the water that is delivered.

Map 6
Households Lacking Drainage



The U.S. Census collects information about the status of plumbing within households and the sources of residents' water. In 1990 in the United States as a whole, 99 percent of households had complete plumbing facilities, which are defined as "hot and cold piped water, a bath-tub or shower, and a flush toilet" (U.S. Dept. of Commerce, 1999). For the border counties this figure was essentially the same. Sources of water include public systems, 96 percent in the border region and 84 percent nationwide; drilled wells, 3 percent in the border region and 15 percent nationwide; dug wells, less than 1 percent in the border region and 2 percent nationwide; and finally other with less than 1 percent in the border region and about 1 percent nationwide. Differences between the border as a whole and the United States as a whole are not that great. There are more significant variances among individual counties that we will discuss shortly.

In 1990 in Mexico as a whole, about half of all households had piped water inside their dwellings, and 26 percent had access to water outside of their homes or in their yards. About 3 percent of Mexican households get their water from a public source or a hydrant, and about 20 percent do not have access to piped water and have to get their water from other sources. Overall conditions among border municipalities are better than in Mexico as a whole. Along the border, 57 percent of households have piped water in their homes, and 24 percent have access to piped water outside of their homes but very close by. Only about 2 percent get their water from a public hydrant, while 13 percent do not have an immediate source of water. These figures vary greatly when we focus on individual municipalities, and in some cases up to 56 percent of households in a municipality do not have access to piped water.

Map 7 shows the percentage of households in the United States that get water from other sources, and the percentage of households in Mexico that lack access to piped water. Unlike in the previous maps, there seems to be less of a pattern here. Three counties in the United States, Imperial, Hudspeth, and Jeff Davis, have a higher proportion of households getting water from other sources. With the exception of Imperial, the populations are very low among the counties although two of the three counties experienced population growth of over 10 percent in the period between 1990 and 1995. Unfortunately, there is no updated information on households' sources of water, so we cannot say how conditions have changed.

In Mexico, towards the eastern portions of the border, conditions vary greatly between municipalities with an apparent increase in the percentage of households lacking piped water. Differences between municipalities can be fairly substantial with Cananea, Sonora, having only 1 percent of households lacking piped water in contrast to Mendez, Tamaulipas, where 56 percent of households lack piped water. Using a method similar to the one applied in the analysis of wastewater, we can examine correlations in population growth and access to piped water. We find that just like with wastewater there has been a small improvement in access to piped water between 1990 and 1995 so that there was an increase of about 2 percent in households having access to piped water. This can be attributed either to increased infrastructure or to measurement error. Examining the relationship between access to water and population growth we have found that the municipalities with improvements in access to piped water had an increase in population of 887,282 people, while municipalities that had declines in access to piped water had an increase of only 60,720 people. There do appear to be improvements in household level infrastructure, but a large number of households still lack access to piped water.

GIS and the Border

Up to this point, maps have been used to offer an overview of the border and to highlight some of the problems the area is confronted with. Geographic information systems (GIS) allow a user to create maps and study the geographic relationships between variables. The maps used so far help depict a variable in an individual county, while also showing the relationship between adjoining counties. Additional variables can be included and added to the maps to depict additional relationships. GIS is a powerful tool that can play an important role in studying the border. Some examples of how it can be used are briefly discussed in this section.

There are several binational institutions whose responsibility it is to resolve the infrastructure issues discussed here. Historically, binational efforts at improving conditions along the border have been criticized for placing too great an emphasis upon the most politically influential regions (Mumme, 1982; Sanchez, 1994; Ingram *et al.,* 1995). As a result of these past accusations, new institutions, such as Border XXI, BECC, and NADBank, were created and designed in part to allocate resources more equitably. It is difficult to evaluate the effectiveness of these agencies because their responsibility stretches over a large geographic area, where need and political influence vary greatly. GIS can be used to show relationships between counties that are getting assistance from these agencies and those that are not receiving assistance. Map 8 again shows education distribution, but it also shows BECC projects that are either certified or in the application stage. On the map, projects appear to gravitate towards areas with higher levels of education. By including additional variables and using GIS and spatial regression, it becomes possible to examine the statistical significance of this observation. Similar research is being conducted by Bob Gray who, with the Southwest Center for Environmental Research and Policy and BECC, is creating a GIS database that can be used both to evaluate agencies and to study conditions along the border by using geography as an analytical tool (Gray 1999).

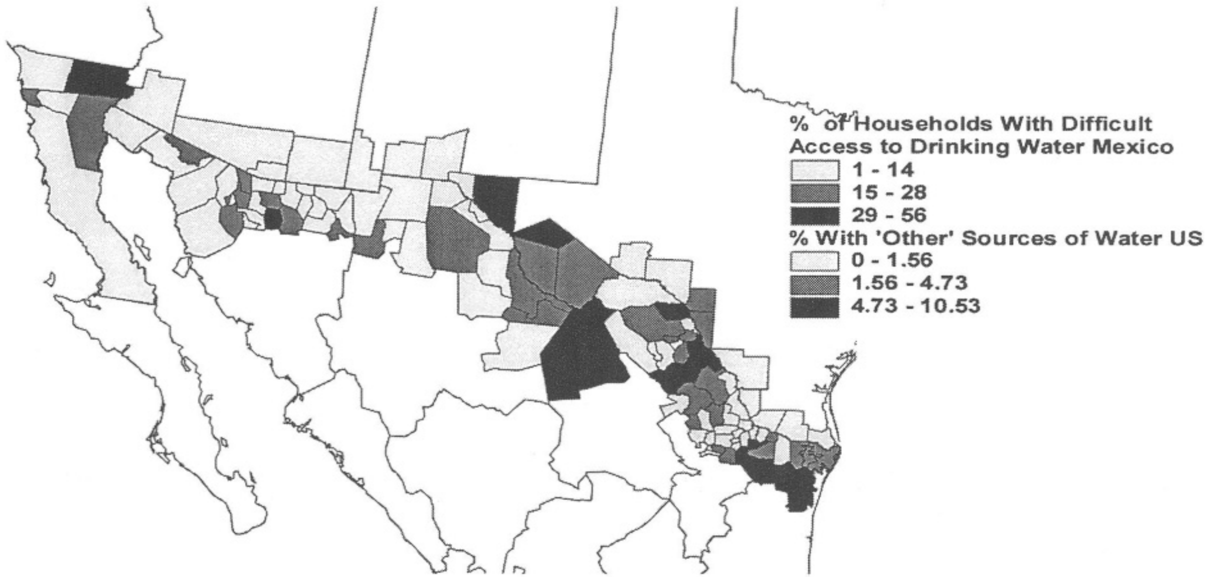
The United States is using GIS to better understand problems along the border. The Texas Water Development Board (TWDB) has created a detailed GIS database of colonias in order to track water related infrastructure programs. The California Department of Health Services is conducting GIS research as part of a project entitled *Population, Environment, and Health: A Nexus at the Border.* The group plans to move away from the use of health indicators such as infant mortality and try to create a more detailed understanding of specific health concerns and their likely causes by studying what they term sentinel health events (English, 1998). With GIS they can plot variables they are interested in and examine the geographic relationship between items, but in time they will also be able to model the possible impact of proposed industrials activities. As knowledge about wind patterns and other physical characteristics of the environment improves, better models become possible.

Summary

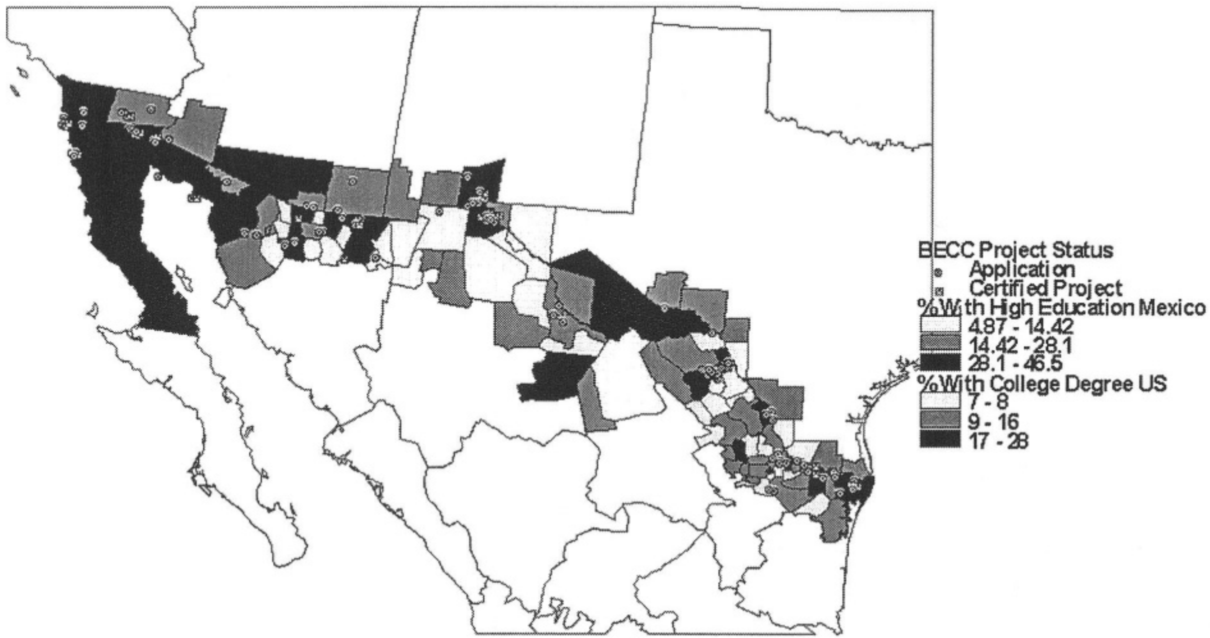
When we begin to consider environmental conditions along the border, there are four general trends that become apparent. First, population is increasing at a rapid rate. Population distribution is biased towards the eastern and western edges of the border. There are some exceptions, particularly in Eastern Texas and Chihuahua, as well as near Arizona and Sonora, where there is a significant population growth. There are close correlations between growth patterns in neighboring cross-border communities. Rapid growth on one side of the border is typically accompanied by rapid growth on the other side. Similar cross-border relationships are apparent in general population distributions. When there is a large community on one side, there is a large community on the other side as well.

Second, we find that, in general, conditions in the United States are much better than in Mexico. Residents have higher incomes and better education. In addition to this, we find that

Map 7
Access to Water 1990



Map 8
1990 Education and BECC Projects Through 1999



Americans are much more likely to have a desirable means for disposing of wastewater and are unlikely to have difficulties in obtaining drinking water. Looking at the border population as a whole, in 1990 less than one percent of U.S. border residents lacked a desirable wastewater disposal system or access to piped water or a well. In contrast to this, 32 percent of Mexican residents lacked wastewater disposal systems, and 20 percent had no direct access to piped water. In Mexico, shortages of infrastructure do not appear to be worsening in proportion to the growth experienced between 1990 and 1995. In both countries there is significant variance between comminutes, which brings us to our third point.

There are fairly large differences between counties within each of the nations; these differences are greatest in Mexico. With socioeconomic factors we see very significant differences between counties on both sides of the border. In the United States, some counties have characteristics close to the national average, while in Mexico there are municipalities that exceed the national average in relation to income and levels of education. Other municipalities in Mexico are, however, significantly below both the national average and their neighbors. As far as infrastructure is concerned, differences are less pronounced among U.S. counties, although there are some small differences. In Mexico there are tremendous differences between municipalities. In some municipalities only about 1 percent of people lack access to piped water, while in other municipalities over half of the households have access to piped water. The situation is similar for wastewater disposal.

Finally, it is important to place some of these findings in a larger context. The U.S. border residents have lower incomes and slightly lower education levels than the national average. For infrastructure, levels along the border are comparable to the U.S. national average. However, this is not the case in Mexico. There are large disparities between Mexican border municipalities and the U.S. counties. Mexicans earn less, have lower education levels, are more likely to lack access to piped water, and often lack desirable methods for disposing of wastewater. When comparison shifts to within Mexico, the environmental conditions in the border municipalities as a whole slightly exceed Mexican national averages. Mexican border residents have higher incomes, better education, and better household level infrastructure. This is not to say that the current state of affairs is desirable, but conditions along the border are better than average Mexican conditions.

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"Off the Backs of Others": The Political ecology of credit, debt, and class formation and transformation among the Colonias of New Mexico and Elsewhere[1]

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In few places are the costs of globalization more deeply felt than in the lives of those living in U.S. Mexican rural "colonias" that line the border between the U.S. and Mexico. Their physical and ecological disparities are similar to those suffered by migrating populations to cities all over Latin America 40 years previously but now extend into the United States as well. In fact, there are over 1,800 such communities that began in the early 1980's and now are inhabited by between 900,000 to a million Mexican-origin residents in the southwestern United States. These arise particularly in the border states of Texas and New Mexico, while emergent colonias exist in Southern California and Arizona. These populations suffer tertiary labor conditions at the minimum wage, without health coverage, legal protection, or promise of future employment. Seventy percent of households are engaged in the informal economy and others are forced into underground economies that create even greater anxiety, and insecurity for all members of already stressed households.[2]

Yet these populations are a small part of a much larger demographic transition and increase of Mexican/Latino populations to the United States. And although the central focus of this work concentrates on the political and economic ecology of colonias the broader theoretical question that arises is the manner in which these population, and many other similarly situated Mexican/Latino(a) populations in urban and rural contexts, in fact subsidize their own lack of income, lack of infrastructures, community development, institutional support, and ecological inequities by engaging in far-flung social and economic practices that attempt to mitigate these disparities.

We take a political ecology approach that basically is a method that is inclusive of the complex relations between polity, economy, and physical and environmental resource use. This approach recently articulated by Greenberg and Park (1994:8) states that "the environment ranges from the largely cultural. . .through the intensely political. . .to the natural" (unculturalized physical resources or even climate itself). This approach does have a variety of theoretical lineal ancestors including Marx and even the less revolutionary thinkers like Adam Smith and Richard Ricardo. They all share a common vision of the absolute inseparability of economics from politics since inevitably class interests emerge from the inequitable distribution of value and resources and such interests will pursue their own welfare.[3] The natural environment is a crucial exploitive

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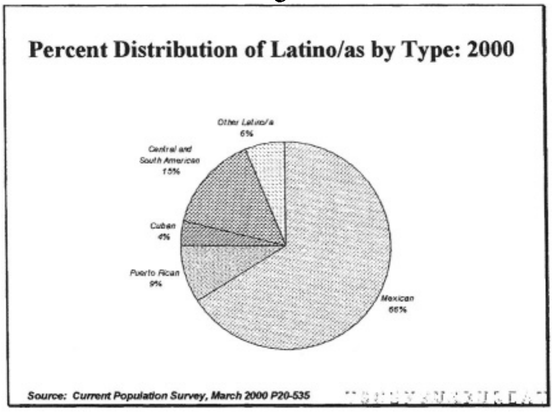
base upon which the political economy rests as an extractive source and eventually becomes a culturally-defined artifact that seems "natural" through practice, legislation, imposition, control, and made marketable. In the present, the sale of water, long held to be a physical resource held in common for use has become like any other commodity to be sold in the market place. Thus this "natural" artifact has become commoditized and perhaps eventually the case may arise when homosapiens has so polluted the air that special "pure" air tanks may become part of the market place as well.

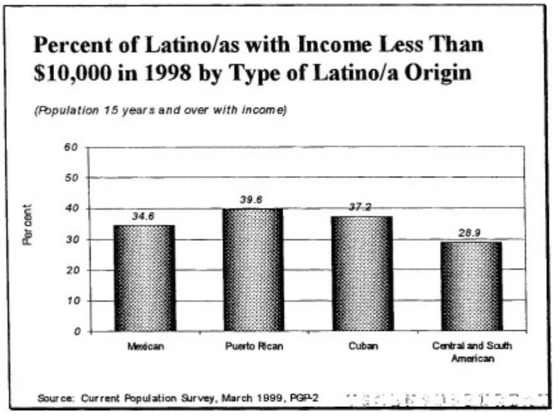
But to gain a sense of the breadth of what is addressed we need to consider the dynamic demographic processes in the U.S. in which Mexican/Latino populations are engaged. I use the term Mexican/Latino as the basic reference for as Figure 1 illustrates, in which the great majority of Latino populations are in fact Mexicans: 66 percent, Puerto Ricans: 9 percent, Cubans: 4 percent, Central and South American 15 percent, and Others: 6 percent. However, of crucial importance is that by 2025 fully 30 percent of the population of the United will in fact be Mexican/Latino, and will more than likely also have similar income and educational attainment.

Figure 1



Characteristics like those shown in Figures 2 illustrate that almost 35 percent of Mexicans earn less than $10,000 annually.

Figure 2



In 1998, slightly more than 27 percent of the Mexican population lived in poverty,[4] of which a large percentage was recent migrants to cities. Slightly over 30 percent of Puerto Ricans and 20 percent of Central and South Americans suffered from poverty. Cubans who are considered the "golden exiles" had only a slightly higher poverty rate of 13.6 percent than the general non-Latino population of 11 percent. Removing the Cuban statistic, Latinos in the United States will have suffered a poverty rate of 25 percent in 1998.[5] This is a significant percentage because it is only five percent lower than in 1993 even in the midst of a booming economy in 2000.[6]

Given the data in 1999, as Figure 2 shows, the cultural grouping is even larger than the percentage in poverty. The "working poor" very much fits this profile and for Mexicans and Puerto Ricans, this denotes extremely difficult financial straights for a considerable percentage of the Mexican population in the United States. In part, such characteristics are an artifact of youthfulness of 38 percent under 18 for Mexicans and 35 percent for Puerto Ricans, and only 24 percent for Anglos. This is compounded by the fact that the number of persons per households are twice as large among Mexicans than Anglos.

However, for the most part, Latinos suffer from low wages and underemployment rather than unemployment with 72 percent of the Mexican population earning less than $30,000 per year according to the 2000 Census.[7] Latinos are largely urban and close urban populations and in reality only about 9 percent of the Mexican populations live in rural areas.[8] Mexicans and Latinos both work and reside in metropolitan cities and their outskirts. Through their low wages, they subsidize the ability of urban and suburban, upper middle and upper class, mostly non-Mexican households to have two salaries, have their homes and children cared for, and have their meals prepared. There are probably no sushi restaurants, dry cleaners, car washes, construction projects, warehouses, light industries, office and janitorial services, and neighborhood gardening businesses without the employment of U.S. bom and foreign-born Mexican workers throughout the Southwest, and increasingly in states to the east coast like New York. Thousands of these urban and suburban enterprises and households are in fact subsidized by the low

Figure 3
Remittances 1979-1995, Mexico

Year	Workers' Remittances (Millions US$)	Compensation of Employees (Millions US$)	Migrants Transfers (Millions US$)	Total (Millions US$)
1979	0	177	0	177
1980	698	341	0	1,039
1981	859	361	0	1,220
1982	844	382	0	1,226
1983	984	407	0	1,391
1984	1,127	434	0	1,561
1985	1,157	459	0	1,616
1986	1,290	481	0	1,771
1987	1,478	507	0	1,985
1988	1,897	542	0	2,439
1989	2,213	580	0	2,793
1990	2,492	606	0	3,098
1991	2,414	616	0	3,030
1992	3,070	630	0	3,700
1993	3,332	647	0	3,979
1994	3,694	647	0	4,341
1995	3,672	695	0	4,367
				TOTAL = 39,733

Source: IMF Balance of Payments Statistics Yearbook. Annual.

wages paid to Mexican workers and simultaneously these same workers pay an array of local, city, county, state, and federal income taxes.

Colonia Formation and Processes

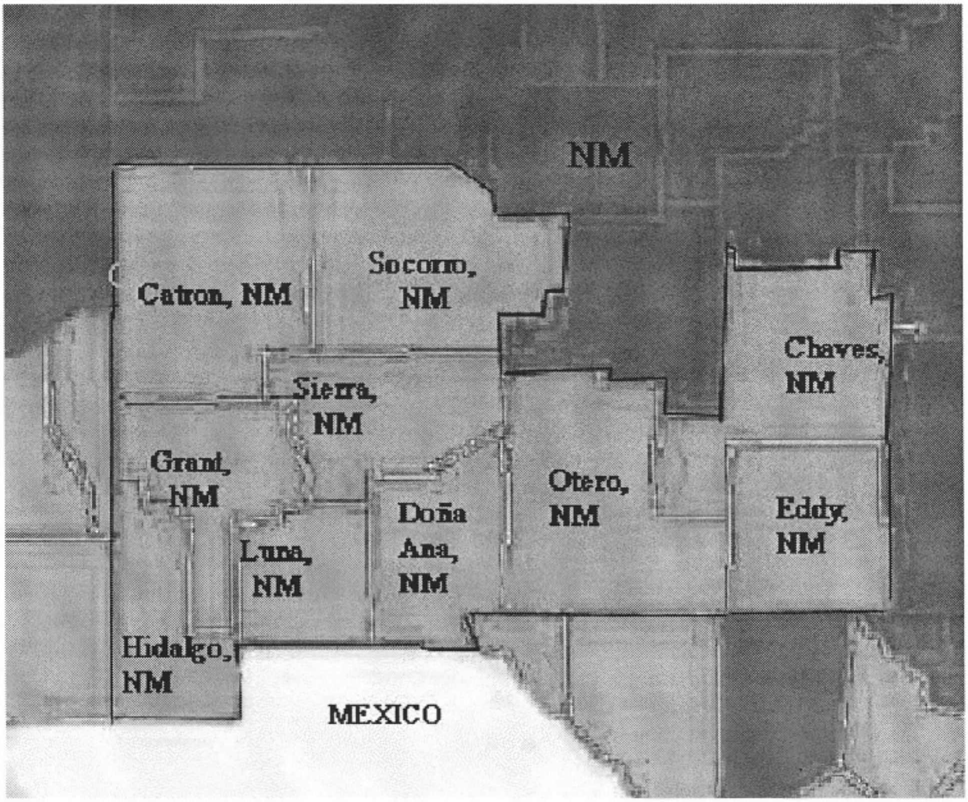
In a similar way, American agriculture is subsidized by the presence of Mexicans in colonias. The growth of colonias is tied in almost every instance to the development of industrial agriculture in California and Texas, New Mexico and Arizona. The various national policies which both support the funneling of agricultural labor to these areas, the 1986 IRCA legislation which provided migrants a small window of opportunity to settle, the various closed doors initiatives which limit circular migration, and simply the search for a better place to live have all contributed to the growth of U.S. Colonias. They are ecologically problematic given the physical niches in which most of the colonias are situated.

Colonias throughout the Southwest are ensconced in rural areas and emerged since the early 1980s usually occupying physical spaces undeveloped for human residential use and lack infrastructures that would provide basic amenities like sewage, potable water, and electrical and telephone lines. On the other hand, it is also the case that "colonias" (as it is often the case in New Mexico) are the result of demographic replacement in long settled townships whose previous populations had left for larger urban areas. This phenomenon characterizes rural California as well.

In both cases, however, "colonias" are generally recognized as relatively small human aggregations from between 30 to 400 families situated in ecological circumstances not amenable to the occupying populations. The Federal Government recognizes them spatially as being within 75 miles of the U.S.-Mexico border, absent of infrastructure, and most below the poverty line. This "official" designation was a political category largely created as a type of compromise between the Federal Government and struggling states like Texas and New Mexico that needed federal assistance to provide the needed infrastructure. On the other hand, the word "colonia" is a traditional word in Spanish that describes any community in which Mexicans and other Latinos live but are not necessarily characterized by the federal descriptors.

In New Mexico, Most of the approximately 148 colonias in 1999 are situated along the Mexico-U.S. border as Map 1 shows.[9] However, the county with the largest number of colonias is Doña Ana County through which flows the often curving Rio Grande River that begins in the far north of the Rocky Mountains of Colorado and flows to its final outlet destination 3,200 kilometers later to the Gulf of Mexico.

We are concerned with 37 colonias in Doña Ana County because of three persistent ecological and political features that differentiate them from the other counties and which have stimulated an annual rate of growth at about a rate of 7 percent per year. First, the presence of the Rio Grande as the major ecological referent and basis for agricultural development and human settlement is paramount. Second, the County like others is situated along the U.S. Mexican border and therefore is immensely influenced economically, demographically, and politically by its direct exchange of commerce and populations with Mexico. Third, the majority of the colonias straddle either the Rio Grande or Interstate 25 and State Highway 187 as Map 2 illustrates.



Map 1. Colonias in Counties of New Mexico. (Source: http://www/hud.gov).

Map 2. Map of Doña Ana County.
(Source: http://www.newmexico.org/maps/Southwest.html)

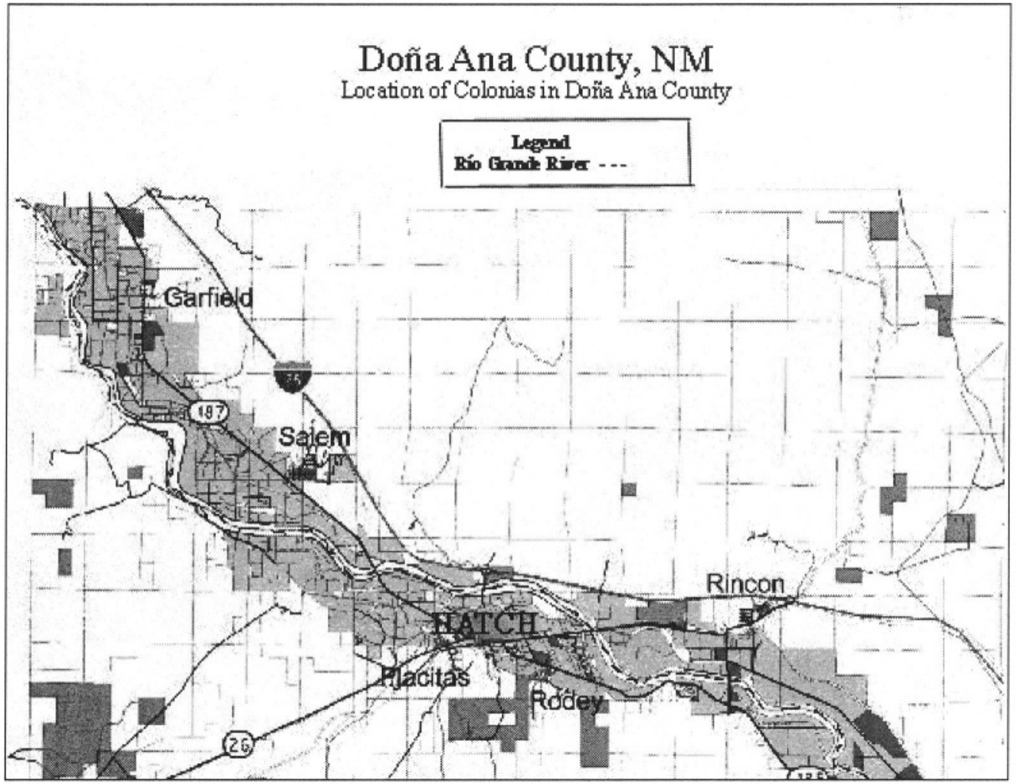
Both highways run somewhat serpentingly parallel to the Rio Grande Rivers and to the agricultural farms, villages and towns that border both. In turn, both highways serve as major transportation avenues to the Mexican border and northern New Mexico and Interstate 10 to points west to California and east to the eastern and southern United States as will be demonstrated. Most colonias are dependent on nearby dairy and the agricultural farms that stretch between the New Mexico and Texas border in the south to the tip of Doña Ana County.

Las Cruces plays an important role as a transportation and processing node for dairies and farms and is an important financial and lending arena for farmers. The local state university serves as a knowledge base that is strongly engaged in local agriculture through its very well developed extension services. Las Cruces in fact links the southern most point of the county and to its tip in the north but also serves as an important juncture to the west and eastern and southern parts of the United States. It is also the major urban site that provides multiple services, educational, and economic functions for all populations of the area like those offered by junior colleges, malls, restaurants, recreational sites, and medical centers.

The Colonias have been described in the literature as mostly being settlements rather than communities. Isolated, nucleated households characterize the former with few horizontal or vertical relations and the latter (fewer in number) are largely associated with the landlords who sold them the property in the first place.[10] However, as will be suggested, this description is only partially appropriate. As human settlements, most colonias in the New Mexican case are isolated in part by physical geography and by institutions. There are no self-governing institutions linked to any broader authorities except in the most minimal of terms and the colonias are only partially served by adjoining incorporated villages or towns in terms of fire, police, and sewage and water services. In at least four of the 37 colonias, some are still without garbage services, and only recently has the county government of Doña Ana County supported road repair. The County however does not service other colonia roads because these are designated as “private” harkening back to the period in 1980 when these colonias emerged from largely unzoned privately owned desert scrub rush.

As Map 3 illustrates, we will be concerned with a snow ball sample of 25 households from Garfield, Rodey, Rincon, and Placitas and an almost 100 percent sample of 27 households from a colonia will refer to here as “El Recuerdo.” This colonia does not appear on the map but is within a few miles of all of the above and close to the township of Hatch, which is known as the “chili capital” of the world.

As can be seen on the Map 3, most of the colonias border agricultural fields and adjoining roads and are largely situated as labor providers to the surrounding farms. According to our sample, there are four main employment venues in the formal and informal economies for colonia residents: more than 70 percent of men and women are engaged in agricultural labor, another 10 percent as labor contractors, foremen, and truck haulers, and a small percentage owning very small businesses such as informal garages, mini junkyards, hidden grocery stores, and child care in homes. A small but significant resulting percentage is engaged in the underground economy mostly transporting undocumented relatives from Mexico to the United States. As will be seen this is a significant phenomenon that creates the basis for class mobility, transregional mobility,



Map 3. Location of Colonias in Doña Ana County. (Source: Doña Ana County Planning Department 2000).

and the establishment of colonia-like settlements in Alabama, Kansas, Oklahoma, Mississippi, and other southern agricultural states like North and South Carolina.

As a comparison to other colonias in other states, the literature describes the residents in the Texas colonias as being 40 percent foreign born and 60 percent native born.[11] Our work in New Mexico would turn the percentages around where most of the colonia residents are Mexican born, with probably less than 20 percent U.S. bom. In five colonias sampled most of which were founded around 1980, it is only in the present that a second generation is being born in the United States since in many families their own offspring were also born in Mexico and came to the U.S. at a very early age.

In Texas, the economic standing of colonia dwellers is modest; the median income is approximately $7,000-11,000. The average family is between five and six persons and all have low average educational achievements. Generally workers are part of the tertiary agricultural wage labor sector, if employed at all. Many are unemployed or dependent on informal economies. A simple demographic profile of one such colonia, "El Cenizo" (the Ash), in the state of Texas will shows the following: 254 families, of which 220 are Mexican an average of 5.4 persons per family. Single houses are densely occupied beyond the nucleated family and of 193 houses, more than 110 have more than five persons and of these 70 have more than seven persons per household.

The majority of the 1,312 inhabitants are young with only 10 percent of the population over 40 and more than 50 percent under 18. Most households are far below the minimum poverty level of $11,203 for a family of four as defined by the federal government. Most adults have less than a high school education. However, it should not be concluded that such demographic characteristics define the social and cultural characteristics of El Cenizo's population. They are responsible for a great deal of community improvement stimulated by locally and extra locally organized schemes, including the extension of potable water, sewage, electricity, and the development of an important social service center which provided medical, occupational, and familial services.

However, only seven years after its formation, the population of El Cenizo had increased to three times that cited above and the best prognosis is that the population will continue to increase between seven and ten percent per year. Only 24 percent had a high school education, 70 percent read or wrote English "poorly" or "not at all," 70 percent lived below the poverty level, and median household income was slightly less than $7,500. Unemployment of inhabitants 25 years or older was more than 25 percent compared to a statewide unemployment rate of only 7.1 percent.[12]

Our sample of 25 households from five colonias and a 100 percent sample of a single colonia in New Mexico is somewhat at variance with the income generated and importantly much more complex. Our sample among the five colonias shows that mean income is $22,578 for an average family of 6.2 but with an indebtedness of $26,240 annually. As we will see, this negative income is offset by a variety of combinations of credit, indebtedness, the informal and underground economies, and network pooling.

For this sample and as will be shown in the micro ethnography of El Recuerdo, most persons derive their income as agricultural laborers or in the numerous dairies in the valley with a scattering of persons involved in trucking, contracting of agricultural laborers, and petty entrepreneurship. Almost 40 percent of monthly income is devoted to food and automobile and truck debts, while gasoline and repairs account for another 10-

15 percent. The rest goes for clothing, mortgage, medical, food, repair, and schooling expenses. Between 30-50 percent of the adults in the five colonias migrate to other states such as Alabama, Mississippi, Oklahoma, and Kansas when agricultural work is unavailable in the area. Significant numbers of close relatives also seem to have migrated to the Midwest to Chicago and return to the colonias annually for visits as well as others who sojourn between the colonias and Alabama.

The mean age is 44 for males and 42 for females—much older than the study in Texas indicated. The average educational attainment for the first generation was 5.6 years and generally much lower than those either raised as children in the colonias or born in the communities with children to age 16 already surpassing their parents in educational attainment by three or more grades. However, the drop out rate for secondary schools is in the 60 percent range and that does not bode well for their own children in the future. However, we have also ascertained that the colonias have already celebrated their first two university and junior college graduates. We are aware of at least another ten persons who are attending technical schools and junior colleges, while a few are currently enrolled in the local university.

El Recuerdo

El Recuerdo is a perfect example of the development of the typical colonia and those that will emerge in the near future. The colonia encompasses an area of 80 acres and it first became inhabited in 1987 after the original owner-a local rancher sold four 10 acre parcels of undeveloped land to different families for $1,000 per acre who then themselves subdivided these parcels into ¾ to 1 acre plots and sold them for $3,000 each. By 1994, approximately 10 families had moved to Recuerdo and by 2001, 31 households had been established in a combination of trailers, trailer/homes and finished concrete block homes.

Housing varies in composition and design. Lots on which they are built generally are no less than ¾ of an acre. Construction usually follows a sequence of settlement: a trailer first, then hybrids with permanent structures attached, some trailers surrounded and incorporated, and some houses built entirely of block or adobe construction. As part of our work, we also measured lots and we have a precise knowledge of each, as well as details of actual materials and construction on hand. Map 3 provides a schematic of housing and the accompanying plates are examples of the "modular" building process involved. Plate 1 provides a partial overview of the Colonia and Plates 2-4 show different types of housing.

Of the 40 dwellings of assorted types present in El Recuerdo, 30 of the dwellings are former trailers that have been converted to permanency, and in some cases have been ensconced within family-built brick homes. When a resident is asked where the former trailer was situated, she will point and answer "aliá" (over there). The observer actually sees nothing, but the bare outlines of interior walls of the former mobile homes. Many of these dwellings, even in this third millennium, will have no access to sewage or gas lines and all at one time or another suffered from the lack of electricity and water services.

Eventually the residents themselves essentially create "miracle" communities out of nothing and with only the strength of their courage, tenacity, and knowledge that persons in dire need often display. They literally fight as "colonos" or colonists to have state authorities introduce basic water services and electricity.

Of the 27 households sampled (3 household members were elsewhere during the research) 11 lived in tri-generational arrangements with 6 in clusters of two or more households on the same lot and 5 shared a single hearth. Sixteen nuclear families occupied the rest for a total population of 177 persons with a mean of 6.7 persons per household. The average age of heads of households of the 27 households was 44.5 and 42.5 and from our ethnographic information, Figure 3 illustrates the range of income and labor activities in the community with the preponderant occupational activity was in agricultural labor ranging from agricultural wage labor to loading agricultural products on trucks.

Almost half of the El Recuerdo family sample reside in household clusters of extended families. Many live either in an arranged modular housing combining trailers and permanent structures or permanent brick homes built over time. Some surround the original trailers that they occupied early in their residential history. However, what is significant is that the household clusters are important mechanisms that mitigate the perpetual problem of negative income with scarcity shared among many members in the extended households. Our research shows that the clusters function as important child care centers for related satellite households, as well as for borrowing money during the slack periods in January, February, and May when income especially falls due to insufficient work in the fields.

As a relatively common example, a single household in El Recuerdo, the Mario and Sylvia Benito family, is trigenerational with a married couple, two children, and grandparents while in the same colonia within 100 yards live the maternal grandparents and their unmarried son. Equidistant to the Benito residence from the maternal grandparental household live Mario's brother, spouse, and four children. One mile north of El Recuerdo, in the colonia of Placitas, reside Sylvia's sister and spouse and a second sister with her spouse. Mario's sister and spouse and seven children reside in Placitas as well while another sister and husband and two children live in Salem and yet another sister and spouse and two children reside close by. In the Colonias alone, 34 related consanguineal and affinal relatives reside. Our research clearly indicates that these individuals are connected by frequent visitations, commensal activities, ritual participation, the care taking of children, the exchange of information about the availability of work, and importantly the sharing of trucks and automobiles for work. Crucially, the lending of money between households and, less importantly, the participation in tandas or rotating credit associations, were frequent activities in the colonias.[13]

Both Mario and Benito easily recounted that in the state of New Mexico five aunts and uncles and five cousins lived in nearby Rosewell, Albuquerque, and Las Cruces. In other states, four aunts and uncles lived in Abeline, Texas and California; nine cousins in Chicago; one brother and sister with their families in Alabama; and six brothers and sisters who migrated back and forth between the colonias and Alabama and El Recuerdo. Thirty relatives were named in the city of Juarez, Chihuahua Mexico, and the city of Guanajuato, Guanajuato, Mexico. While proximity was important in maintaining the density of relationships, nevertheless almost every relative regardless of distance, region, and country were visited at least one time a year, and often those visits lasted between two weeks to six months.

Thus while it is accurate to state that "horizontal" relations do characterize the nature of social life in these communities and also lack vertical institutional relations, the former serve as the basis of identity, support, and assistance. These obviously cross colonias, states, region, and in fact serve important transnational functions not the least of which is the recruitment of more relatives.

Ecological Imbalance

Yet community life is not absent in organization, and members of households do participate in "Brigadas de Limpieza" (clean up brigades) about every 3 to 4 months that scour the colonia for broken bottles, plastic bags, assorted paper, and discarded wrappers and sundry other trash that is easily strewn about by strong winds that emerge from out of the hot desert in the Summer. In the winter, these same brigades try to cover the perennial potholes that are created by colonia trucks and cars that run over roadways already weakened by heavy rains that pour through the colonias in the rainy season. Primarily a flood plane, El Recuerdo is often threatened by rain from the surrounding low hills and flooding is not an uncommon occurrence. Before its present development, El Recuerdo was used as a dumping ground and an adjacent area served as pasture for a herd of cows belonging to a non-colonia owner. Frequently, people from Hatch and other colonias continue to dump unwanted materials including bottles and garbage. The herd of 10 or so cows continue to use the pasture and in the evening forage through the community plowing up flower beds and depositing animal manure and urine on the colonia itself. Children often run about barefoot with the obvious consequences.

But there are number of physical conditions suffered by all colonia residents of the five colonias sampled, which are endemic to many other colonias not part of this sample and continue to pose serious health problems. For the most part many "colonos" rely on septic tanks that often overflow or incomplete sewage lines that allow its collection and overflow in pools of partially filtered but untreated sewage. In fact, most of the septic tanks have less than a 500-gallon capacity. Since families and households in general are large (6.7 in El Recueredo), underground septic tanks fill up quickly and often and colonos are forced to spend \$300 six times a year to empty them. However, since most everyone suffers from negative income, as a later section will show, colonos also permit the tanks to overflow on to the property as Plate 3 demonstrates.

Many will purchase a \$300 water pump with two hoses; one is inserted into the cesspool itself and the other led out to either a neighbor's empty lot or into the desert. In some older colonias, where homes are closer together, the hoses are placed in the their own backyard and will be connected in the late evening to hide their activity. However, from the sound of the motor most colonos know what is going on. Since everyone is involved in the same practice, little is said unless someone else's sewage is pumped onto their lots. As well, those households close to the many dikes and irrigation canals will use them as their dumping sources for untreated sewage. How many households are engaged in this particular practice we do not know; however, the implications for using contaminated irrigation water on already pesticide-treated crops cannot remain unappreciated.

If one considers that in one colonia alone there are 70 households each to varying degrees suffering from the same problem and each one pumps out a conservative estimate of 50 gallons at a time, at least twice a month, then 7,000 gallons of sewage are being dumped in just one single colonia. If one multiplies this by 5 colonias in this area of study with the number of households ranging between 40 and 230 households with an average of 100 households per colonia, then the scope of ecological contamination can be appreciated. Needless to say children suffer from high rates of gastric and pulmonary diseases and over 80 percent of adults 25 or over suffer from traces of Hepatitis A.

As well, it is only within the last five years that potable water, electrification, and passable roads have been introduced. Prior to this period, tanker trucks provided water to the area by filling 50-gallon drums formerly used to store insecticides, oil, and sundry other materials. Lighting of homes was accomplished by candles, flashlights, and occasionally bonfires to keep out the numerous desert animals that abounded in the area: coyotes, rattlesnakes, javelinas, and the ususal desert rats, mice, and ground squirrels However, these conditions were mitigated by use of the cell phone that probably was the single most important communication device between households and household members regardless of the availability of other infrastructure. As will be seen, this continues to be the major method of communication but also of social formation across great distances.

The Labor and Income Cycle

Even though most residents work in nearby agricultural and dairy farms at minimum wages, a lucky few have jobs as service workers or in construction in a nearby city. About a third of this population travels the migrant stream for three or four months in order to provide subsistence for their families when the crop cycle of the area slows to a trickle of production, especially for the major crops: red and green chili, and onions. Pecans and cotton are largely machine-picked and labor is limited only to gathering what the machines are not capable of collecting.

Such migration occurs during the months of January and February and somewhat in the month of May and extends from the colonias to Alabama, Oklahoma, Kansas and Mississippi. Almost every household owns at least one car or truck and many two or more trucks and automobiles, which are called "muebles" (furniture). The term is symbolic of the nomadic nature of migratory existence in which literally their households are carried with them to points very distant from the colonias themselves. The term also attempts to soften the utilitarian function of vehicles with a more familial sense since the travel is strenuous, tiring, and saps familial resources in gasoline and travel expenses especially spent on six or more persons per households.

Yet such travel is also part of a rather elaborate and complex mechanism that is developed by the agricultural labor needs in the southeastern part of the United States. The process often is initiated by telephone from labor contractors who communicate with "cuadrilla" leaders (labor group leaders) who then recruit mostly kin and friends. This aspect of the migrant process, however, also provides an interesting avenue for class formation. Some individuals begin the process by purchasing a second-hand truck and actually drive them on to the onion, pecan, and chili fields where they will bag, box, or shovel product on to the pick-up truck's bed for transfer to a warehouse or processing plant. In time they will invest in a larger truck and eventually truck products to markets in the state or elsewhere in the United States. Simultaneously the same individuals will be involved in labor contracting and will lead the "cuadrillas" to Alabama, Mississippi, or any other state needing labor. Once established, however, the same individual will invest in the purchase of a garage, grocery store, and restaurant/bar in the southern town since the cuadrillas sometimes establish "colonias" in the southern state itself. The individual will recruit relatives as mechanics and others to work in the grocery store and restaurant/bar. These establishments serve as the basis for community life and function as central nodes for further recruitment to the area and fill the obviously important needs for a trustworthy mechanic, familiar food and articles, and lastly provide a community meeting place for otherwise very isolated Mexican families in an alien Anglo world.

The formative class aspects emerge clearly as new recruits into the businesses avoid work in the fields, miss the necessity of joining the migrant stream, and are afforded an opportunity to establish a lower middle class existence without having to rely on the vagaries of agriculture labor. Thus some relatives jump from an agriculturally based manual labor in Mexico to petty businesses, and therefore avoid being "stuck" in a similar labor situation in the United States. It is in this process that literally the emergent class formation is "off the backs of others" as is the entire migrant/agricultural industry.

When insufficient kin are available then simple telephone calls to kin in Mexico (usually Guanajuato, Chihuahua, and Zacatecas) are made, and a relative who is also a smuggler and who will charge $700 per person will then arrange for transportation from the point of origin to a safe house or hotel. In some cases, relatives will be transferred to a ranch in Mexico close to the border and then moved into New Mexico through very well elaborated routes and communication links, the latter usually involving cell phones that are difficult to tap and to trace. Once safely housed in the region, they then may be moved to other regions and states. However, such safety is often illusory since border check points are well manned, surveillance apparatuses technologically sophisticated, and roaming INS agents very familiar with the same routes traveled by the smuggler and his kin.

The danger, anxiety, and indeterminacy created often fill colonia residents with dread since too often relatives are arrested and vehicles impounded and for many this represents the loss of a very hard-earned necessity. But it must also be said, that the percentage of those so engaged in this underground economy represent a small percentage of the all the residents of this and other colonias.

The Means of Credit, Debit, and Class Formation

From the founding of the household to the myriad daily costs of maintenance and child support to the various migratory strategies utilized, money is the central necessity that is always scarce and seldom in sufficient quantity to accomplish many of the basic life cycle functions. The question then arises if the income is mostly negative how then are lots purchased, homes purchased, improvements made, gardens grown, children clothed, food purchased, automobiles and trucks afforded, and the basic costs of daily living met. How are such emergencies like illness, immigration raid outcomes (such that household members are sent to Mexico), visits to relatives, travel to Alabama, and the other various costs associated within the contexts described here?

The simple answer is a constant balancing between debt and credit and income and over expenditure. Such balancing involves 1) shuttling between informal and underground economies, 2) pooling available resources and participating in rotating credit associations, 3) borrowing from local banks and the local loan sharks or using credit cards, 4) creating margins of favorable returns on goods purchased in pesos and sold in dollars, and finally, 5) reneging on loans from the formal or informal credit sources. We discuss each in turn.

However, what must be understood is that each of these approaches may be simultaneously engaged and are not exclusive one to the other. As well, considering that the households are so large and the extended households themselves serving as a kind of "corporate" group in regards to the sharing of resources, different individuals within households and within the larger network may be engaged in one or more of these activities. The key variable as to which of the above becomes more important is dependent at what stage in the life cycle the household(s) are engaged and the number of household members present,

But there is a constant struggle in keeping the negative income ratio to less than 20 percent. In recalling the percent of expenditures for transportation, gasoline, and food, 55 percent of household incomes are taken up by these expenditures. Of this 55 percent, 70 percent is paid in auto or truck payments to banks, finance companies, or individuals with interest in the 13 to 16 percent range per month. When automobile or truck insurance is added another 15 percent may be added to the monthly cost. Gasoline costs are very high with an average cost of $200 monthly which adds another 10-15 percent of gross costs per month. Thus fluctuations in gasoline prices, costs of periodic mechanical dysfunctions, tire replacements, and many other costs of up keep, add to the transportation costs so that another 10-15 percent of income is added to the already 55 percent spent on transportation and food. Any fluctuation, then automatically will move these households towards a greater negative income percentage so that a combination of informal and underground activities become mandatory. At times, this will eventually mean a total movement into the latter with very large returns made for the very large risks also accrued.

The second important balancing strategy is the pooling of resources and participating in rotating credit associations. The former usually involves the pooling of income, wages, and future earnings for the purposes of making the initial down payment on land, trailer, or automobile. The cost of land in 2001 in the colonias is between 5,000 and 10,000 dollars per acre with ¾ of an acre the minimum to build or place a trailer. Paid on payments of $150 per month on a 10-year mortgage payment, the actual price may double at the end of the payment cycle. The trailer itself, second hand, ranges between 3,000 and 10,000 dollars usually paid in payments with an approximate down payment of 20 percent. The monthly payment for the most part ranges between $100 and $300 per month with interest in 15 percent range. Therefore the level of credit indebtedness for lots, housing, and the necessary infrastructure like cesspools increases the overall additional monthly debt, when added to the 55 percent increases, is close to 75 percent.

However, the initial costs are usually pooled with older siblings also contributing to the costs of land, housing, and infrastructure. However, it is also true that once married, the siblings must call upon their parents and each other for assistance. In situations where two or more generations share the same house lot, the cycle of debt is inherited. Essentially, new housing creates new debts. Meanwhile the original generation assumes the costs of the land.

Rotating credit associations (RCAs) have two major functions: debt reduction and purchase of gifts for rituals or simply to defray the costs of everyday needs. For the most part, the rotated amount is no more than $200 a month with a rotation of five to six months. Thus at one time an individual may receive amounts between $1,000 to $1,200 and considerable relief is noted especially during the slack periods of employment. Many seek to have their fund collection fall in May or June and for the most part RCAs do not operate during these periods. From our research, however, RCAs are mostly in the hands of women and play a less important role than familial pooling.

Borrowing from banks is mostly the exclusive prerogative of households that have been in the colonia area for one year or more and have established credit with stores or have a record of relatively steady employment. Banks use a combination of safeguards with less regard for collateral and with a greater dependence on the local networks of farmers who vouch for the reputation of their employees as well as provide income information to banks when loans are solicited. But the banks have a policy of never providing more than 75 percent of the estimated maximum of any given loan for two reasons: first, according to the banks, no household should use up their maximum estimated credit value because they know that for the most part households will return for more credit borrowing during the Christmas holidays when the great majority of the households return to Mexico for visits. Second, conscientious bank officers who understand that colonia residents are often at the brink of insolvency, realize that borrowing more will put them in an untenable position in which they will loose the bit of property that they own in any foreclosure action by the bank. In one case, a bank officer wanted a colonia borrower to have a financial cushion in case of emergencies for relatives in Mexico. As well, in some instances, bank officers will not approve credit cards not because colonia residents are poor risks but rather because they think that colonia residents are simply unacquainted with using the mail as the means of repayment.

In some cases, colonia residents will take advantage of the proximity of the Mexican border (75 miles to the south) by purchasing Mexican foodstuffs and religious items and then reselling them in the colonias. Carbonated drinks heavily concentrated with sugars, candies, bakery goods, flour, sugar, beans, and spices are sold in tiny home stores or simply stored and through the dense information networks of the colonias, have their availability advertised. The return on investment is limited given the cost of gasoline to the border, the limited quantities allowed by U.S. Customs, and the increasing costs of these as well. Only about 20 percent of households may be involved in these activities.

Reneging on their debts is the last of the possible balancing measures taken and the least desired choice. Reneging on bank loans places the household in direct danger of even greater risk since banks may be the one and only source of needed cash for emergency situations involving relatives, either in the colonia areas or in Mexico. As well, if lots or homes are used as collateral then the one greatest valued physical representation of security is eliminated. However, there is still another pressing consequence. Farmers and bank officers often have close personal and professional relations, and the bank can bring informal pressure to bear on colonia workers through employers. Farmers, as well, may threaten to garnishee their wages as a consequence of a conversation between a farmer and bank officer over simple cups of coffee drunk at the local diner in the early morning before both go to their respective jobs.

Borrowing and reneging on informal borrowing may have both social and physical consequences depending on the relationship with the creditor. If a relative, close colonia resident, or friend is involved, reneging has far-reaching consequences in that the failure to pay a debt breaks “confianza” (mutual trust), which is the central value in the many reciprocal and obligatory relations between colonia residents. Since reciprocal relations based on exchange endure even though the commodities they entail may not, reneging on debts places relations based on other obligations in danger. The rupture of relations is simply too dangerous socially for colonia residents given their negative income situation, marginal economic stability, immigration enforcement dangers, and numerous other uncertainties and indeterminacies.

There is also a small percentage of a type of “loan sharking” among colonia residents that may also be present, especially among men. For the most part women do not participate in this underground credit economy and men usually contacting other men may in very few steps reach someone who may also be engaged in other underground activities and who may lend money at weekly interest rates. The lender’s response for someone reneging on such debts is in part dependent on the attitude of the borrower and in some cases may result in physical violence. In one case, the borrower dared the lender to collect his debt and the lender together with his father, brothers, and cousins ambushed the borrower and broke his kneecaps.

These endemic financial factors and situations are major contributors to the clearly stressful and indeterminate conditions faced by colonos and create the basis for contested relationships and psychological and social uncertainty. These conditions importantly contribute to the degradation of already strained desert environments in which these communities emerge. Tragically, these same conditions serve as the means by which agriculture and its supporting institutions like banks are provided more secure margins of return.

General Observations

All of these processes have also emerged in rural agricultural contexts in Arizona, California, New Mexico, and Texas and more recently in places such as Alabama, Georgia, Kansas, North Carolina, and Mississippi. Here, Mexican residents struggle daily to not succumb to ecological situations and conditions that would easily overwhelm even the most seasoned survivor. Mexicans are also reinvigorating and reoccupying largely vacated California rural towns. Over the past 30 years, these towns have been abandoned by non-Latinos, largely because of a maturing development cycle in which the young move out and their parents follow them to other states or to suburban sites nearby.[14]

However, this process is a double-edged sword so that while towns are being reoccupied, businesses reborn, and civic government re-established and literally raised from their developmental deaths, poverty, low income, poor housing, and decaying institutions also mark their rebirth. There is also similar nascent growth of Mexicans in rural Iowa and Indiana in mostly farming communities where local institutions have been hard-pressed to adjust to the educational and cultural needs of the newcomers. Yet even within these “non-Mexican” regions of the Midwest and south, Mexican-oriented restaurants, stores, and other services are being developed by Mexican migrants who have been contractors for fellow migrants or in some cases participants in the underground portion of the economy.[15]

Conclusions

Clearly the political ecology of the colonias reflects the asymmetry of the interaction between the labor needs of agriculture and the labor regulatory role of the nation-state. The meager provisioning of Mexican households coupled with the lack of available housing stock induces residential settlement in the cheapest areas possible and these are set in ecological circumstances unsuited for settlement because of the lack of infrastructure. The impacts on environments are serious especially where land developers do not provide the basic amenities including water, sewage, and electrification.

While these are in fact poor households, their inhabitants are also innovative and develop inventive practices using whatever materials, wages, relationships, and opportunities to establish their homes in the midst of often unsettling physical conditions. Thus it must be noted that these colonias are not inhabited by marginal, poverty-stricken, and "underclass" households. These households although beset with many health, economic, social, and psychological pressures, still remain vibrantly resistant and remarkably stable.

But it must be stated unequivocally, that the colonias are the manifestation of one type of human subsidy that meets the needs of the agricultural industry. The colonias in fact are the human settlements that serve as available sources of labor without the necessity of the state or industry providing the basic provisioning necessary to develop healthy communities. It is only with great struggle that services are introduced, community formation made possible, and relatively stable households formed and that state institutions provide some of the basic infrastructure for community living.

In fact, the agricultural industry within the political economy demands an initial underpaid, under provisioned, and largely uninsured and unprotected labor force. Colonias function as important platforms from which to gain profits in a risky and uncertain enterprise beset not only with local, regional, national and international market prices but with also all the usual cost demands in farming such as transportation, processing, marketing, chemicals, equipment, and sundry other costs.

At one level, the entire edifice is dependent on the human subsidies provided by the colonias since their formation is a cost born by the inhabitants themselves and only later by institutions. The reciprocal relationships of extended households used in the colonias such as the exchange of money, information, and favors provide a modicum of security and the basis of community life. This is the social capital that is imperative to make up for the lack of monetary capital unavailable to colonos and serves as a type of subsidy to the local and regional economy. The structure of credit and debts are importantly associated with this subsidy function as well and undergrids the entire process. The underground economy provides an added invisible subsidy for the recruitment of relatives to fill the work needs of agricultural interests. Costs associated with such recruitment are entirely in the hands of those being recruited and the risks to the smuggler-relative also entirely debited to him/her. In no case is the agricultural industry bearing any risk or cost associated with this process.

On the other hand, class mobility of some individuals is guaranteed by the same subsidy system as well as it guarantees social and economic inequality that is the central principle of social development in all capitalist systems—rural or urban. These subsidies of sacrifice, invention, reciprocity, indebtedness, and community formation are at all levels always "off the backs of others."

Endnotcs

[1] The fieldwork conducted was partially supported by the Ernesto Galarza Applied Research Center, University of California Riverside.
[2] This percentage is an estimate based on fieldwork conducted by Vélez-Ibáñez, Guillermina Nunez, and Dominique Risolo between 1998-2001 in various "colonias" in New Mexico. The specifics of parts of the underground economy will have to remain masked.
[3] See James B. Greenbcrg and Thomas Park (1994:8) Political Ecology, *Journal of Political Ecology,* Vol 1:pp. 1-12.
[4] The minimum poverty level of $ 11,203 for a family of four as defined by the federal government.
[5] See the following for a detailed rendering: Population by Poverty Status in 1998, Selected Age Categories, Hispanic Origin and Race, and Sex: Table 12.2, March 1999. http://www.census.gov/population/socdemo/hispanic/cps/12.2.tr
[6] Selected Economic Characteristics of All Persons and Hispanic Persons, by Type of Origin. Table 2, March 1994. http://www.census.gov/population/socdemo/hispanic/cps94/syntab-2 txt.
[7] See a rendering of The Hispanic Population in the United States: Population Characteristics 1999, Figure 9 (Internet Release Date: 2000). http://www.census.gov/prod/2000pubs/p20-527.pdf.
[8] See a rendering of The Hispanic Population in the United States: Population Characteristics 1999, Figure 11 (Internet Release Date: 2000). http://www.census.gov/prod/2000pubs/p20-527.pdf
[9] Colonias Maps, Where are the Colonias Located. 11 (Internet Release Date: 1999). http://www.hud.gov/cpd/c2020/coloinias/map4.html..
10 See Peter M Ward (1999: 165-202) *Colonias and Public Policy in Texas and Mexico: Urbanization by Stealth.* Austin: University of Texas Press.
11 See Internet Sources: Welcome to the Colonias Program (1997), The Colonias Program, College of Architecture: Texas A&M University. Internet Source and Colonias Factbook Summary: A Survey of Living Conditions in Rural Areas of South and West Texas Border Counties (1988), Austin: Texas Department of Human Services.
[12] Welcome to the Colonias Program, The Colonias Program, (1997) and College of Architecture: Texas A&M University. Internet Source. Electronic Document
[13] See Carlos G. Velez-Ibanez (1983) *Bonds of Mutual Trust: The Cultural Systems of Urban Mexican andChicano Rotating Credit Associations.* New Brunswick: Rutgers University Press.
[14] See Elaine Allensworth and Refugio I. Rochin (1995) *Rural California Communities: Trends in Latino Population and Community Life.* The Julian Samora Research Institute, Michigan State University.
[15] In a future monograph, "Off the Backs of Others: The Political Ecology of Rural Class and Community Formation among Mexicans in the United States," (In Process, Expected Completion: 2002) by Vélez-Ibáñez, the full details of this type of vertical mobility will suggest that these processes as being only possible within a highly segregated labor market.

Immigration, Agriculture, and the Border

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Abstract

The Mexico-US border highlights population and economic growth in an "artificial" desert environment—there would not be 12 million residents along the 2000 mile border if it were not an international border. For most of the 20th century, there were only three major population centers along the border: the lower Rio Grande Valley, the El Paso-Juarez area, and the San Diego-Tijuana area. There were one million residents along the border in 1942, but then the border-area population became to grow, especially on the Mexican side, during the 1942-64 Bracero program, under which Mexicans could work legally on US farms. The border area population grew even faster after the maquiladora or foreign-owned assembly plant industry expanded in the wake of peso devaluations in the 1980s and 1990s.

In 2000, there were 6.5 million people in the counties along the US side of the border, and 5.8 million on the Mexican side—the total border area population rose 50 percent in the 1990s, from 8 to 12 million, and is projected to double to 24 million by 2020. The border area's major economic engine is manufacturing and related services—some 1.4 million Mexicans are employed in 3,500 border-area maquiladoras, and the presence of these assembly plants explains much of the population growth on both sides of the border in the past two decades. The North American Free Trade Agreement (NAFTA) was expected to divert the industrialization of Mexico away from the border, but has so far not had this effect.

The Mexico-US border area in the 21st century is at a crossroads. Irrigated agriculture is shrinking on the US side, and not growing significantly on the Mexican side—scarce water is likely to be diverted from irrigating crops to higher value urban uses. Wages are lower but unemployment and poverty rates on the US side of the border are typically 2-3 times higher than the US average (San Diego county is the exception). By contrast, the Mexican side of the border is marked by higher-than-average wages and lower-than-average unemployment: maquiladoras constantly advertise for workers, population growth outstrips infrastructure development, and traffic to move goods, migrants, and shoppers across the border leads to significant waits at border crossings. Thus, the people picture of the border is one in which Mexicans migrate from poorer inland areas to what is for Mexico and relatively rich area, and the American residents along the border are largely Mexican-Americans with relatively little education and skills (San Diego is the exception).

Introduction

The Mexico-US border stretches for about 2000 miles, separating about 100 million Mexicans from 285 million US residents. The border region, which includes some the richest areas of Mexico and some of the poorest areas of the US, witnesses one of the world's great contemporary migrations, the movement of Mexicans to the US.

Most of the border area is a desert. The border area population began to grow especially rapidly in the 1950s, as Mexicans seeking entry to the US as Braceros learned that they had a better chance of being selected if they were in the border area, largely because US farmers had to pay the cost of transportation from the worker's residence to his farm—if the worker's residence was the border,

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transport costs to the interior of the US were lower. The border population rose rapidly after 1965, in response to the maquiladora program, which aimed to attract foreign investment to create jobs for ex-Braceros and their families who had moved to the border area, and had nothing to return to in the interior of Mexico. Border area population growth was slow during the 1970s, but when the peso was devalued in 1982-83, there was a rapid expansion of maquiladoras and a new burst of population growth on both sides of the border.

The poverty that marks the U.S. side of the border have led some to describe it as the third world part of the United States: three-quarters of all families on the US side had incomes in 1990 below the poverty line of $13,359 for a family of four. In Texas and New Mexico, many of these poor families live in colonias, areas in which lots without water and electricity connections were sold, producing substandard housing.

Mexico-US Immigration

Migration has more often been the source of conflict than cooperation in Mexico-US relations. The United States accepts immigrants from and trades with many nations, but virtually all Mexican emigrants and most Mexican exports come to the United States. For most of the 20th century, Mexico-US migration occurred outside formal channels. There has been significant Mexico-US migration since 1917, but during only two periods, 1917-1921 and 1942-64, did formal agreements regulate the employment of most Mexican workers who were temporarily in the US.

The North American Free Trade Agreement, which went into effect on January 1, 1994, was expected to convert this migration relationship into a trade and investment relationship. However, migration specialists predicted that, in the first decade of the agreement, migration pressures would increase, not decrease, as Mexicans displaced by economic restructuring would lead to temporarily more migration, a migration hump (Martin, 1993). The migration hump suggests three policy lessons:

• if there is a pre-existing migration relationship between two integrating economies, migration should not be ignored in trade and investment negotiations that are likely to affect migration patterns.

• restructuring an emigration country for faster long run growth has a pain now, gain later flavor, which suggests that both emigration and immigration countries should acknowledge that trade affects the size and duration of the migration hump, and take steps to deal with increased migration in order to prevent a backlash against immigration and migrants.

• long run solutions to unwanted migration lie largely in sending countries, but immigration countries should be careful not to add to or maintain the demand for migrant workers by subsidizing and protecting from free trade industries such as agriculture that rely on migrants.

The United States is the world's major country of immigration, and Mexico is the world's major country of emigration. There is an asymmetry in migration patterns. The United States accepts immigrants from many nations, but virtually all Mexican emigrants head for the United States. In FY98, the most recent data available, there were 131,000 legal Mexican immigrants, 3.5 million legal Mexican nonimmigrants admitted for business, pleasure, or temporary work,[1] and 1.6 million unauthorized Mexicans apprehended, most just inside the US border with Mexico. Every day and night, some 10,000 to 15,000 Mexicans and other foreigners attempt to enter the US, usually between ports of entry. Both legal crossings and apprehensions of unauthorized foreigners record events rather than individuals-- a

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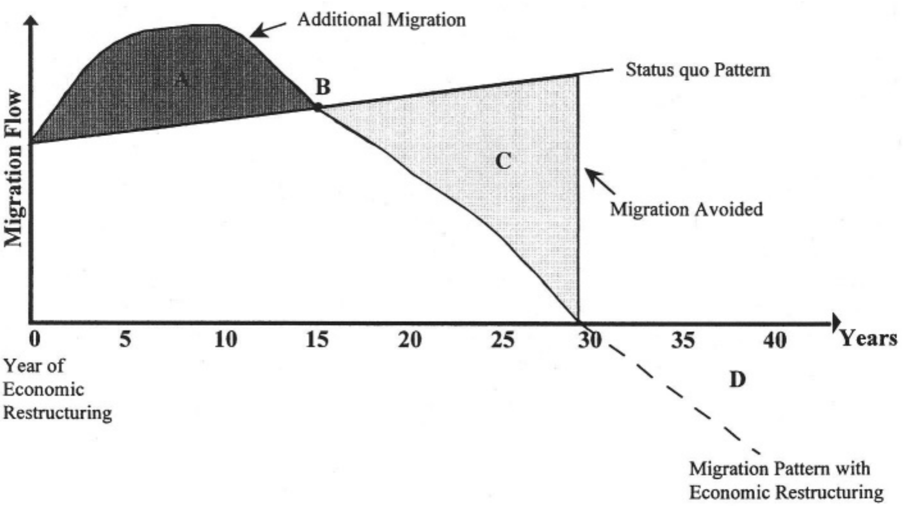
[1] In addition to Mexicans admitted as nonimmigrants, the US has issued five million border crossing cards to border area Mexican residents that permit card holders to enter US border areas for up to 72 hours; such border crossings are excluded from nonimmigrant admissions.

border commuter is counted each time she enters the US, and an individual is recorded in apprehension data each time he is apprehended.

NAFTA was expected to slow especially unauthorized Mexico-US migration (US Commission, 1990). The immigration issue was downplayed during the NAFTA debate in the US in order to avoid discussion of an issue that has no easy answer. The major issue debated in the US was whether there would be, in the words of Presidential candidate Ross Perot, a "giant sucking sound" as US jobs went to Mexico. Most US government statements in support of NAFTA emphasized that an important side benefit of freer trade was likely to be less illegal immigration, e.g. US Attorney General Janet Reno said: "We will not reduce the flow of illegal immigration until these immigrants can find decent jobs at decent wages in Mexico." (quoted in the San Diego Union-Tribune, November 14, 1993, 1).

Figure 1. The Migration Hump



Source: Philip Martin. 1993. Trade and Migration: NAFTA and Agriculture. Washington: Institute for International Economics.

A migration hump (Figure 1) is a temporary increase in migration between two countries that are integrating their economies by increasing trade and investment between them. Economic integration and migration can be short-run complements for many reasons. An analysis of the evolution of the factors that initiate and sustain migration in the context of the demand-pull, supply-push, and network factors linking Mexican migrants to US employers concluded that there was likely to be a significant migration hump (Martin, 1993):

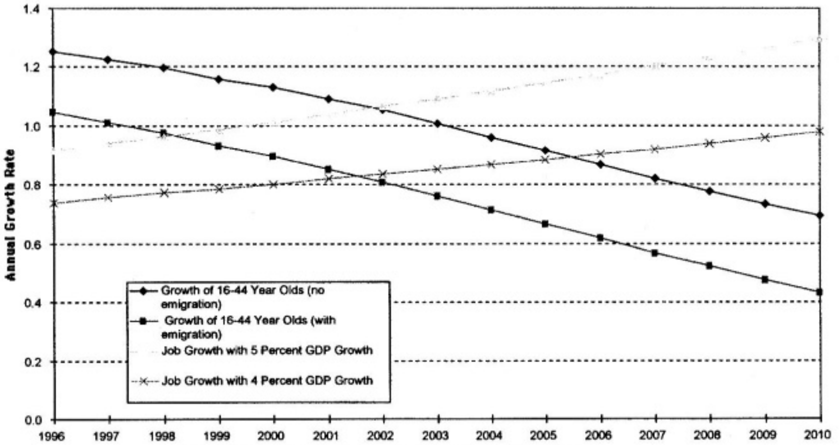
- First, economic integration does not suddenly eliminate the demand pull of jobs in the US. Instead, economic integration can increase exports of US goods produced with migrant workers, as occurred when US fruit and vegetable exports to Mexico increased after 1994.

- Second, supply-push pressures to emigrate often increase as a result of closer economic integration, as some industries and sectors prove to be non-competitive. Mexican agriculture provides a case in point. About 30 percent of Mexico's 95 million people live in rural areas, and most depend on agriculture for at least some of their income (US House of Representatives, 1993; Cornelius and Myhre, 1996; de Janvry, Sadoulet, and Anda, 1994). Rural residents in 1995 had an average per capita income that was only one-third of the $3,000 average for Mexico, and one-fifth of the $5,000 average in Mexico City. As NAFTA liberalizes agricultural trade, crop prices and rural incomes fell in the 1990s Mexico implemented a number of policies—including permitting the sale or lease of privatized ejido land and shifting to direct payments to farmers—that have the effect of loosening ties between farmers and the land.
- Third, job growth in Mexico is concentrated in the northern part of the country--over one million of Mexico's 3 million manufacturing jobs are in 3500 maquiladoras, most of which are in border cities. As Mexicans look north for opportunity, some find that their networks can take them over the border, into jobs in the US. These networks encompass everything that enables people to move across borders and earn money in another country, from expanded tourism to training programs to easier entry procedures for business visitors (Seligson and Williams, 1981; Massey, et.al, 1987; Massey, 1988).

The Binational Study on Migration (1997) emphasized that the demographic and economic factors that in the mid-1990s were producing high levels of emigration may soon ebb, so that e.g. the US border control buildup may be completed just as Mexico-US migration falls for demographic and economic reasons. Mexico in 1997 had 970,000 labor force entrants, but birth rates fell sharply in the 1980s and 1990s, so that the number of new job seekers will fall to 500,000 to 550,000 per year by 2010. Second, each 1.35 percent increment to economic growth was associated with 1 percent job growth in Mexico between 1988 and 1995 (Figure 2). If this ratio persists, then 5 percent economic growth can generate 3.7 percent job growth, or 1.1 million new jobs each year, enough to employ new job seekers and begin to reduce un- and underemployment; Mexico in the late 1990s was averaging 5 percent growth.

Figure 2

Labor Force and Job Growth in Mexico: 1996-2010



Job growth in Mexico is likely to match labor force growth by 2005-06

Border Agriculture: Imperial and San Quintin

The Mexican-American border region is not a major center of agricultural production—the major US agricultural county along the border is Imperial county, California, which produces farm commodities worth $1 billion a year. Imperial county is in the southeast corner of California, and is bordered by Mexicali, the capital of the Mexican state of Baja California to the south, the Salton sea to the north, to which drainage water from Imperial Valley farm land flows, San Diego about 120 miles to the west, and the Colorado River and the Arizona border about 50 miles to the east.

The Imperial Valley has been described as a 100 mile long below sea-level "trench" that contains about 600,000 acres of farm land irrigated by relatively low-priced--$15 per acre foot--water from the Colorado River that is brought into the Valley by the 80-mile long All-American Canal, which was built in 1934.[2] The Imperial Valley tilts south to north, so Colorado river water is delivered to Imperial farm land primarily by gravity.

The Imperial Valley was developed for agriculture in 1904, when a canal brought water from the Colorado river. There were reported to be 100,000 irrigated acres in 1904, when the Imperial Valley was anchored by Calexico on the U.S. side and Mexicali on the Mexican side. Harry Chandler, later the publisher of the Los Angeles Times, owned the Colorado River Land Company, which imported Chinese workers into Mexico to dig canals to irrigate the Mexican side of the Imperial Valley (the US barred Chinese immigration in 1882). However, a flood in 1905 diverted the entire lower Colorado River into the Imperial Valley, creating the Salton Sea. Chandler's man-made canal is today called the New River; it begins in Mexico and flows about 60 miles north through Imperial County to the Salton Sea.

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[2] As early as 1915 there were 300,000 acres of crops being grown in the Imperial Valley, irrigated by Colorado River water. The Imperial Valley gets about 3 inches of rain a year.

Imperial Valley farm land in 2000 sold for $2,000 to $5,000 an acre; at an average price of $3,000 an acre, Imperial Valley crop land worth $1.8 billion generate total farm sales of about $1 billion a year (Rural Migration News, 2001). There are three major agricultural sectors—field crops, livestock and vegetables and melons. Over half of the irrigated crop land is used to grow field crops such as alfalfa and grasses, wheat and cotton or used for pasture for beef cattle and lambs—much of the alfalfa and grasses are shipped out of the area to dairies in southern California and the San Joaquin Valley or made into pellets and exported as livestock feed. Another 100,000 to 125,000 acres of land are planted in vegetables and melons—the most valuable are lettuce and carrots. There are also important seed crop, wheat, and nursery industries in the Imperial Valley.

Water made border area agriculture possible, and rising water costs may spell the end of border agriculture. Most water along the border comes from the Colorado river in the west and the Rio Grande in the east, plus underground aquifers. In the west, some Colorado river water may be redirected from agriculture to urban uses, with farmers being paid for the water they give up. In the east, a 1944 agreement divided the Rio Grande's water between Mexico and the US--Mexico should give the United States one-third of the water flowing from its tributaries into the Rio Grande--and a minimum of 350,000 acre-feet of water each year. Mexico has not done this since 1994, and accumulated a deficit of 1.1 million acre-feet between 1994 and 2001. Both Mexican and US farmers alleged that Mexico in the 1990s was diverting Rio Grande water to Monterrey.

Imperial County was the scene of the first strike by Mexican farm workers in the US, a 1928 strike against growers who required workers to be hired through farm labor contractors (FLCs). Although no contract was signed, the strike ended with growers agreeing to stop withholding 25 percent of each worker's wages until the harvest was completed, and growers rather than FLCs became responsible for assuring that workers received their full wages (Martin, 1996, Chapter 2).

Imperial county was the scene of the largest strike called by the United Farm Workers in its efforts to raise wages and improve working conditions for farm workers. The first wave of UFW contracts under the California Agricultural Labor Relations Act expired January 1, 1979, and the UFW submitted its economic demands to growers, and published them in the Mexicali newspaper, La Voz, on January 5, 1979, demanding a 42 percent wage increase for field workers, bringing the entry wage from $3.70 to $5.25 an hour. The UFW also demanded five more paid holidays, COLA, and standby and reporting pay. On January 18, 1979 the employers offered a 7 percent one-year wage increase, and told the UFW to allocate the 7 percent between wages and benefits as the UFW saw fit--growers cited the recommendation of President Carter that wages not increase more than 7 percent to avoid inflation. (Martin, 1996, Chapter 3).

On January 19, 1979, the UFW called a strike against 8 vegetable growers in the Imperial Valley, and positioned pickets at the port of entry from Mexicali to discourage strike breakers from entering the US (most Imperial county farm workers commuted daily from Mexicali). The UFW said 4,300 workers were on strike in early February 1979, and there was a great deal of violence and property destruction, as strikers attempted to intimidate strike breakers and to flood fields by sabotaging irrigation canals. Growers hired replacement workers as well as security guards, and a UFW strikerwas killed February 10, 1979 by a foreman. Reflecting the tensions of the time, Gov. Edmund G. (Jerry) Brown Jr., a close ally of Chavez, marched in the funeral procession, while Imperial county authorities ruled that there was insufficient evidence to prosecute the foreman for the killing.

The UFW charged that the growers were not bargaining in good faith, and the Agricultural Labor Relations Board agreed, ordering them to pay workers the difference between $5.25 and the wage they received during most of 1979-81. The growers appealed, and a state Court of Appeals in 1984 agreed with the growers. The UFW never recovered from these lost vegetable contracts, and in 2001 represents only a handful of the 30,000 to 40,000 vegetable workers that were once under contract.

The San Quintin Valley in Baja California, about 200 miles south of the Mexico-US border, grows tomatoes for the US market during the winter and spring months, and illustrates the fragility of Mexican agriculture. About 40,000 people live in the area, with critics arguing that nonreplenished water is being drawn from underground aquifers to produce tomatoes that could also be grown in Sinaloa, Mexico or Florida.[3] Most of the tomatoes are picked by migrants from Oaxaca and Chiapas, more of whom are settling in the area despite the availability of only seasonal farm work (Thompson and Martin, 1989).

In the mid-1990s, there were only ten tomato growers in the San Quintin Valley, and they relied on U.S. capital and seeds to produce tomatoes and other vegetables for the U.S. and Mexican markets. Several of these ranches had 1,000 to 4,000 acres, making them large employers by Mexican or U.S. standards, with peak migrant work forces of 2,000 or more. Most of the peak 35,000 migrant workers they employ are Mixtec Indians from the southern Mexican state of Oaxaca. Baja California growers have adapted to their inability to retain the Mixtec migrants that they recruit in southern Mexico. Some report that two of three workers brought by bus to Baja California to harvest tomatoes then migrate on to the United States before the end of the harvest season, prompting the growers to "over-recruit" migrant workers (Zabin et al, 1993).

Maquiladoras and Migration

The largest industry on the Mexican side of the Mexico-US border are maquiladoras, assembly plants typically owned by foreigners that import components duty-free into Mexico, assemble them into finished electronics or other products, and export the finished goods, usually to the US and Canada.[4] As the finished goods enter the United States, the U.S. tariff schedule limits duties on them to the value that was added by Mexican assembly operations, mostly wages and benefits paid to Mexican workers, as well as any Mexican-produced inputs. These are typically less than 10 percent of the value of a TV or computer printer.

The maquiladora industry was launched by Mexico in 1965 in response to the unilateral U.S. decision to terminate the Bracero program in 1964—the hope was that maquiladoras could provide year-round employment financed by U.S. investors for Mexican workers who had become dependent on the U.S. farm labor market. Many Braceros moved their families to Mexican border cities to save US farmers transportation costs, stimulating population growth on the Mexican side of the border.

There were 12 maquiladoras employing 3,000 workers in 1965, 120 employing 20,300 workers in 1970, and almost 600 employing 120,000 workers in 1980 (Table 1). The number of maquiladoras and employment surged during the 1980s with the devaluation of the peso: between 1985 and 1990, the number of maquiladoras more than doubled from 800 to 1,900, and maquiladora employment rose from 212,000 to 472,000. Growth continued in the 1990s, so that by September 2000, there were 3,900 maquiladoras employing 1.4 million workers (www.maquilaportal.com).

[3] Mexico's export-oriented vegetable industry is centered in Sinaloa, about 600 miles south of the U.S. border. Large farms there employ about 170,000 Mexican workers for four to five months each year– most are migrants from other parts of Mexico, and seasonal work in Sinaloa ends in March-April, just as U.S. growers begin to hire farm workers. After the U.S. embargoed trade with Cuba in 1960, Sinaloa production expanded, so that by 1969 Sinaloa was providing 75 percent of the fresh tomatoes consumed in the United States during the winter months.

[4] Beginning November 20, 2000, parts assembled in maquiladoras may enter Mexico duty-free only if they originate in Canada or the US.

About 78 percent of maquiladoras are in the Mexican states bordering the US--25 percent of maquiladora employment is in Chihuahua (Juarez) and 20 percent is in Baja California (Tijuana). Maquiladora employment is expected to increase at a rate of 125,000 jobs a year.

Table 1. Maquiladora Employment and Exports: 1965-2000

Year	Maquiladoras	Employment	Exports* ($ mil)	Exports (%)**	Wages & Benefits Paid ($ mil)
1965	12	3,000			
1970	120	20,327	83	6	
1975	454	67,213	332	11	194
1980	578	119,546	772	5	456
1985	789	211,968	1,268	6	540
1990	1,924	472,000	3,635	14	
1995	2,206	674,692			
2000	3,900	1,400,000			

Source: Adapted from Hufbauer and Schott, 1992, p. 92; Huerta, 1991, p. 75
*Value-added in Mexico. For example, in 1990, the difference in value between the components imported into Mexico an value of maquiladora exports was $3.6 billion, or about 14 percent of Mexico's $26 billion merchandise exports.
**Percent of Mexico's merchandise exports.

Maquiladoras have many border-area impacts, but their primary one is that they attract residents of interior Mexico to the border, especially young women. Most maquiladoras in 2000 paid assembly-line workers—60 to 70 percent women-- $1 to $1.50 an hour, and provided benefits that cost an additional $0.50 to $1 an hour, so that total labor costs were $1.50 to $2.50 an hour. The wages and benefits paid in maquiladoras are considerably less than wages and benefits paid in other Mexican manufacturing industries. Turnover is very high—many plants have five to 10 percent turnover each month, meaning that they must hire 60 to 120 workers in the course of one year to keep a 100-person factory fully staffed.

Critics have long emphasized that maquiladoras employing mostly young women are not the basis of sustainable development. Surveys of production workers consistently show that most are young and unmarried workers in their first job—almost half were under 20 in 1988-89-- and that many migrate to the border area from elsewhere in Mexico (Table 2). One of the largest maquiladora worker surveys was conducted in 1988-89 for the U.S. Commission for the Study of International Migration and Cooperative Economic Development. Some 1200 workers were interviewed in 1988-89, and most had only an elementary school education and went to work without training.

Table 2. Mexico's Maquiladora Work Force 1988-89

Worker Characteristics	Percent		Percent
Age 15-19	45	•Moved from Urban Area	72
20-24	34	•In Area less than 4 years	51
Not Married	80	Major Reason for Migrating:	
		•Seek a Job	27
Elementary Education	80	Accompany Family	21
In First Maquiladora Job	58	•Seek a Better Life	14
No Training Received on the job	52	•Had maquila job offer before migrating	10
		•Other	28
			100

Based on a survey of 1,200 maquiladora workers conducted in December 1988–January 1989.
Source: Adapted from Huerta, 1991, pp. 80-83.

Maquiladoras have expanded away from traditional assembly-line jobs. For example, "service maquiladoras" wash hospital linen in Mexicali for US hospitals for $0.30 a pound. There are an estimated 50,000 Mexicans employed in maquiladoras that provide such services to US firms, including call centers, and their exports were worth $1 billion in 1999. Maquiladoras are partly responsible for rising Mexico-US trade: two-way Mexico-US trade (exports plus imports) increased from $80 billion in 1994 to $200 billion in 2000.

By drawing Mexicans to the border area and putting them in high-turnover jobs, it is often alleged that maquiladoras promote Mexico-US migration. The evidence on whether maquiladoras act "as a magnet for the internal migration of Mexicans to the north of the country and internationally to the United States" is mixed (Seligson and Williams, 1981, p. 9). Most of the studies are based on interviews with maquiladora workers who are leaving their jobs, and the interviewers determine the workers place of origin, satisfaction with maquiladora employment, and plans to migrate further. Such studies reach similar findings:

- During the 1980s and 1990s, more Mexicans began to migrate to the border in search of maquiladora employment, indicating that the migrant percentage of migrants in maquiladora work forces has been rising
- Few maquiladora workers had ever worked in the United States at the time they were interviewed– legally or illegally – and few expressed an interest in using their maquiladora savings to finance illegal entry into the United States.[5] Few thought that their maquiladora training would help them to obtain a United States factory job.
- However, there seems to be a small but rising amount of stepping-stone migration, perhaps attributable to the rising proportion of internal migrants and men in maquiladora work forces who do see maquiladora employment as a stepping stone to the US.

[5] Some 16 percent of the workers interviewed by Huerta wanted enter the U.S. illegally, and 41 percent indicated that, if they had legal status, they would prefer to live in the United States (Huerta, 1990, pp. 25-26).

Maquiladoras could become a trampoline that brings more Mexican workers to the United States, reinforcing environmental and infrastructure reasons to encourage job creation further from the border.

NAFTA

The North American Free Trade Agreement (NAFTA) aims to reduce barriers to trade in goods and capital flows between Canada, Mexico, and the United States, and thereby accelerate job and employment growth in all three countries. NAFTA, a 22-chapter agreement, went into effect on January 1, 1994, with virtually of its provisions will be fully effective in 2009, and it may reshape the border environment.

Mexico set the stage for converting what had primarily been a migration relationship into a trade relationship by changed its economic policies from inward-oriented to export-oriented, joining the General Agreement on Tariffs and Trade (GATT) in 1987, proposing NAFTA in 1990, and then becoming a member of the OECD (Weintraub, 1990; Lustig, 1992). Mexican President Salinas in 1991 urged quick approval of NAFTA in the early 1990s, arguing that freer trade and investment would stimulate employment and economic growth in Mexico and that "more jobs will mean higher wages in Mexico, and this in turn will mean fewer migrants to the United States and Canada. We want to export goods, not people."

There was agreement in the US that trade-stimulated economic growth was the surest path to less Mexico-US migration (Hufbauer and Schott, 1992). The U.S. Commission for the Study of International Migration and Cooperative Economic Development, for example, concluded that "<u>expanded trade</u> between the sending countries and the United States <u>is the single most important remedy"</u> for unauthorized Mexico-to-U.S. migration (1990, p. xv, emphasis added).

Many US economists agreed that freer North American trade would speed job growth in Mexico and have small but positive effects on the US economy, which was 20 times larger than the Mexican economy in the early 1990s. However, once Mexico proposed NAFTA, the major opposition proved to be in the US; Presidential candidate Ross Perot predicted that there would be a "giant sucking sound" as US jobs went to Mexico, and the agreement was approved in the US House of Representatives on a close 234-200 vote in November 1993.

Mexico-US trade has increased under NAFTA, by an average 16 percent a year between 1994 and 2000. Mexican exports to the US rose from $61 billion in 1994 to $168 billion in 2000, and Mexican imports from the US rose from $79 billion in 1994 to $176 billion in 2000. This increase in trade five years after NAFTA went into effect is far larger than increases in trade when e.g. Greece or Portugal joined the EU. About half of Mexico-US trade is intra-industry trade, as e.g. auto parts are sent to Mexico, and cars are returned to the US.

NAFTA does not deal explicitly with Mexico-US migration. Only Chapter 16 of the NAFTA agreement deals with migration, and it deals with business visitors, traders and investors, infra-company transfers, and professionals, generally persons with at least a first university degree. Professionals who are citizens of Canada, Mexico, and the US may accept job offers in another member country, and simply present proof of citizenship and the job offer at the border to receive a work permit. There is no limit on the number of Canadians who can enter the US as NAFTA professionals, but there is a limit of 5,500 Mexicans until January 1, 2004. In 1998, there were 59,000 NAFTA pr ofessionals admitted to the US, and they brought with them 18,000 dependents.

Conclusions

For most of the 20th century, the major linkage between the two most populous countries in North America has been the migration of people from Mexico to the United States. “Go north for opportunity” is an idea deeply embedded in rural Mexican youth, especially in rural areas.

Many Mexicans stayed in the border area, fueling a growth that has made it one of the fastest growing areas of North America. Both the US and Mexico are responsible for making the border area one of the fastest growing areas of their integrating economies and societies, and dealing with the demographic, economic, and environmental challenges of large population centers in a desert environment.

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PART III

BORDER WATER

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Financing Bilateral Water Projects on the U.S.–Mexico Border: Past, Present and Future

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INTRODUCTION

Over 10 million people live within 100 km of the U.S.– Mexico border. Of these, 90 percent are clustered in 14 pairs of border sister cities that share common water sources and pollution problems. Rapid industrial and population growth in border cities continues to outstrip their environmental infrastructure that supplies water, collects and treats wastewater and disposes of municipal solid waste and industrial hazardous wastes. Thousands of residents on both sides of the border lack access to safe drinking water, wastewater collection and treatment and solid waste disposal services. Untreated wastewater is a major transboundary externality, as raw or partially treated sewage flows into drinking water sources on both sides of the border.

The United States and Mexico have a long-standing history of institutions devoted to bilateral water resource negotiation and management. The International Border and Water Commission (IBWC), which has pre-eminent authority over U.S.–Mexico border water issues, was established by treaty in 1944. The IBWC initially focused on surface water management, but with rapid growth along the border, its attention has shifted increasingly to water pollution. While the United States and Mexico have reached numerous agreements to build, finance and operate water projects, these agreements have been reactive to immediate health emergencies, limited in scope, and have failed to address market failures that contributed to the environmental problems in the first place.

Binational planning of water projects and transboundary pollution control along the border is complicated by large income differences between the two countries. U.S. GDP per capita is nine times Mexico's. The disparity in economic development leads to disparities in the two countries' willingness and abilities to fund water treatment projects, supply public infrastructure, collect hydrologic data, and monitor pollution. San Diego's per capital municipal budget is 27 times that of its border sister city Tijuana. Cultural and institutional differences have also hampered cooperation (Herzog; Ganster; Varady et al., 1995; Hinojosa-Ojeda).

In 1983, the United States and Mexico signed the Agreement on Cooperation for the Protection and Improvement of the Environment in the Border Area (the La Paz Agreement). Its goal was to institutionalize bilateral cooperation to address water pollution, air pollution and other environmental problems in the U.S.–Mexico Border Region, which The La Paz Agreement formally defines as the area lying 100 kilometers to the north and south of the border. In 1994, in response to border environmental concerns raised during NAFTA negotiations, the two nations established the Border Environmental Cooperation Commission (BECC) and the North American Development Bank (NADBank). The NADBank arranges public and private financing of environmental infrastructure projects within the 100-km border zone that must be certified by

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[1] The views expressed are the authors' and not necessarily those of the Economic Research Service, USDA.

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the BECC. The BECC determines project eligibility based on environmental, technical and financial criteria. Its priorities include water, wastewater, and municipal solid waste projects. In addition to extending loans, NADBank administers the EPA-funded Border Environmental Infrastructure Fund (BEIF), which provides grants for border water and wastewater projects.

The NADBank, BECC and other institutions offered the promise of greater external financial and technical assistance to help border cities address water management problems. Despite early growing pains, these new institutions have helped both nations plan, build, and finance new facilities in a more coordinated, open, participatory and proactive manner. NADBank's goal of developing locally self-financing municipal water systems on both sides of the border has remained elusive, however. Less than 5 percent of project funds approved by NADBank have been loans, while over 95 percent have been BEIF grants.

A recent report of the U.S. General Accounting Office (GAO) on border environmental infrastructure concluded that many border communities could not afford the loan rates charged by NADBank and that existing programs would not meet the needs of the growing border population. The GAO report also questioned the political sustainability of heavy reliance on grants from the U.S. EPA and other U.S. federal agencies as primary means of financing projects. The report recommended that U.S. and Mexican agencies jointly develop a Border Infrastructure Strategic Plan that would include a needs assessment, strategies to address constraints on infrastructure development and a statement of measurable goals. The report also suggested that the U.S. Congress might consider altering the NADBank charter to allow for provision of lower cost loans. Recently the NADBank has proposed expansion of its loan activities to cover a wider range of projects and to cover a wider geographic area.

Aims and Scope of Chapter

This chapter considers the "impediments to border infrastructure development" discussed in the GAO report from a broader historical, economic and hydrological perspective. The main impediments discussed in the report – lack of human capital, unaffordable project loans and lack of comprehensive planning – are more appropriately viewed as *symptoms* of more fundamental economic problems. Binational negotiations over border water infrastructure projects have historically separated water quality issues from surface and groundwater allocation and management issues. This, despite the facts that water quantity and quality are inextricably linked and that watersheds and aquifers stretch across political boundaries. Policy remedies continue to take the form of structural, engineering solutions to border water problems. Underlying economic problems – lack of policy instruments to induce firms to internalize environmental externalities, rapid growth, coupled with persistent poverty and stagnant real wages – appear to be taken as given. Needs assessments or strategic plans that ignore transboundary water *quantity* issues (both surface and groundwater) or fail to address poverty alleviation along the border will fail to address fundamental causes of recurrent environmental problems.

The chapter proceeds with a broad overview of the population, water resources and water policy issues along the U.S.–Mexico border. It then describes the evolution of U.S.–Mexico transboundary water management institutions and agreements. Next, we examine more fundamental economic incentive problems that are at the heart of transboundary water pollution problems. We then discuss the structure and performance of new border environmental institutions created in the wake of NAFTA. We conclude by discussing future prospects for binational financing of border water projects.

U.S.-Mexico Border Population

The growth of large metropolitan areas along the borders of nation-states is a relatively recent historical development (Herzog). Since the end of the Second World War, however, large international border cities have grown in Western Europe and along the U.S.–Mexico border. Both the United States and Mexico have pursued policies encouraging growth along the border. In response to a wartime shortage of agricultural labor, the United States instituted the *bracero* program in 1942, a guest worker program allowing Mexican nationals into the United States for seasonal employment. The bracero program continued into the 1960s, stimulating migration to Mexican border cities (Brown and Mumme).

In 1965, Mexico established the Border Industrialization Program that increased infrastructure investment along the border and established the maquiladora program. The maquiladora program allowed firms located in Mexico to import production inputs duty-free to assemble or manufacture goods for re-export. Tariffs on these goods are only applied to the value-added from assembly. In the early stages of the program, maquiladoras could be located only within 12 miles of the border and in the Baja California free trade zone. Maquiladoras offer U.S. (and other foreign) firms access to low-cost Mexican labor. Critics have also argued that they allow U.S. firms to avoid environmental regulations and taxes to support local infrastructure (e.g., Johnstone). The program did not expand border production significantly until the 1980s when Mexico's peso devaluation reduced effective wages. The peso devaluation in 1994 further reduced average wages (from $1.23 in 1994 to $0.78 in 1996). The number of maquiladoras grew from fewer than 100 plants in the 1960s to over 2,000 today. About 60 percent of them are located in the border region. Maquiladora exports have grown 15 percent a year in the 1990s. Employment grew by 65 percent between 1990 and 1996. The maquiladora sector employs over 700,000 workers and accounts for 40 percent of Mexico's exports.

Since 1945, the border population has grown twelvefold. Tijuana illustrates the explosiveness of this growth. Its population grew from 1,000 in 1920 to 462,000 in 1980, to more than a million today. In 1980, about 4 million people lived within 100 km of the U.S.-Mexico Border. By 1990, the population exceeded 9 million with over 90 percent of the border population clustered in 14 pairs of sister cities. About 83 percent of the border population lived within ten border twin cities (Table 1). More than half lived in San Diego/Tijuana and El Paso/Ciudad Juarez alone. The border population grew to 10.5 million by 1997 and is projected to double over the next 20 years.

Despite the great disparity in income between the two countries (U.S. GDP per capita is nine times Mexico's), the U.S. and Mexican economies have the highest level of economic integration between a developed and developing country. This includes the largest trade relation and debtor-creditor relation between a developed and developing country, the most extensive in-bond co-production relations (maquiladoras), and the highest level of border crossings (Hinojosa-Ojeda).

Table 1. Population in Major U.S. - Mexico Border Cities

City (US – Mexico)	1990 population (millions)	Percent of total border population	Cumulative percent of border population
San Diego [a] – Tijuana	3.20	34.8	34.8
El Paso [a] – Ciudad Juarez	1.87	20.3	55.1
McAllen [a] – Reynosa	0.65	7.1	62.2
Calexico – Mexicali	0.62	6.7	68.9
Brownsville [a] – Matamoros	0.53	5.8	74.7
Laredo – Nuevo Laredo	0.34	3.7	78.4
Yuma [b] – San Luis Rio Colorado	0.18	1.9	80.3
Nogales – Nogales	0.12	1.3	81.6
Del Rio – Ciudad Acuna	0.08	0.9	82.5
Douglas – Aqua Prieta	0.05	0.5	83.0
Total Border Region	9.20	100	

Sources: U.S. 1990 Census Data; U.S. EPA U.S. Mexico Border Environmental Plan; Public Advisory Committee; Instituto Nacional de Estadistica, Geografia e Informatica.
a. SMSA
b. Includes San Luis and Somerton, AZ

Many of the disparities between countries are less pronounced in the border region [EPA, 1999 Appendix 8 US Mexico Border XXI]. Population growth in the border region is much faster than population growth in either country. Birth and poverty rates in the Mexican border region are lower than the Mexican national average. Birth and poverty rates in the U.S. border region are higher than the U.S. average. Education levels in Mexican Border States are above the national average, while education levels in most U.S. border counties fall below the national average.

BORDER WATER ISSUES

Disputes over surface water quantity have been muted over the last 50 years (Szekely, 1993a; 1993b). Transboundary water disputes have been primarily over water quality. Historically, water quality problems have been bi-directional (e.g., salinity of Colorado River water flowing to Mexico, sewage from Tijuana affecting San Diego). Bilateral negotiations over rules of use of transboundary aquifers have yet to begin. Groundwater management is becoming a growing source of disputes exemplified by the controversy over the lining of the All-American Canal in California and its impact on Mexican groundwater resources.

Surface Water Allocations

The two main surface water sources serving the border region are the Colorado River, which flows south from the United States into Baja California and the Rio Grande River, which forms the physical border between Texas and Mexico. Surface water rights in both river basins were established under the International Boundary Waters Treaty of 1944. Mexico successfully linked negotiations over allocation of Colorado River water, where it was the downstream country, with negotiations over allocation in the Lower Rio Grande Basin, where it was the upstream (Ragland, 1995; Bennett et al., 1998).

Other surface water sources include: (a) the Tijuana and New Rivers, draining from Baja California into California, (b) the Rio Sonoyta, which originates in the Tohono O'odham Indian Reservation in Arizona, flows into Mexico, then back into Organ Pipe Cactus National Monument in Arizona, (c) the San Pedro River, flowing from Mexico into the San Pedro Riparian National Conservation Area in Arizona, and (d) the Santa Cruz River, which flows from Arizona into Mexico, then north into the twin cities of Nogales, Sonora and Nogales, Arizona. Domestic political opposition in the United States has prevented the two nations from agreeing on apportionment of these streams (Mumme, 1984; Mumme, 1993; Ingram and White). Each country has acted unilaterally to capture streamflow in these watersheds.

Transboundary Groundwater Issues

There are three major transboundary aquifers in the Border Region. The Hueco Bolson extends 3,000 square miles across the El Paso–Ciudad Juarez region. The Mesilla Bolson extends 7,450 square miles across New Mexico and Chihuahua. The Mesa San Luis aquifer extends 3,000 miles across the Arizona/California–Sonora/Baja California region (Szekely, 1993a). Smaller aquifers underlying the Santa Cruz and Sonoyta rivers are important local water sources in Arizona. Many smaller aquifers also exist in Texas, while many small water utilities rely on shallow wells in the Rio Grande / Rio Bravo watershed. These aquifers are directly affected by the quantity and quality of water flows in the Rio Grande / Rio Bravo.

Groundwater has been treated as a common pool resource. Absent transboundary controls, both countries have adopted a "use it or lose it" approach to groundwater leading to groundwater pumping wars (Mumme, 1993; Kishel). Irrigated cotton farming in the Sonoyta River basin in Mexico has contributed to groundwater overdrafting of 55,000 acre-feet / year. Managers of the Organ Pipe National Monument in Arizona have been concerned about the effects of this draw down on endangered species that inhabit desert springs there (Varady et al., 1995).

Population growth in El Paso–Ciudad Juarez and Ambos Nogales has placed great pressure on local groundwater resources (Ingram and White; Kishel; Hayes; Liverman et al.).[2] In Ambos Nogales, the falling water table in the 1980s left Nogales, Sonora residents vulnerable to water shortages in drought years (Ingram and White). Additional water is now piped in from groundwater wells 20 miles south of the city. The population of Ambos Nogales is projected to surpass 400,000 by 2015. Proposals to more than double groundwater pumping on the Mexican side of the Santa Cruz basin could seriously limit water availability in Nogales Arizona and threaten riparian areas to the north (Liverman et al.). The water table of the Hueco Bolson serving El Paso and Ciudad Juarez has been falling from increased urban use and heavy use for irrigated agriculture. This has affected both the quantity and salinity of the water, as there is less water to dilute salts. Samples from some Mexican wells found TDS to be at levels usually considered unfit for human consumption with some wells having water so saline as to be classified as "brackish" (Hayes).

The United States and Mexico did jointly exercise restraint in groundwater pumping in one case. In 1972, both sides averted a groundwater pumping war by limiting groundwater pumping within five miles of the border in the Yuma, Arizona – San Luis Rio Colorado, Sonora area (Kishel, 1993). There, growth of agriculture on both sides of the border was leading to groundwater overdrafting. Despite this one instance of cooperation, there has been virtually no

[2] Ambos Nogales refers jointly to Nogales, Arizona and Sonora. “Ambos” is Spanish for “both” or “both together.”

formal bilateral negotiation to establish rules for groundwater use (Szekely, 1993a, 1993b; Mumme, 1993).

The controversy of the lining of the All-America Canal in California signals the beginning of a new era of U.S.–Mexico disputes over transboundary groundwater resources. The 80-mile canal diverts 3.5 MAF of water from the Colorado River to supply farmers in California's Imperial Valley. Because the canal is unlined and built on sandy desert soils, 0.2 MAF of the diverted water seeps into ground every year. The United States is planning to line a 23-mile stretch of the canal to reduce seepage losses by about 70,000 acre-feet per year. Under the plan, California would reduce the amount of water it draws from the Colorado River. It is currently using more than its allotment of water from the Colorado. The Metropolitan Water District of Southern California would pay for the lining of the canal. The conserved water would be transferred from the Imperial Valley to urban water users in San Diego County.

The reduction in seepage, however, would reduce aquifer recharge, affecting the quantity and quality of groundwater available to Mexican farmers. The canal seepage recharges the Mesa San Luis aquifer that supplies groundwater to the Mexicali Valley. Water users there pump 0.5 to 0.75 MAF of groundwater annually for irrigation (Kishel). About 60 percent of Mexicali Valley farmers rely exclusively on groundwater for irrigation and another 20 percent use groundwater to supplement Colorado River water (La Rue). Although the seepage only supplies about 10 percent of the annual recharge, canal water is less saline than the water in the aquifer. The reduced recharge would reduce the quantity and increase the salinity of the groundwater available to Mexican farmers.[3]

Water Quality Issues

Historically, water quality problems have been bi-directional. The major issues have been the salinity of Colorado River water flowing into Mexico and wastewater flowing from Mexican cities into ground and surface waters in the United States.

Colorado River Salinity

The 1944 Treaty determining surface water allocations between the United States and Mexico allocated 1.5 MAF of Colorado River to Mexico annually. The treaty did not, however, explicitly address the quality of water Mexico would receive. Increased U.S. diversions of water for irrigated agriculture and urban development raised the salinity of the water flowing to Mexico (Kishel, 1993). The level of total dissolved solids (TDS) rose from 800 to 1,500 parts per million (ppm) between 1960 and 1962. Kishel (1993, p. 707) notes that water "with TDS greater than about 1,000 is generally considered unfit for irrigation purposes."

Throughout the 1960s and early 1970's, the salinity issue was the most contentious U.S.–Mexico waters dispute (Mumme, 1993). Initially, the United States' position was that the letter of the law of the Treaty was being followed. Mexico countered that delivery of the agreed *quantity* of water with such seriously impaired *quality* was a violation of the Treaty's intent. The dispute impeded negotiations on a whole series of bilateral negotiations.

In 1973, both sides reached an agreement on a minimum salinity standard for Mexico's allocation of Colorado River water, the Permanent and Definitive Solution to the International Problem of the Salinity of the Colorado River (IBWC, Minute 242). The TDS of water delivered

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[3] For an excellent review and summary of transboundary groundwater issues on the U.S.-Mexico border, see the special issue of *Natural Resources Journal,* vol. 40, Spring, 2000. This special issue contains papers presented at the 1999 Binational Conference on Groundwater Management.

to Mexico under the treaty is to be within 115 ppm of the TDS of water at Imperial Dam in the United States. In 1992, a desalinization plant began operation in Yuma, California reducing TDS to 800 ppm.

This agreement may prove less "permanent and definitive" than originally planned. While the agreement may resolve the issue of the relative salinity of water used by the United States and Mexico, it does not directly address problems of basin-wide increases in absolute salinity (Mumme, 1993). Further, effluent from the desalinization plant flows into Mexico's Santa Clara *cienega* (marsh), substantially raising its salinity (Varady et al., 1995).

Wastewater Collection and Treatment in Border Cities

From a public health perspective, the most serious water quality problem in the border region is lack of access to safe drinking water and lack of sewage treatment. Of 16.1 million people residing in Mexican border municipalities and U.S. border counties, 12 percent do not have direct access to potable water, 18 percent of the Mexican population and 3 percent of the U.S. population (Table 2). Thirty percent lack access to wastewater treatment facilities, 33 percent of the Mexican population and 27 percent of the U.S. population. Ciudad Juarez, adjacent to El Paso, Texas, has a population of over one million and its first wastewater treatment plant is only now nearing completion. Another 25 percent of Mexico's border municipalities lacked solid waste disposal facilities. In 1997, only 69 percent of the Mexican border population lived in residences connected to sewage collection systems and only 34 percent of the collected wastewater were treated.

Table 2. Lack of Access to Environmental Infrastructure on the Border

	Population (millions)	Population lacking services (millions)	Percent lacking services
Mexico border municipalities	9.6		
Potable water		1.72	18
Wastewater treatment		3.17	33
Solid waste disposal		4.04	42
U.S. border counties	6.5		
Potable water		0.21	3
Wastewater treatment		1.72	27
Solid waste disposal		N/A	N/A
Total	16.1		
Potable water		1.93	12
Wastewater treatment		4.89	30
Solid waste disposal		>4.04	>25

Source: U.S. General Accounting Office, 2000. Figures for 1999.

As table 2 shows, problems are not confined to the Mexican side of the border. U.S. problems are most acute in *colonias* – low income, unincorporated subdivisions lacking basic public services (Texas A&M University). Over 400,000 people live in colonias, primarily in Texas and New Mexico. A study of colonias residents in Texas estimated that half of the state's *colonia* population of 350,000 did not have direct access to potable water (Texas A&M University).

Untreated wastewater is a major transboundary externality, as polluted water flows, in many instances, northward from Mexican to American cities.[4] Raw or partially treated wastewater flows into drinking water sources on both sides of the border. In 1980, less than 57 percent of Tijuana households had water piped into their homes, 15 percent had access to a communal tap, and 27 percent had no direct access to piped water (Herzog). Tijuana's population has more than doubled since 1980, but investment in water infrastructure has not kept pace with this rapid growth. Over 10 million gallons per day (mgd) of untreated domestic sewage from colonias, combined with industrial waste and leakage from collector systems flow into the Tijuana River, then north into San Diego and its coastal estuary (Johnstone; IBWC, Minute 283). Another 13 mgd of Tijuana's sewage is piped to the San Diego treatment plant. Treated and untreated sewage flows into the ocean have led to frequent beach closures in San Diego and Ganster notes "the ocean from Imperial Beach to Rosarita Beach in Mexico is simply unsafe for human contact." Problems are exacerbated by the fact that San Diego's own sewage treatment system needs upgrading. The city, through federal legislation, has obtained a waiver from Clean Water Act Standards based on the argument that sewage treated at a lesser standard than required by the CWA can still be safely discharged into the ocean.

The New River is a drainage canal that flows north from the Mexicali Valley, through the cities of Mexicali and Calexico, through the Imperial Valley, and empties into the Salton Sea. Along the way, the New River becomes contaminated with raw and partially treated sewage from Mexicali, heavy metals and other industrial wastes and agricultural chemicals. The New River has received the dubious distinction of being one of the most polluted rivers in the United States (Kishel; Johnstone; Ganster). Samples taken by the California Regional Water Quality Control Board since 1994 have found consistently high levels of fecal coliform, from 130,00 colony forming units per 100 milliliters (130,000 CFU / 100 ml) up to 2.2 *million* CFU / 100 ml (Hayes, 1996). Hepatitis, polio, cholera, and typhoid have been identified in its waters (U.S. - Mexico Chamber of Commerce, 1999).

The Nogales Wash, a tributary of the Santa Cruz River, flows through the center of Nogales, Sonora and Nogales, Arizona. The Santa Cruz River feeds the aquifer that is the primary water source for both cities. On the Mexican side of the border, rapid industrial and population growth have outpaced development of the city's infrastructure (Ingram and White; Varady et al., 1995). Thousands of residents live without sewer connections or garbage removal services. The Nogales area has hilly terrain and receives half of its rains during the July-August monsoon. During heavy rains, raw sewage flows into the Nogales Wash through the center of Ambos Nogales and through neighborhoods on both sides of the border (Ingram and White; Varady et al., 1995). In the summer of 1990, flooding and broken sewer lines led to fecal coliform levels ranging from (8,000 CFU / 100 ml) up to 1.6 *million* CFU / 100 ml. The maximum allowed by state standards is 4,000 CFU / 100 ml. Other contaminants such as giardia, cryptosporidium, parasites, petroleum and heavy metals have also been detected in the Wash (Varady and Mack). These contaminants have also shown up in the groundwater of the underlying Santa Cruz Basin aquifer, the primary source of drinking water in the area. All but one of the public water systems serving Santa Cruz County, Arizona are either classified as "small" (serving 1,000 – 3,300 persons) or "very small" (serving fewer than 1,000 persons) (Sprouse et al., 1996). The rapid growth of population and pollution just south of the border has stressed these small systems' abilities to meet requirements of the Safe Drinking Water Act. Seven of the water systems have been found in non-compliance with the SDWA because of

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[4] Johnstone notes, however, that Las Cruces, New Mexico dumped raw sewage into the Rio Grande River up until the late 1980s.

bacterial contamination and one system was found in non-compliance because of nitrate contamination (Sprouse et al.).

More examples abound. Overflow from Mexican sewage ponds in Naco, Sonora has threatened drinking water supplies in Naco and Bisbee, Arizona (IBWC, 1987; Mumme, 1993). The city of Nuevo Laredo deposits 24 mgd of raw sewage into the Rio Grande. While water samples taken upstream of the city have concentrations on the order of 200 fecal bacteria per 100 mls of water, below the city, concentrations have reached 22,000 (Johnstone). The point is that lack of wastewater collection and treatment infrastructure is a pervasive problem throughout the border region.

Industrial Wastes

Rapid industrialization along the border has outpaced growth in environmental infrastructure. One study commissioned by the U.S. – Mexico Business Committee estimated that $6.5 billion is needed for water, wastewater, and hazardous waste infrastructure over the next 10 years. A number of studies have identified *maquiladoras* as a major source of hazardous wastes (Udall Center; Johnston; Hinojosa-Ojeda). In 1994, over 80,000 tons per day of waste were generated in Mexico, with the border zone accounting for over 5,000 tons per day. Of these 80,000 tons per day, over 80 percent were improperly dumped or discharged into water bodies (EPA, Appendix 4). Mexican law requires that hazardous wastes produced by maquiladoras must be either treated in Mexico or returned to the country of origin (primarily the United States). According to Hinojosa-Ojeda, 85 percent of the hazardous wastes produced in Baja California are neither shipped to the United States nor treated in Mexico. Ganster points out, however, that:

> "While maquiladoras are often singled out by critics as responsible for significant pollution, there is a notable lack of reliable data and studies to support this assertions. For example, a limited analysis of hazardous waste in Mexicali maquiladoras carried out recently by EPA failed to turn up significant polluting by these companies."

About one in four maquiladoras are engaged in textile production, which is not a pollution intensive sector, while one in five is engaged in electronics production which is pollution intensive. EPA's Haztracks system records shipments of hazardous materials from firms in Mexico to disposal sites in the United States. In 1997, 11,057 tons of hazardous waste (regulated under the Resources Conservation Recovery Act) were shipped from Mexico to U.S. disposal sites. Shipments from Tijuana and Ciudad Juarez accounted for 36 and 12 percent of this tonnage. One firm, Samsung Display Mexicana, accounted for 22 percent. While these figures give an indication of sources of hazardous waste production, they only measure the quantity of materials disposed of at approved sites. They do not measure the extent of illegal dumping of waste materials that make their way into water supplies. Illegal dumping is not confined to Mexican-based firms. There have been a number of instances where hazardous materials have been smuggled to Mexico and dumped (Johnstone; Ganster). Johnstone notes with irony that these materials may find their way back into U.S. water supplies via transboundary aquifers. Ganster also points out that Mexican domestic industries in Baja California produce significant pollution and that, "Only a portion of this waste is disposed of properly; the rest is discarded into the sewer systems, solid waste dumps or simply dumped on the ground in canyons or other areas."

Whatever the source, inorganic pollutants are making their way into U.S. water bodies. In water sampling of the New River, 13 of the 16 volatile organic compounds used by the electronics sector were detected in water samples (Johnstone). In Nogales, Arizona groundwater samples have found levels of VOCs in excess of current Safe Drinking Water Act Standards (Hayes). Following heavy rains in 1990, VOC levels were found to be so high that the county government declared a health emergency (Sprouse et al.). In 1994, 2,000 residents had to be evacuated from the downtown because the dumping of petroleum products into the Nogales Wash produced potentially explosive fumes (Varady et al., 1995). Copper mining and smelting in Cananea, Sonora has led to the pollution of the San Pedro River affecting agriculture and wildlife downstream in Arizona (Johnstone; Varady et al. 1995). Contaminants associated with mining operations include arsenic, cadmium, copper and zinc. In 1989, the U.S. government established the San Pedro Riparian National Conservation Area a few miles north of the border. Since a major spill in 1979, environmental management of the mine has improved and a diversionary canal was built to reduce pollution of the San Pedro.

TRANSBOUNDARY WATER MANAGEMENT INSTITUTIONS

The IB WC

The Treaty on Utilization of Waters of the Colorado and Tijuana and of the Rio Grande, signed in 1944, established the International Boundary and Water Commission (IBWC) in its current form. The IBWC superceded and extended the powers of the International Boundary Commission (IBC), itself established by treaty in 1889.[5] The IBWC is made up of a U.S. and a Mexican Section. Each section is responsible to its own national governments and the 1944 Treaty requires that the commissioner for each section be a licensed engineer.

The jurisdiction of the IBWC is specific and narrow. Its authority extends only to water management issues that are fundamentally binational. The commission and its sections are responsible for:

> "boundary demarcation, channel rectification, construction and maintenance of flood control, water storage, hydroelectric and drainage works, construction and maintenance of sanitation and sewage facilities, scheduling water deliveries under treaty, stream gauging, and the diversion of waters for domestic functions (Mumme, 1991, p 95)."

Aside from these functions, the Commission may conduct investigations and project planning studies. It also has authority to adjudicate differences in interpretation of the 1944 Treaty subject to approval of the two governments. The 1944 Treaty itself precisely defines allocations and use priorities. The IBWC is also authorized to address water sanitation problems, through projects mutually agreed upon by the two nations. These agreements are called "Minutes" of the IBWC. The Commission is primarily a technical agency, focusing on scientific appraisals and engineering solutions to water management problems. In this respect it is similar to the Army Corps of Engineers and like the Corps it has cultivated close relations with congressional delegations and maintained a certain degree of autonomy from the Executive Branch (Ingram and White). Although the Commission's jurisdiction is limited in scope, its authority within that jurisdiction is significant. On issues of U.S.–Mexico border water management, the Commission's authority supercedes the claims of other domestic agencies.

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[5] There is an extensive literature on the history of U.S.–Mexico water commissions. See Mumme (1991; 1993) for references.

Any attempts to alter the jurisdiction or authority of the Commission would require a new treaty approved by both governments.

The IBWC has received considerable praise for its ability to find diplomatic, cooperative solutions to border water problems and for its sheer longevity as a bilateral negotiation and planning institution (Mumme, 1993; Szekely, 1993a). Indeed, the Commission has been the only permanent institution, conducting bilateral negotiations and planning of any kind, between the United States and Mexico.

The Commission earned its reputation for effectiveness from its success in transboundary surface water management. Demographic and institutional change have forced the Commission to address a wider array of water management problems in an increasingly complex institutional setting. Since, the Commission's creation in 1945, the population of the border region has increased twelve fold, placing severe stress on the region's water sanitation infrastructure. Consequently the Commission's attention has been drawn toward water quality problems. In the 1960s and early 1970s, the Colorado River salinity problem was the chief concern. Since then, the Commission has had to react to the numerous water pollution problems of border cities. Increased competition for groundwater has become an increasingly important and contentious issue. Minute 242, signed in 1973, gave the Commission authority to regulate groundwater in the Lower Colorado Basin around Yuma-San Luis and to begin discussions toward a bilateral agreement on transboundary groundwater management. The Commission, however, has yet to initiate broad negotiations over groundwater (Mumme, 1993; Szekely, 1993a, 1993b). The creation of the EPA, along with passage of the National Environmental Policy Act, Endangered Species Act, Clean Water Act, Safe Drinking Water Act, and other environmental legislation, has greatly increased the number of factors the Commission must consider and federal and state environmental agencies it must interact with. The EPA has also become an important source of funds for IBWC approved projects.

More recently, the Commission has drawn criticism from academics and environmental groups (for examples and additional citations, see Mumme 1992, 1993; Ingram and White; Szekely, 1992, 1993a, 1993b; Varady et al., 1996; Sprouse and Mumme). Four related criticisms are common in the literature. First, critics have complained that the Commission has been slow in addressing water quality problems and groundwater management issues. Second, ambiguities in its mandate regarding water quality have hampered state and federal environmental agencies' abilities to regulate water pollution. Third, it has focused too narrowly on structural, engineering solutions to immediate crises, without addressing underlying causes of problems or anticipating future problems. Fourth, its decision-making framework insulates it from public participation and comment.

Part of this criticism arises because the Commission's structure and decision-making system differs considerably from other domestic natural resource management agencies regarding requirements for public participation and *ex ante* review of its decisions. The 1944 Water Treaty does not require the Commission to hold public meetings or invite public comment. The degree to which the Commission seeks public input is at the Commission's discretion. This greatly contrasts with other U.S. resource management agencies with multiple public hearings and 45-day comment periods.[6] Because of the diplomatic aspect of negotiations between the U.S. and Mexican sections, the Commission has gained a reputation for being secretive, to the frustration of environmental groups (Mumme, 1992). The binational structure of

[6] In contrast, the International Joint Commission, the IBWC's U.S.-Canada counterpart, is explicitly required to hold public meetings by the 1909 Boundary Treaty.

the Commission is another significant difference from other natural resource and environmental agencies. Mexico is a sovereign nation, so solutions to environmental problems must take the form of Coasian bargaining rather than regulatory enforcement.

The shift from praise to criticism of the Commission in the literature coincides with management of water quality and groundwater supplanting surface water management as the major border water issue. One reason for the Commission's success in gaining both binational acceptance and appropriations for projects has been its rather cautious approach to expanding its activities into new areas. A second reason is that the Commission has functioned as technical agency providing recommendations for structural, engineering solutions to specific problems, rather than a policy or regulatory agency. Structural, engineering issues tend to be less important in groundwater management than pricing policies or use rationing.[7] In the area of border sanitation, the Commission has focused primarily on developing immediate engineering solutions in response to potential health crises. Many of the fundamental causes of these crises have to do with market failures that have allowed industrialization and population growth to proceed without consideration of the full social costs of that growth. These problems involve broader issues of local public finance and land use planning. It should not be surprising that an agency whose expertise is in hydraulic engineering and whose focus is providing technical recommendations has not moved into these areas.

The ambiguity in the Commission's mandate regarding water quality management has also been frustrating for environmental groups and state environmental agencies (Mumme, 1992). For example, hazardous waste affects water quality, yet it is not strictly speaking a "sewage" or "sanitation" issue. This leaves open the question of whether the Commission can address this issue or whether it is the purview of EPA or state environmental agencies. This ambiguity has left a vacuum where no single agency necessarily has the responsibility of authority to act.

La Paz Agreement / Border XXI Program

The United States and Mexico signed the Agreement on Cooperation for the Protection and Improvement of the Environment in the Border Area, known as the La Paz Agreement, in 1983. The agreement established a framework for government agencies of both countries to formally discuss border environmental issues, share data and information and coordinate activities to reduce pollution in the border area (defined as the area within 100 km of the border).

The agreement established the EPA and Mexico’s Secretaria de Desarrollo Urbano y Ecologia as National Coordinators to coordinate and monitor implementation of the agreement and any future subsidiary agreements (referred to as Annexes). Five such Annexes have been agreed upon to develop specific plans to address border sanitation in San Diego – Tijuana, hazardous waste spills, transboundary shipments of toxic wastes, urban air pollution in El Paso - Ciudad Juarez, and air pollution from copper smelting. The national coordinating agencies oversee workgroups on environmental issues: air, water, hazardous and solid waste, environmental health, natural resources, emergency response to hazardous releases, pollution prevention, and enforcement and compliance. The agreement also formally calls for meetings at least once a year and coordination with state government agencies. The Border XXI Program has been constituted as an interagency group to coordinate and report the activities of the nine workgroups.

[7] The lining of the All-American Canal is an important exception.

Despite its more participatory structure and more diverse focus, the Border XXI Program has received its share of criticism from environmental groups (Mumme, 1992 summarizes these). Much of this criticism centers on the program's lack of enforcement authority. The IBWC addresses a limited range of water resource issues, but is able to achieve binding commitments from each country. In contrast, the La Paz Agreement / Border XXI Program addresses a wide array of environmental issues, but is not set up institutionally to make or enforce such binding commitments. First, the La Paz Agreement is not a formal treaty, but an Executive Agreement. There is no formal arbitration or enforcement mechanism to implement goals set forth in its Annexes. Second, the national coordinating agencies do not have administrative authority or budgetary control over many of the activities they oversee. Activities are spread over several state and federal agencies of both countries, with no one agency strictly accountable of the program's performance. This decentralized system is likely a blessing for the program's research and information sharing functions. More data and research is sorely needed on border environmental problems. While the Border XXI program itself provides no formal framework to make binding commitments, a better information base will prove useful to inform future bilateral environmental negotiations.

FINANCING BORDER WATER INFRASTRUCTURE

Playing Games on the Border

In much economic analysis, the focus of attention is markets with many atomistic buyers and sellers who take each other's actions as given. Game theory, in contrast, focuses on cases with few actors who act strategically – they take into account the reactions of a small number of other "players" (von Neumann and Morgenstern). One can view negotiations between the United States and Mexico over financing water infrastructure as a type of game. As other social scientists frequently point out, institutional rules, structure, and power relationships are critical considerations in evaluating border water negotiations. Here, institutional rules affect how a game is played and what outcomes are possible. The bargaining power of players at different times and contexts can be parameterized in a particular game. More importantly, the game-theoretic framework sheds light on the nature and limits of that power.

IBWC Project Development as a Cooperative Game

The U.S. and Mexican Sections of the IBWC have reached numerous agreements on water pollution control projects. These agreements specify the scale and siting of wastewater collection systems and treatment plants as well as allocate the share of construction and operating costs borne by each country. These Minutes of the IBWC, defining terms and conditions of agreements, are then submitted to each national government. Once approved by both the United States and Mexico, a Minute enters into force as a binding agreement with the force of the 1944 Water Treaty behind it.

The U.S. and Mexican Sections of the IBWC may be thought of as two strategic players. The IBWC framework allows the two nations to make binding commitments. Consequently, one can model IBWC negotiations as a cooperative game, using for example, the Nash (1953) solution introduced by Nobel Laureate, John Nash.[8] The Nash solution maximizes the product $N = [u_m - \underline{u}_m][u_u - \underline{u}_u]$ with respect to the terms being bargained over. The u_m and u_u terms are the

[8] Cooperative games are ones where players can make binding commitments. In contrast, non-cooperative game theory addresses problems where binding commitments cannot be enforced.

utilities or payoffs to the two nations (m for Mexico, u for United States) and the $\underline{u}_m$ and $\underline{u}_u$ terms represent the countries' reservation utilities or disagreement payoffs that reflect the status quo.

The Nash solution has several desirable features. First, the outcome is efficient in the economic sense – there are no alternative outcomes where both parties would be better off Second, it can be shown that for two agents bargaining over division of treatment effort to meet a drinking water quality standard, the Nash solution guarantees that the standard is achieved at the least cost (Frisvold and Caswell, 1995). Fourth, it is simple to compute. Fifth, despite its simplicity, the Nash solution can closely approximate solutions to more sophisticated dynamic bargaining games (Binmore et al.).

This approach can be used to examine negotiations and outcomes of pollution control projects in three border metro areas: San Diego - Tijuana, Calexico - Mexicali and Laredo - Nuevo Laredo. Three salient features enter into these bargaining processes. The first is Mexico's limited financial capacity to fund large projects. Second, the United States' is often in the downstream position, making them a recipient of untreated wastewater. Hence they are often the major beneficiaries of wastewater collection and treatment projects. Third, U.S. environmental water quality standards are more stringent than Mexico's. Our analysis suggests that, after some early missteps, negotiated outcomes have made progress toward economic efficiency.

The Commission negotiated construction of the first joint U.S.–Mexico sewage treatment facility in 1951 to serve Ambos Nogales. To finance the project, the Commission recommended apportioning costs in proportion to benefits (Mumme, 1993). The downstream position of the United States, combined with its greater willingness and ability to pay for water sanitation meant that the United States would derive relatively larger benefits from the joint project. The United States therefore assumed a higher share of the project costs. This policy of apportioning costs in some proportion to benefits was used as a general guideline in subsequent negotiations for over 30 years (Mumme, 1993). In 1984, however, the Reagan Administration shifted from this policy (EPA, 1984; Mumme, 1993). The United States adopted the position that the Mexican government should finance half the cost of jointly developed pollution control projects.

While allocating costs in some proportion to benefits can be shown to be consistent with Nash solutions, requiring joint projects to be equally funded will generate efficient solutions only in highly specialized and, given the empirical realities of border water problems, highly unlikely circumstances (Frisvold and Caswell, 2000). Commission engineers frequently make recommendations about the siting and scale of waste collection and treatment systems based on the principle of minimizing cost to achieve a particular objective. This objective might be to minimize the quantity of untreated waste flowing into a water body or to insure that effluent from a treatment plant complies with a domestic water quality standard. Once the cost minimizing collection and treatment infrastructure is identified, the bargaining problem simplifies to one of allocating costs. An equal cost-sharing rule could be viewed as a constraint on the bargaining process such that countries try to maximize N subject to a constraint that Mexico’s cost share be at least 50 percent

Frisvold and Caswell (2000) have shown that an equal cost sharing rule will tend to force the outcome to the non-cooperative solution $\underline{N} = [\underline{u}_m][\underline{u}_u]$ in cases where transboundary externalities are significant. Also, ironically, the equal cost-sharing rule is biased against finding a cooperative solution for projects with high *relative* benefits for the United States and where *absolute* benefits are large.[9] The equal cost rule impeded development of a cooperative solution to border sanitation problems in San Diego–Tijuana (Mumme, 1993). In the early 1980s, Commission engineers recommended a gravity flow collection system, with the main treatment plant located in San Diego. One of the main objectives of this system was to eliminate uncontrolled sewage flows into the Tijuana River and into San Diego. The Mexican government balked at paying half of the estimated $730 million cost of the project. Instead Mexico decided to act unilaterally, building a smaller, less expensive, self-financed system in Tijuana [IBWC, Minute 270]. Rapid growth in Tijuana soon outstripped the 25-mgd capacity of the first of two facilities to be built. By 1990, the Commission conceded:

> "It has not been possible to eliminate uncontrolled sewage that continuously flows in amounts of 0.11 mgd at Goats Canyon (Canon de los Laureles) and of 10 mgd in the Tijuana River, respectively (IBWC, Minute 283)."

Rather than construct the second facility, the Mexican government developed plans to construct a secondary treatment plant that would discharge its effluent into the Rio El Almar, a tributary of the Tijuana. U.S. engineers, however, considered the proposed plant at Rio El Almar "suboptimal and less reliable as a mechanism of managing Tijuana's growing sewage production (Mumme, 1993, p. 117)."

In 1990, the Commission agreed to pursue the larger joint sewage collection and treatment project along the lines originally proposed (a gravity flow system with the treatment facility sited in San Diego):

> "The Commissioners agreed that the construction and operation of the conveyance, treatment and final disposal works ... would permanently and definitively resolve the existing border sanitation problem and concluded that the joint solution is the best alternative to this common problem (IBWC, Minute 283)."

Under Minute 283, the insistence on equal cost sharing was abandoned.

> "The cost corresponding to Mexico shall be in an amount ...equal to that which would have been used in the construction, operation and maintenance of the treatment plant planned for the Rio Almar (IBWC, Minute 283)."

Minute 283 represents an improvement over the earlier non-cooperative solution. Given the proposed scale and siting of facilities, the U.S. Section believes it can comply with domestic water quality standards cost-effectively. The Mexican government will incur no greater costs than those associated with its new disagreement point, yet will derive benefits from the more efficient larger system.[10]

The equal cost constraint also affected Minute 274, Joint Project for Improvement of the Quality of the Waters of the New River at Calexico, CA–Mexicali, BC signed in 1987. In this case, the principal engineers were asked to develop plans for a jointly funded project to improve the waters of the New River "utilizing funds to be provide in equal parts by the Governments of the United States and Mexico (IBWC, Minute 274). The result was a small, $1.2 million project intended to reduce 19.8 mgd of untreated sewage entering the New River. The engineers

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[9] For the equal cost sharing constraint to be binding, the benefit cost ratio of the project must be relatively large (Frisvold and Caswell, 2000). Benefit cost ratios tend to be higher for small projects relative to large projects. So, when net benefits are large in *absolute* terms, the benefit cost *ratio* tends to be smaller.

[10] Problems with the international treatment plant persist, however, as new disputes have arisen over construction and citing of a secondary treatment facility.

conceded that the project features were "but a small part of the total works required for solution of the border sanitation problem (IBWC, Joint Report of Principal Engineers, 1987)" and also noted that some features were abandoned because they fell outside of the Mexican government's budget constraint.

In Minute 288, signed in 1992, the Commission developed a new plan for the New River:

> "the works should be designed, constructed, operated and maintained in a manner that will ensure that no untreated domestic and industrial wastewaters are discharged into the New River or its tributaries and that the effluent from treatment facilities in Mexico have a quality such that the waters of the New River at the international boundary meet standards agreed to by the two Governments in a Commission Minute."

Minute 288 makes no mention of how costs are to be apportioned, but gone is any reference to equal costs. In 1995, the two countries agreed to several "quick fixes" to pressing wastewater problems in Mexicali with the United States funding 55 percent of costs.

In 1997, the Commission signed Minute 297, apportioning the costs of a wastewater treatment project to improve the quality of the Rio Grande at Laredo–Nuevo Laredo. In this case the externalities of untreated wastewater flowing into the Rio Grande affect the two countries more symmetrically. Under the project, collection and treatment capacity in Nuevo Laredo was expanded. The goal of the project was to prevent any discharges of untreated sewage into the Rio Grande and to have discharges from the new treatment facilities conform to U.S. water quality standards, which are higher than the standards required by Mexican law. Under the agreement, United States agreed to pay Mexico for the incremental cost of operating and maintaining the project to meet the higher U.S. effluent standard. These incremental costs were not to exceed 33 percent of total actual costs. Estimates of the incremental costs of early phases of the project were 25 percent. Industries in Laredo and Nuevo Laredo are required to pre-treat of industrial wastes to reduce costs of operating treatment facilities. After 2005, both countries would review actual operating costs and differences in water quality standards. The agreement allows future U.S. payments to fall if the difference between Mexican and U.S. discharge standards falls.

The structure of this agreement also appears to be relatively efficient. The U.S. Section believed that expanding facilities in Nuevo Laredo was a more cost-effective means of meeting U.S. discharge standards than unilaterally building infrastructure on the U.S. side of the border. Mexico is compensated for its incremental costs of meeting the higher U.S. standard. The agreement allocates effort between pre-treatment and treatment and the agreement allows for future adjustments to changes in costs and environmental standards.

Environmental Grant Development as a Strategic Game

The experience of the IBWC suggests that coordinating construction of infrastructure across borders can significantly reduce project costs. Given high fixed costs, there are gains from avoiding duplication of treatment facilities. Local geography determines the optimal location of conveyance systems and treatment plants. Yet, this may involve developing projects across borders.[11]

Yet, thus far, border cities seeking NADBank loans or environmental grants through the BECC process have done so unilaterally. Varady et al. (1996) argue:

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[11] Some of the largest customers of the Nogales, Arizona Water District are in Nogales, Sonora. Deeper wells on the U.S. side provide more stable water supplies (Varady et al., 1995).

"BECC does not seem to have assisted these linked communities to develop comprehensive, binational approaches to environmental decision making. Environmental policy within these communities remains relatively isolated vis-à-vis their partners across the border. If BECC adopts a more active and comprehensive position in identifying and alleviating environmental degradation, then facilitating local binational decision making should be high on its list of priorities."

This section considers the problem of two border cities seeking external financing of a jointly developed water project. Joint project development could be a condition of the funding agency.[12] For example, the Border Environmental Infrastructure Fund's criteria states:

"Projects may be located in either the Mexico or the United States, but must have a U.S. side interest. Priority will be given to projects which benefit both sides of the border (NADBank, 1998b)."

Negotiations over the terms of a proposal may be modeled as a sequential bargaining game with an exogenous risk of breakdown. One player makes an initial proposal that specifies how grant funds will be allocated. The other player accepts or rejects the offer. Players make proposals and counter proposals until they reach an agreement or negotiations end without an agreement. Bargaining could end if negotiations break down or if the funding agency decides to fund competing proposals. The opportunity to receive funding is time dependent. Delays in reaching an agreement increase the probability that funding will go to other projects instead.

Binmore et al., have shown that, in this type of sequential bargaining game with an exogenous risk of breakdown, the outcome is approximated by the Nash solution. Negotiations over the grant proposal can then be modeled as a Nash bargaining game of the form:

$$N = [v_m(x, \alpha A) - \underline{v}_m(\underline{x}, \alpha A = 0)]^{\beta}\ [v_u(\underline{x}, (1\text{-}\alpha)A) - \underline{v}_u(\underline{x}, (1\text{-}\alpha)A\ = 0)]^{1-\beta}$$

where:

(a) N is the Nash product,
(b) v_m and v_u are the city's utilities if they receive the assistance,
(c) $\underline{v}_m$ and $\underline{v}_u$ are the city's utilities if negotiations break down, or if the granting agency decides not to consider the project,
(d) A is a measure of the value or size of the assistance package,
(e) α is city m's share of the assistance package,
(f) x is the vector of bargaining parameters,
(g) $\underline{x}$ are the values of parameters in the event negotiations breakdown or the granting agency decides not to consider the project,
(h) β is a parameter measuring the bargaining power city m relative to city u.

The Nash solution maximizes N with respect to x. The vector x could represent the quantity and quality of water flowing from the upstream to the downstream country, use of effluent by each country, the level of pre-treatment required by each country's industries, the costs borne by each country of conveyance and treatment systems, the structure of user fees, groundwater pumping changes or water transfer prices.

The bargaining power parameter β will depend on the time preference of each player (Binmore et al.). In this model, β increases if country u is more impatient that country m. This

[12] This basic approach could also be used to model negotiations between a local government and the BECC.

might be the case if $\boldsymbol{u}$ is downstream and there is a serious border sanitation problem such as risk of a hepatitis outbreak. The model suggests that downstream cities should be pro-active, developing joint project proposals before crises emerge.

Binmore et al. have also shown that β will depend on the time it takes for each player to respond to proposals and to make counter proposals. The city whose negotiators can formulate and evaluate proposals more quickly will have greater bargaining power. The ability to assess the benefits and costs of each offer requires evaluation of complex hydrologic, environmental and economic relationships. Organizations without access to data or the technical expertise are more likely to get less out of joint development projects. Third parties can balance asymmetries in bargaining power by ensuring that access to information and technical expertise is not monopolized.

Border institutions have explicit policies to provide technical assistance to communities seeking project financing. The BECC has established a $10.5 million Technical Assistance Grants Program, funded primarily by EPA, to help disadvantaged communities prepare project proposals to meet BECC certification criteria (Varady, et al., 1996). BECC provides staff and consultants to help organizations conduct planning studies, environmental assessments, and financial evaluations and to prepare certification applications. IBWC Minute 294 (1995) established a Facilities Planning Program. Funded by the EPA, the program assists border communities in developing wastewater infrastructure plans that meet BECC criteria. The IBWC provides expert technical assistance to local water agencies. In addition, funds may be used for economic and environmental impact studies, financial analyses and public information dissemination. Communities receiving support must demonstrate that they have insufficient funding to advance project plans for BECC certification.

Water use rights or environmental regulations influence bargaining outcomes even if they are non-binding constraints. For example, an element $\boldsymbol{x_i}$ of $\boldsymbol{x}$ might be a city's surface water use, effluent use or level of pre-treatment of industrial wastewater. One player's payoff may be increasing in some these parameters, while another's is decreasing. Water rights and environmental regulations place guarantees and limits on the values bargaining parameters can take. A city may be guaranteed a minimum allocation of surface water, the right to use effluent, or its firms may be required provide a minimum level of wastewater pre-treatment. Under a cooperative solution, however, a city may forgo some of its water rights or supply water of a higher quality than the minimum required by law. This may be in exchange for a concession by the other city. In this case, the water right or environmental standard may determine $\underline{\boldsymbol{x}}_{\boldsymbol{i}}$, the value of $\boldsymbol{x_i}$ in the event negotiations break down. This means that altering water rights or environmental standards will affect a player's disagreement payoff. A player's payoff in a Nash bargaining game rises with its disagreement payoff. So, altering water rights or standards affect the bargaining outcome even if a city is not using its full water entitlement or is providing environmental clean-up in excess of the minimum standard.

Non-exercised rights can be important bargaining chips. For example, the U.S. and Mexico maintain the right to return and reuse effluent from treatment plants corresponding to each country's sewage inflows. Currently, Mexico does not use its share of the effluent from the Nogales International Wastewater Treatment Facility. The treated effluent flows into the normally dry Santa Cruz River, raising nutrient levels, encouraging growth of riparian vegetation and providing wildlife habitat (Hamson). Mexico has the right to claim the effluent, but currently does not (IBWC Minute 227). The possibility that Mexico might exercise its claim does influence IBWC negotiations over water project development in Ambos Nogales (Ingram and White, GUAC).

Perverse Incentives and Border Environmental Management

The IBWC has responded to border sanitation problems *after* they arise. As a scientific-engineering agency, they have focused on engineering, structural solutions. The agency has neither the mandate nor the expertise to address problems of market failures or incentive problems that lead to water pollution crises in the first place. Here, we identify three proximate causes of border water pollution crises. Unless, these proximate causes are addressed, water project construction will continue to be a temporary, stop gap solution. First, maquiladoras and other firms located on the border have not had to pay the full social costs of their production and release of industrial wastes into water bodies. Hinojosa-Ojeda notes:

> "The border represents one of the clearest examples of a failure of market mechanisms to have local investments cover externalities of environmental and infrastructure strain. Neither market nor regulatory mechanisms have efficiently worked to have firms internalize these costs."

Requiring maquiladoras and other businesses along the border to internalize the external costs of their pollution, either through user fees or environmental regulation governing pre-treatment and disposal of industrial wastes, would be one important remedy to border environmental problems. Yet, much of the pollution is not emanating from large multi-national corporations, but from poor Mexican households in the form of untreated or poorly treated wastewater.

The second cause of continuing water pollution problems is lack of water supply and sanitation infrastructure needed to support the rapidly growing population, working on the border. Historically, firms have not paid much in the way of user fees or infrastructure taxes to finance safe drinking water or sewer systems for the growing workforce. While Mexican wage rates along the U.S. border are higher than the national average, they remain insufficient to make U.S.-style water systems or environmental infrastructure affordable to the population. As discussed above, this has led to recurrent water pollution crises.

The organization of production of the Mexican border economy is an almost classic example of an export enclave economy. The economy is not “articulated” (de Janvry). In an articulated economy, consumer goods are purchased with wage income. Demand for consumer goods creates derived demand for capital goods. Growth in wage earnings drives demand and production in the economy. Put simply, businesses have to pay labor enough for labor to afford their products or the economy cannot grow. While wage payments are a cost to individual businesses, wage earnings collectively are a benefit to business to via their effect on consumer demand.

Contrast this situation with an export-enclave economy, specifically the maquiladora sector. Sales of maquiladora products are driven by foreign demand, not domestic wage earnings. Indeed, law had prohibited maquiladora output from being sold domestically.[13] The capacity to consume is developed externally by the demand for exports. The export demand for maquiladora products creates derived demand for capital goods, but the foreign market supplies these goods as well. In the export-enclave economy, payments to labor are a cost, but not a significant source of demand growth. In this case, the economy is *disarticulated* – growth is tied

[13] This restriction has been relaxed over time and will be effectively phased out by 2001 as part of NAFTA.

export sales and importation of capital goods, but the link between wage earning growth and demand growth is broken. There is little incentive for businesses individually or collectively to pay wages above the bare minimum necessary to prevent the workforce from migrating elsewhere. Given competitive pressures, low wages will persist even with growth in export sales and labor productivity. Wage rates in the maquiladora sector have been stagnant and remain well below Mexican wages in manufacturing. Moreover, turnover rates are extremely high 60-150 percent per year making skill development less likely (Galhardi). Galhardi observes:

> "In Mexico, until the mid-1980s, maquiladora plants were low-wage export enclaves with virtually no connection to the rest of the domestic economy via either material inputs or local sales."

Industrial development in the Mexican border economy has been based on wages too low to make U.S.-style water delivery or sewerage services affordable to many communities. Construction of water delivery systems, sewer lines and wastewater treatment systems entail large up-front costs that must be debt-financed to spread costs out over a long time period. The BEIF requires affordability assessments to determine project eligibility of projects for grants, providing grants only to projects deemed unaffordable. The criteria involves first calculating the annualized cost per resident, which includes operation and maintenance costs plus the debt service for construction costs. A project is deemed affordable if this annualized cost per household is less than 1.7 percent of median household income of the project area (EPA, 1997). To date, the great majority BECC and NADBank approved projects have qualified for BEIF funds because costs per household exceed the affordability threshold.

The Mexican tax system presents additional problems by limiting the taxation authority of local governments (Liverman et al.). Under Mexican law, locally collected taxes go back to the federal government. Communities are dependent on uncertain, annual legislated appropriations for infrastructure funds. This precludes communities from issuing bonds or qualifying commercial loans (GAO) to finance infrastructure construction costs. As documented above, this has led to domestic sanitation problems literally spilling over into the United States. Had firms either paid for water services for their workforce directly, or paid households wages high enough to pay for these services, the level of growth along the border would have been slower than it has been. Imposing user fees on households, *after* they have settled along the border, may be quite a shock. Establishing a user fee system raises income distribution issues, which eventually come back to wage earning issues. This, in turn, points to the need to transform the Mexican border economy from an export-based enclave to one where growing wage incomes are a more important engine of growth. There is some evidence that "second generation" maquiladoras, newer operations often run by Asian multinationals, are more capital intensive, rely on more Mexican inputs and use more skilled labor (Galhardi). It remains to be seen, however, whether the maquiladora sector "graduates" from its reliance on low-skill, labor-intensive production.

A third problem is the policy response to the first two problems – continued U.S. federal subsidies for water pollution abatement. Cities on either side of the border have not had to bear the full costs of addressing water pollution problems. To illustrate, Table 3 shows cost allocations for IBWC approved projects in San Diego –Tijuana and Ambos Nogales. Local municipalities pay only a fraction of the cost of constructing local water treatment infrastructure. The U.S. federal government's willingness to bail out border cities is an understandable response to immediate health concerns over poor sanitation. However, federal subsidies do not induce border cities or industries to internalize the full environmental costs of continued growth. If anything, continued federal bailouts increase incentives for even higher rates of growth along the border.

The dependence of U.S. border cities on federal funding has also had a stifling effect on local-level cooperation between U.S. and Mexican cities. For example, Ingram and White document how local officials in Nogales, Arizona and Sonora expressed interest in developing a common water delivery and treatment system and agreement over water supplies. Yet, the U.S. Section of the IBWC recommended against negotiating with Mexico over water supply because the United States was using more water from the Santa Cruz River watershed than it contributed. To this day, communication between local officials is limited over water issues such as use of effluent from the International Wastewater Treatment Plant (GUAC). Local officials and water users continue to look to the U.S. federal government to finance solutions to local water problems and defer to the IBWC (GUAC).

Table 3. Allocation of capital costs for water treatment plants

	Costs ($ millions)	Cost share (%)
San Diego / Tijuana:		
U.S. EPA / Other U.S Federal	208.0	52
California	31.6	8
San Diego	75.2	19
Mexico	85.2	21
Total	400.0	
Ambos Nogales, 1967		
U.S. EPA / Other U.S. Federal	7.3	65
Nogales, Arizona	3.0	26
Mexico	1.0	9
Total	11.3	
Ambos Nogales, 1967:		
U.S. EPA / Other U.S. Federal		54
Nogales, Arizona		17
Mexico		29
Total		

Sources: Ingram and White; Johnstone.

The Public Advisory Committee for the U.S.-Mexico Border Environmental Plan recommended in 1993:

> "A greater emphasis in funding should be placed upon sustainable management and the design of user fees ...The federal governments alone cannot fund these projects, and local municipalities need the ability to help themselves (Udall Center)."

Border cities, however, face a number of constraints limiting their abilities to self-finance water infrastructure. Because of political and financial risks associated with these investments, it is difficult to obtain long term financing through international markets. Lack of capital at the local level further raises local financing costs. In addition Mexico's legal system limits the ability of local governments to issue bonds against user fees or real estate taxes (Hinojosa-Ojeda).

WATER PROJECTS IN THE POST NAFTA ERA

In response to objections by environmental groups to NAFTA, both nations established the Border Environmental Cooperation Commission (BECC) and the North American Development Bank (NADBank) in 1994. The NADBank arranges financing of water and municipal solid waste projects within 100 km of the international border. NADBank's purpose is to help border communities with long-term funding of water and solid waste projects. Capitalized by both the Mexican and U.S. governments, NADBank can secure financing at lower commercial rates than border communities could otherwise obtain for commercial loans. NADBank also uses funds to leverage other private loans and grants that communities may not otherwise be able to secure. The NADBank was established as a bank, not a grant-giving agency (although it does help administer an EPA grants program). From its inception, it was planned that water projects would have to be able to repay loans, raising funds through user fees or other mechanisms.

BECC must certify projects before the NADBank may finance them. The BECC certification criteria include project impacts on human health and the environment, technical and financial feasibility, project management, community participation, and sustainable development. The BECC also provides technical assistance for local entities developing proposals, analyzes environmental and financial aspects of projects and helps arrange public financing for projects (EPA, 1998).

The BECC has a binational board of directors with the Administrator of the EPA and Secretary of SEMARNAP (EPA's Mexican counterpart) and the two IBWC commissioners as ex officio members. Six other directors include two state government representatives, two local government representatives and two public representatives from each country. In addition there is an 18 person advisory council. The BECC certification criteria are designed to have project sponsors internalize the social costs of projects. These criteria include human health and environment, technical feasibility, financial feasibility and project management, community participation, and sustainable development.

In its first two years of operation, BECC was not able to secure NADBank funding for any of its certified projects (Varady et al., 1997). While there was much internal and external debate over BECC's development and implementation of the sustainable development criteria, proposed projects were not meeting NADBank's criteria of being financially sustainable (Varady et al., 1997). NADBank (1998) identified five major constraints limiting project development:

(a) insufficient community resources to fund high cost projects,
(b) lack of master plans and inadequate preparation of proposals,
(c) limited financial, administrative and commercial capabilities of local water agencies,
(d) inadequate revenue for the sound operation of existing services and resistance to raising user fees,
(e) lack of private sector involvement in environmental projects.

Given the history of financing of border water projects, these problems should be of little surprise. The level of growth and development on the border has been fostered by a no or low-user fee environment for several years. The pace of growth is much greater than it would have been had projects been funded on a "pay as you go" basis. Internalizing externalities after high population densities and pollution problems have been reached entails high adjustment costs. In addition, communities on both sides of the border have grown accustomed to receiving federal funding for federally planned water projects, albeit sporadically and in response to crises.

To address the problems of transitioning to a more locally self-financing system, the U.S. EPA and NADBank established the Border Environmental Infrastructure Fund (NADBank, 1998). The fund receives and administers grants that may be combined with loans or loan guarantees. EPA supplied $170 million in start-up funds for water and wastewater projects. Grants may support municipal infrastructure, drinking water treatment plants, and treated water distribution systems. Funds may be used to allow user fees to be phased in over a 5-7 year period or to complete financial packages covering construction costs not funded by other sources.

Since 1995, the BECC has certified 40 projects receiving funding or commitments of funding of more than $1 billion. The BECC has earmarked more than $20 million dollars in grants for technical assistance to aid communities move projects through certification. Despite early growing pains, water project development throughout the border area is now proceeding in a more coordinated and proactive manner (Millich and Varady; Varady et al., 1997). Investments are being made before crises emerge and projects are being developed with more considerations of long-term needs in mind.

Yet, the goal of developing locally self-financing municipal water systems on both sides of the border has remained elusive. The United States and Mexican governments have contributed $152 million each in paid-in capital to the NADBank. Combined with callable capital, this adds up to a lending capacity of roughly $2 billion (Reed, 2000). NADBank has approved financing for 29 projects, but loans account for a small fraction of project financing. While NADBank has approved $265 million in loans and grants, $253 million, over 95 percent, of this has been BEIF grants. Actual loans account for less than 5 percent of financing (Reed, 2000). While U.S. borrowers could obtain loans at rates lower than taxable municipal bonds, NADBank rates are higher than rates available through the State Revolving Fund or tax-exempt municipal bonds, which are subsidized. (For additional discussion of interest rate charges and demand for NADBank loans, see U.S. GAO, 2000). Since 1994, the U.S. federal government has provided $2.02 million for border infrastructure spending, 65 percent of the total. Mexico has provided $0.65 million (21 percent) and U.S. border states $0.45 million (14 percent) (U.S. GAO). The EPA accounts for more than half of U.S. federal appropriations. In short, EPA (via BEIF) continues to be the major source of funding for water projects on both sides of the border.

While local self-financing has proven elusive, so also has truly binational project development. Thus far, border cities seeking NADBank loans or environmental grants through the BECC process have done so unilaterally (Varady et al. 1997). The experience of IBWC joint project development suggests that coordinating construction of conveyance and treatment facilities across borders can reduce costs. Local geography determines the cost of optimal location of conveyance infrastructure and treatment plants. Yet, this may involve developing projects across borders. Given high fixed costs, there are also gains from avoiding duplication of treatment facilities.

THE FUTURE OF FINANCING BORDER WATER PROJECTS

A recent report of the U.S. General Accounting Office (GAO) on border environmental infrastructure concluded:

> "… as currently structured and implemented, existing programs and activities are not likely to close the gap between what is needed and what exists for the foreseeable future, particularly in view of expected population growth."

The GAO report noted that many border communities could not afford the loan rates charged by NADBank and questioned the political sustainability of heavy reliance on grants from the U.S. Congressional appropriations as primary means of financing projects. The report also suggested the U.S. Congress might consider altering the NADBank charter to allow for provision of lower cost loans. The U.S. Treasury Department responded to the report by noting that NADBank's practice of combining loans with BEIF grants effectively reduced the costs of borrowing for projects and that a fundamental problem was "border communities are extremely poor." Treasury also pointed out that NADBank loans were in fact lower than other commercially available rates and that other types of financing available such as municipal bonds or the State Revolving fund, while more affordable than NADBank loans, are heavily subsidized (GAO). It appears that the only short-term means of lowering loan rates would be to subsidize them. If this is indeed the case, there seems little distinction between loan packages subsidized via combination with BEIF grants or concessional loans subsidized by other means.

The GAO report recommended that U.S. and Mexican agencies jointly develop a Border Infrastructure Strategic Plan that would include a needs assessment, strategies to address impediments to infrastructure development and a statement of measurable goals. This chapter has tried to highlight some of these fundamental impediments. These included:

(a) lack of implementation of policies to internalize environmental externalities that allow growth to proceed at a faster rate than is socially optimal.
(b) the export-enclave nature of the Mexican border economy that allows real wage rates to stagnate despite rapid production growth and prevents communities from affording infrastructure.
(c) lack of federal encouragement of city-to-city transboundary cooperation over a broad range of water issues, including surface and groundwater management.
(d) the centralized allocation of funds for infrastructure in Mexico.
(e) lack of local taxation authority in Mexico
(f) lack of technical capacity to manage and maintain border environmental infrastructure in a financially self-sustaining manner.

For a Border Infrastructure Strategic Plan to be successful, it will have to address these more fundamental constraints and not just the symptomatic problems listed in the GAO report.

But what other issues might a strategic plan address? One is an examination of the relative payoffs of different types of investments. A stated goal of the BEIF program is "that grant funds be applied toward projects where the value of the grant funds has the greatest marginal value (EPA, 1997." It does not clear that most funds are being spent where the benefit cost ratios are the highest. According to GAO's own report, nearly 2 million border residents lack direct access to potable water (see table 2 of this chapter). Providing safe drinking water would arguably yield the highest public health benefit. Surveyed colonia residents in Texas responded that water supply infrastructure was their top priority (Martinez Engineering Group). This suggests they would have the highest willingness to pay for drinking water supply infrastructure. The costs of obtaining drinking water drop dramatically with infrastructure. Ironically, it is often the poorest of colonia residents that must obtain drinking water in its most costly form - purchased bottled water (Ingram et al., Martinez Engineering Group). Yet, most BEIF funds have gone to wastewater treatment. This may be a higher priority of those residents of U.S. border cities who already have access to drinking water and are most concerned about transboundary externalities.

A second issue has to do with industrial policy for the Mexican border regions. The long-term solution to border infrastructure problems is to raise labor productivity and real wages in the Mexican border zone. Over time more maquiladora operations have shifted into the interior of Mexico, become more capital-intensive and improved linkages with other Mexican industries. A plan could address the scope for encouraging this trend and transforming production in Tijuana and Ciudad Juarez, especially along these lines.

A third issue would be linking water quality and quantity issues. Recently the NADBank has proposed expansion of its loan activities to cover a wider range of projects and to cover a wider geographic area. While expansion may allow NADBank to make more loans, it is not clear how expansion would increase the affordability of loans for border water and wastewater projects. One form of expansion that could help in this regard would be to consider projects on a watershed basis. Organizing a Border Infrastructure Strategic Plan on a watershed basis would also be logical. Brown and Mumme have recently discussed binational watershed councils (*consejos de cuencas*) as a promising institutional framework to plan transboundary water policy. Improving information collection and sharing in transboundary watersheds would be an important first step to encourage such cooperation. Watershed councils may also be vehicles to improve city-to-city cooperation on water issues.

Historically, planning and financing of binational water projects has maintained a separation between water quality and water quantity issues. It has also separated water quality problems from improper economic incentives and persistent poverty. Consequently, narrowly focused, structural fixes to border environmental problems have proven to be temporary and unsatisfactory solutions. Sustainable development of the border region will require poverty alleviation, infrastructure investment, and balancing water supply and demand issues to be addressed in concert.

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Lessons in Transboundary Resource Management from Ambos Nogales

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The earth, at the beginning of the third millennium, is characterized by a growing number of national entities and by an increasing awareness of the finitude of the natural resources that nations often hold in common. The collapse of communism in Eastern Europe and the Soviet Union and the virtual dissolution of several African states have been accompanied by sweeping changes in the political landscape. New, often ethnically based nations are presently in the process of defining themselves and securing their borders. At the same time, migration, travel, communications and trade are blurring the distinctions among nations.

Since the early 1990s, literally scores of new international boundaries have been created – boundaries that may represent lines of contention between neighboring countries over issues held in common. The increase in the number of international borders may represent a particular cause for concern in the natural resource arena, which is characterized by increasing scarcity of finite resources and by escalating public and governmental attention and concern. Because national boundaries commonly traverse those of ecological systems, the actions of one nation often affect resources that are shared with neighboring nations, or resources that are shared on a global scale. Furthermore, holistic resource management, which is now held to be the ideal, may be complicated or rendered impossible by politically imposed separation of natural systems and the conflicting management perspectives of different political regimes.

Among the natural resource issues that are of significance in border regions, water is certainly among the most salient. Water is essential to the environment since all forms of life, including human life, are dependent upon it. Water is fundamental to economic activity, and the presence of abundant supplies of high-quality water determines whether and where sustainable development can occur. Globally, more than 300 river basins are shared by two or more nations.[1] These watersheds account for well over one-half of the land area on earth and are home to more than 40 percent of the earth's population. Shared water resources commonly represent an arena for international negotiation and policy-making. Historically, over 3,600 treaties have been signed between or among nations to address various aspects of international waters.[2]

Because water is so essential to environmental, economic and human well-being, watersheds and water resources offer a complex and important illustration of the problems that can arise in border regions. Regions in which there is a long historical record and an existing potential for both conflict and cooperation offer an excellent opportunity for case studies of water as a boundary issue. The border between Mexico and the United States presents such a case. The boundary line that separates Mexico and the United States marks the border between a First World nation and a developing one. The very different levels of economic development and records of environmental protection, as well as the sharp differences in legal systems of property rights, politics and decision-making structures between the two nations, represent contrasting features that could easily lead to misunderstandings and conflict.[3]

L. Fernandez and R.T. Carson (eds.), Both Sides of the Border, 161–182.

Water has been the most troublesome of all natural resource and environmental problems between Mexico and the United States. Much of the 3,140-kilometer boundary between the nations passes through regions of water scarcity. Intense competition over the waters of two major rivers, the Rio Grande/Rio Bravo and the Colorado, has historically typified relations between the nations. The United States, first to develop the water resources of both river systems within its own boundaries, has been largely successful in preserving its initial advantage during negotiations through the application of the prior-appropriations doctrine – "First in time, first in right." For instance, the Treaty of February 3rd 1944 with Mexico Respecting the Utilization of the Colorado and Tijuana Rivers and the Rio Grande (Treaty of 1944) allocates to the United States roughly one-half the water in the lower Rio Grande, despite the fact that drainage from Mexico contributes approximately 70 percent of the river's flow.[4] In addition, the Treaty of 1944 only requires the United States to provide Mexico with 1.5 million acre-feet of water per year from the Colorado River, out of what was then estimated to be a mean annual flow of more than 15 million acre-feet.[5]

However, the record of binational relations over water is not limited to the assertion of dominant power by the United States; it does include cooperation and compromise as well. For example, the countries jointly constructed two international dams on the Rio Grande in the 1950s and 1960s to assist in mitigating the cycles of floods and drought that either caused considerable environmental and property damage or left the riverbed almost entirely dry. When dissention arose in the late 1960s over damage to Mexican agriculture from increased levels of salinity on the lower Colorado, the dispute was settled in 1972 when the U.S. guaranteed to Mexico deliveries of water of similar quality to that received by Imperial Valley farmers in California. The Treaty of 1944 also established the International Boundary and Water Commission (IBWC). The IBWC's mandate includes investigating, researching and planning the construction of flood-control and hydroelectric facilities, and extends to decisions regarding settlement of water disputes between Mexico and the U.S., subject to the approval of the two governments.[6]

International relations at specific locations along the U.S.-Mexican border continue to be marred by an array of water problems along the border's entire length, from San Diego and Tijuana in the west to Brownsville and Matamoros on the Gulf Coast. Ongoing historic disagreements over water supply are now regularly superseded by recently arising controversies over water quality. For example, wastewater-treatment plants that lie along the Mexican side of the border are able to treat only a small fraction[7] of the municipal and industrial wastewater generated there. In the Ambos Nogales area, which is the subject of this case study, no facilities exist in Mexico to treat any of the wastewater produced on the Mexican side of the border. Contemporary concerns over water supply, furthermore, increasingly focus on groundwater basins. Aquifers in the U.S.-Mexico border region, which is characterized by scarcity and undependability in water supplies, are being seriously over-pumped to meet the needs of the rapidly growing border population.

In spite of the fact that shared water resources engender contention in the border area, the relationship between the nations has its bright side: Mexico and the U.S. have peacefully – if not entirely equitably – managed to settle their disputes through treaties and executive agreements for more than a century. The institution of the North American Free Trade Agreement (NAFTA) and the increasing power and influence of nongovernmental actors in the border region add further dimensions to the study of the U.S.-Mexican border. As Liverman et al (1999:31) point out, "It is the interaction, in a binational context, between local ecological conditions and global economic restructuring, institutional developments and social movements that makes the US-Mexico border region such a compelling place to study environmental issues and public policy."[8]

A Case Study of Ambos Nogales

The desert community of Ambos Nogales, which sits astride the border that divides the state of Arizona in the U.S. and the state of Sonora in Mexico, exemplifies several transnational water problems, including surface and groundwater contamination, inadequate and inequitably distributed water supplies, flash flooding and endangered riparian habitat. In Ambos Nogales, these problems exist on a scale that can be comprehended, confronted and resolved. Ambos Nogales, which comprises the "twin" municipalities of Nogales, Arizona and Nogales, Sonora, has a combined population of about 370,000.[9] While this is definitely large enough to present a challenge to water resource management in an arid region, it is not so large as to represent an intractable problem or to preclude sustainable development altogether.

A study of Ambos Nogales also demonstrates local mobilization of resources and the creation of binational institutions to deal with border area problems. In Ambos Nogales, a tradition of grassroots binational collaboration on some water issues may facilitate the discovery and implementation of mutually agreed-upon and jointly implemented solutions. Although great differences exist in terms of their historic and current capacity, effectiveness and influence, both national and locally-based nongovernmental environmental and social organizations in Mexico and in the U.S. are now beginning to play an increasingly important role in the formation of environmental policy in the border region. However, this case study suggests that successful bilateral management of water resources will involve increasing the capacity of grassroots actors, particularly on the Mexican side of the border, to mobilize and to operate effectively in the political arena. It will also necessitate building some bridges over the major divides introduced by political boundaries. At least five such major divisions exist in the U.S.-Mexico border region, and the institutions that serve border communities could be better designed to bridge those divisions.

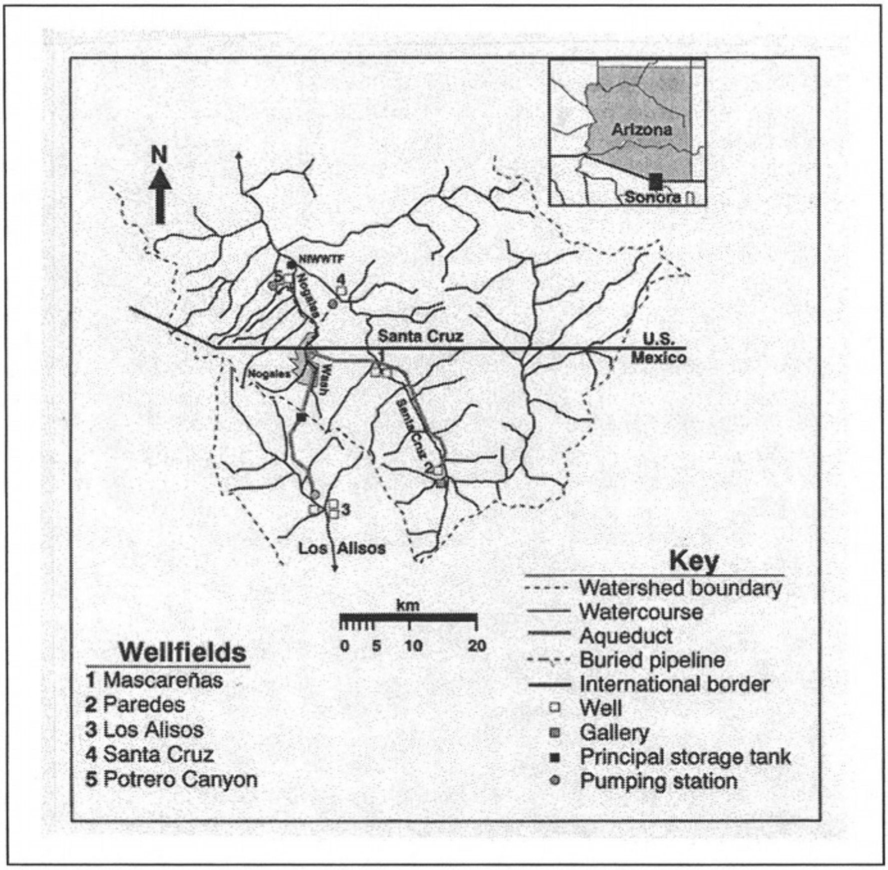
Borders Separate Problems and Solutions

Both domestic and international political boundaries commonly separate the location where environmental problems are experienced from the location in which they are created, which is where the most effective and efficient solutions can be put into operation. This is the case in Ambos Nogales. The Nogales Wash winds northward across the 25-km long, 1-km wide valley that cradles Ambos Nogales. Both the Santa Cruz and the Nogales valleys are intersected by the international boundary, so that portions of each lie within both Mexico and the United States (see Map 1).

In the Santa Cruz basin, water seldom appears at a time or place that is convenient for people. The river and wash are dry much of the year, and actual water flow occurs only during summer and winter rains. More than half of the 400 millimeters of annual precipitation occurs during July and August, when substantial monsoon rains fall in short periods of time. While both communities are subject to flash flooding, the most severe effects tend to occur downstream, that is, within Arizona. Human use of the Santa Cruz River and its Nogales Wash tributary is therefore destined by climate to be complex, even when political realities do not further complicate water resource realities.

In hopes of better forecasting and managing floodwaters in Ambos Nogales, several entities within the U.S. (including the IBWC, the Arizona Department of Water Resources, Santa

Map 1
Regional Water Resources
Ambos Nogales



The major sources of the Ambos Nogales water supply are shown, with the exception of the 14 urban wells in Nogales, Son., which provide about one-fifth of the nominal supply for the Sonoran sector of the city. The NIWWTF is at the confluence of the Santa Cruz Rivera and Nogales Wash.

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Cruz county and the Army Corps of Engineers) are considering a joint Flood Warning System initiative. An agreement that would create a framework for collaboration in the part of U.S. agencies in developing a transboundary Flood Warning System is now working its way through the various interested parties. However, several issues remain pending and are not likely to be resolved in the near future, including the role that Mexico would play in the system, how costs would be shared, and the ability of the U.S. Army Corps of Engineers to maintain and operate equipment on Mexican soil on a long-term basis. These points of discussion highlight the challenges of binational cooperation, even when the border entities involved share a long and closely entwined history.[10]

In Ambos Nogales, transboundary water issues also arise when rainfall is lacking. Periods of drought can be quite severe when the monsoons and the more moderate winter rains fail in the region. When these conditions prevail, water supply in the south end of the basin is most affected. Although surface flows in the Santa Cruz River watershed tend to be intermittent and highly variable, sizable amounts of groundwater are stored in aquifers in the northern (or Arizona) end of the valley. The southern end of the valley, by contrast, has sediments that are consistently less deep. As a consequence, much less recoverable groundwater can be accumulated and stored in aquifers in the southern end of the valley. Some shallow wells that supply water to Nogales, Sonora, run dry during periods of drought. While the aquifers that provide the source for U.S. wells are more robust, heavy pumping in Mexico could, over the long term, draw down U.S. aquifers and affect U.S. wells. Furthermore, while washes in the watershed are dry much of the year, intermittent streams and associated underground flows nourish a rich riparian habitat that is home to many animals and birds and that serves as a natural corridor for migrating species, particularly in the northern reach of the river.

In Ambos Nogales, the nation that bears the brunt of a particular water-resource problem is very often not the nation where the most rational solutions exist. For example, to secure a long-term water supply, the region's wells should be drilled in the northern portion of the basin, where aquifer sediments are deepest. Yet Mexican border communities have no alternative but to depend on shallow, vulnerable wells and costly interbasin water transfers. In another example, both flooding and water pollution downstream would best be prevented by constructing a number of small structures upstream to retain runoff and by careful upstream land-use planning to mitigate hillside runoff and erosion; however, jurisdiction over upstream management is in Mexico. As a result, downstream areas are left with less effective and more expensive options, such as constructing covered water channels through the central parts of Ambos Nogales.

Lastly, downstream riparian zones can only be maintained if upstream areas commit to allowing continuous water flow. Riparian zones, which serve as critical habitat for some life stage of over 70 percent of desert animal species,[11] is especially important in Arizona, where less that 10% of the state's original riparian area still exists. Much of the Santa Cruz River's flow from April to June (68 percent) and nearly all of its riparian vegetation are now almost entirely downstream from the Nogales International Waste Water Treatment Facility (IWTP), which releases treated effluent into the river.[12] Prior to the construction of the IWTP by the IBWC in the 1950s, the combination of natural hydrology and the drawing down of aquifers to meet the demands of agriculture in the region caused the Santa Cruz River to dry up seasonally, except where the floodplain was shallow enough to be above the water table. Construction of the IWTP and population growth in Ambos Nogales have resulted in increased flows into the river, restoring the perennial river for almost 30 km downstream of the plant. The effluent-supplemented flows in the river, together with natural flood events, has helped to reestablish an extensive cottonwood-willow riparian forest along much of the river for 23-30 km downstream of the plant and encouraged the redevelopment of a healthier and more robust riparian habitat.[13]

Not only riparian species, but also the human occupants downstream from the plant depend on the IWTP's 13,000 acre-foot per year effluent stream. The plant's output recharges the Santa Cruz River aquifer, which provides drinking and irrigation water for communities in Arizona. A reduction or interruption in the flow of Mexican effluent through the plant would seriously impact water resources in the Santa Cruz Active Management Area.[14] Approximately 70 percent of the treatment plant's influent is received from Mexico. Consequently, that percentage of the plant's effluent belongs to Mexico. Although Mexico is currently unable to make use of this effluent, it is legally entitled to claim the water at any time, impeding aquifer recharge and leaving the riparian habitat in Arizona high and dry. Although plans to curtail the flow from Mexico have not yet been implemented, Mexico has proposed the construction of a sewage treatment plant on its side of the border. Should the project be constructed, Mexico's portion of the plant's effluent will be used for irrigation in Mexico rather than for river or aquifer replenishment in the United States. The future allocation of the effluent from the existing wastewater treatment facility is currently under negotiation between the nations.[15]

In recent years, surface and groundwater pollution have been added to the slate of water problems in the Santa Cruz basin. Because water has the ability to transport wastes, the consequences of pollution are often felt outside its area of origin. Groundwater and surface water pollution in Ambos Nogales arise from water that carries waste flows downhill and down-gradient from extensive Mexican squatter communities (*colonias*) on the hillsides in Nogales, Sonora, and deposits them in washes and water sources on the Nogales, Arizona side of the border. Thus, as in the case of flooding, the best location to address pollution problems is in Mexico, while the largest incentive to solve them exists in the United States. This situation is made more difficult because the upstream polluter, and not the downstream victim, is commonly held to be responsible for the costs of mitigating problems arising within its jurisdiction. In the case of Nogales, however, it is the downstream victim, and not the upstream polluter, that possesses far superior technological knowledge and financial wealth to address flooding and pollution problems. Mexican border municipalities, and the regional or federal organizations having purview over these problems do not possess adequate resources to address them.

One grassroots approach to managing water resources that is under examination in southern Arizona involves establishing a local water district that could manage both surface and groundwater, regulate well-drilling, provide water to water right holders and build water wheeling infrastructure to move water from one location to another. Although the idea is still in the discussion stage and faces substantial political obstacles, such a district could at some point in the future be extended across the border into Mexico to include Nogales, Sonora as a full member. If this eventuality were to transpire, the district might serve as an entity that could comprehensively manage potable water, wastewater and effluent for the entire basin.[16]

Borders Create Economic Opportunities that Increase Stress on Natural Resources

The economic opportunities that exist in border regions generate a number of perverse incentives for water management. When the forces of global economic competition reinforce a focus on opportunities for immediate economic profit, restraint in using scarce water resources is unlikely to prevail. If a border region of a developing nation has a potential for vigorous economic growth, the long-term consequences of overexploiting shared water resources are not likely to be seen as a significant roadblock to development. In an increasingly globalized world, each individual nation is now forced to compete against every other nation within complex, linked networks and blocs.[17] In North America, long before the NAFTA had been signed in 1993 and began to make its effects felt, economic forces in conjunction with Mexican policies, dictated an industrial and commercial boom along the border that had serious environmental and water-resource impacts.

The high productivity of Mexican workers and the low wages they are paid attract foreign investment and create jobs. This results in a competitive advantage to Mexico that was recognized by the Mexican government as early as 1964. Mexican border industrialization policy (the *maquiladora,* or twin-plant program) specifically encourages industry to locate along the border by adding tax advantages to already low production costs.[18] Most workers in the Sonoran sector of Ambos Nogales earn less than $10.00 per day, and even with bonuses most earn too little to serve basic needs. The Maquiladora Association of Sonora, whose members comprise about four-fifths of the maquiladoras in Nogales, sets starting wages for their new employees at 53.47 pesos, or $6.30 per day, including attendance and punctuality bonuses, and maquila workers remain among the lowest-paid laborers in the world.[19] While workers in Nogales, Sonora maquiladoras earn, on average, nearly triple the Mexican minimum wage of a little over $4.00 (U.S.) a day, they still make less in a day than their American counterparts make in a single hour. But while maquila operations employ large numbers of low-wage workers, the maquilas engender only a small expansion of the tax base for the provision of infrastructure services. In 2000, maquilas paid an estimated $400 million of their $16 billion revenues in taxes. However, tax revenue generated by the maquilas is funneled directly into the national treasury in Mexico City, and very little of it is returned to the border region.[20]

At the same time, global economic forces and border industrialization have tremendously increased water-resource management problems in Ambos Nogales. The number of plants in the maquiladora sector along the length of the border has grown from fewer than 100 in the 1960s to more than 2000 in the year 2000.[21] The number of immigrants attracted to newly created jobs has caused a dramatic population boom, particularly on the Mexican side of the border .In Ambos Nogales, for example, the population has increased from approximately 130,000 in 1990 to approximately 350,000 in the year 2000.[22] Since 1990, the maquiladora labor force has nearly quadrupled, and the already inadequate Nogales, Sonora water supply and wastewater collection and treatment infrastructure has foundered as a result.[23] Local governments in the border region, therefore, are saddled with enormous housing, infrastructure and public health problems and with a dearth of financial resources needed to improve infrastructure or address public health problems. According to expert estimates, it would require nearly $20 billion to meet the infrastructure needs of the present binational border population.[24] In the four years prior to 2001, the North American Development Bank provided approximately $277 million for 32 projects along the border. However, it has fallen far short of its goal of funding almost $3 billion in loans to pay for border-area water projects: Thus far, less than 5 percent of the bank's loan money has been utilized. Because municipal agencies along the border are unable to obtain the loans they need to resolve their immense infrastructure problems either because their proposals are not economically viable according to narrow backing criteria or because the interest rates offered are not attractive to agencies on the US side of the border, most of the bank's participation in projects has come in the form of grants from the U.S. EPA. (See Carter and Ortolano, this volume).

For the vast majority of Nogales, Sonora residents, the only affordable housing close to workplaces is in *colonias.* These squatter settlements, which are often perched precariously on hillsides, have poor drainage, abet erosion, aggravate monsoon flooding and are a source of surface and groundwater pollution. Existing topographical difficulties, in combination with little investment in infrastructure expansion and maintenance, results in inadequate water supply and wastewater removal for many colonia residents. In 1998, only 64 percent of the population was connected to the drinking water distribution system. Of those who are connected, many receive water only intermittently. While Sonora's water and sewer agency has made tremendous strides in recent decades to extend the wastewater collection system, these efforts lag far behind population growth. Most of the residences in Nogales, Sonora have no access to sewage collection or septic tank systems. Wastes are disposed of directly into the environment. The majority of the raw sewage and wastewater produced in the colonias in Nogales, Sonora flows downhill into Nogales, Arizona, contaminating both surface and groundwater. Polluted surface runoff, unimpeded by political boundaries, threatens the health of residents on both sides of the border. Approximately seventy percent of the water that enters Nogales, Arizona flows in from Mexico.[25] These waters have been documented to be contaminated with pollutants such as ammonia and heavy metals, and to contain high fecal coliform levels and Cryptosporidium.[26] Furthermore, poorly maintained sewer lines in the outdated sewer system in Nogales, Sonora frequently rupture; the wastewater contaminates proximal water-supply mains through the infiltration of leaky supply pipes.[27]

A number of diseases are related to the quality and quantity of available water. Some are water-borne diseases that are transmitted by pathogens ingested in drinking water. In the border region, many of the diseases caused by these pathogens are present at high levels. Cholera, for example, has appeared in five of the six border states of northern Mexico and become an endemic disease in the Mexican border state of Tamaulipas. Other water-borne diseases that represent significant sources of concern for public health in the border region include amoebiasis, ascariasis, giardiasis, hepatitis A, intestinal infections, salmonellosis and shigellosis. Equally important are the array of what are termed "water-washed" diseases, or those that are associated with poor hygiene. In terms of their transmission route, many diarrheal syndromes (including cholera) are fecal-oral, and are therefore potentially either water-borne or water-washed. Diseases affecting the eyes or the skin, such as scabies, trachoma or fungal infections, represent a second category of water-washed diseases. While water-washed diseases may be significantly diminished in occurrence as a result of improvements in domestic and personal hygiene, such improvements often depend upon increased availability of water.[28]

Water pollution problems are exacerbated by the use and handling of hazardous or toxic wastes on the Mexican side of the border. Industrial plants, and especially maquiladoras, are a significant source of toxic and hazardous water contaminants in the border region. There is a general lack of tracking and accountability for the industrial wastes that are produced in border industries. The U.S. Department of Commerce estimated that in 1997 maquiladoras in Sonora generated 5.5 million tons of hazardous chemical waste, but according to Department of Transportation records, only 11.9 percent of that waste was returned to the United States for treatment.[29]

Only two companies in northern Mexico are authorized to treat hazardous waste and treatment is expensive; as a result, many wastes are illegally discharged onto land or in watercourses. Water sampling has revealed high levels of chemicals such as volatile organic compounds (VOCs) and heavy metals in rivers and groundwater downstream from industrial facilities in Nogales.[30] Chlorinated solvents such as trichloroethylene (TCE) and perchloroethylene (PCE), which have highly toxic effects on the central nervous system, also contaminate surface and groundwater. While many scientists believe that these substances also cause birth defects, cancer and lupus, others argue that this linkage is not clear. However, in 1993 Mexican officials cited the rate of anencephaly (in which babies lack brains and are stillborn) in Mexican border cities as being four to ten times above the national average. The Sonoran Health Department reported 17 cases of anencephaly in Nogales, Sonora between 1990 and 1992, although there is no indication that an abnormally high rate of anencephaly exists in Nogales, Arizona. However, the incidence of lupus in Nogales, Arizona is the highest ever recorded in the U.S.; the incidence of multiple myeloma, a rare bone cancer, is among the highest. On average, 40 cases of cancer are diagnosed in Nogales, Arizona each month, which, according to the American Cancer Society, is five times the normal rate.[31]

In Ambos Nogales, around 80 maquiladoras, most of which are owned by United States corporations, are involved in the manufacture of electronic parts and plastics. Concerns that these industries are also emitting toxic chemicals into the air and contaminating air quality on both sides of the border are commonly heard.[32] Another source of air pollution is the increase in vehicular traffic. Most border residents wish to own a car and as higher incomes have allowed more of them to achieve this goal, gasoline consumption and combustion has increased considerably.[33] In addition, an ever-growing number of vehicles cross the border into the United States through Ambos Nogales, the third busiest port of entry into the United States. Mexican emission control standards are not as strict as those in the U.S. and existing standards are not well enforced. Because prevailing winds blow from south to north, air pollution problems that have their source in Nogales, Sonora strongly impact Nogales, Arizona. The air pollution problem is compounded during the winter months, when the residents of Nogales, Sonora (which lies at an altitude of approximately 4,000 feet and which can receive snow from October through March) burn wood, tires, and anything else they can find to heat their dwellings, as these represent the only source of fuel for much of the population.[34]

Borders Aggravate Perceived Inequalities

Even more than efficiency in water supply, protection and treatment services, fairness and equity are key values associated with water management. In the Nogales area, inequitable access to and use of shared groundwater aquifers may become topics of increasing controversy. Residents on both sides of the border are supplied by a common aquifer. However they are served by separate water utilities and have distinctively different experiences with respect to water resources. Tremendous inequalities exist in terms of water quality, cost and access and in terms of levels of health risk. Should Sonoran residents begin to perceive these differences as nation-specific and systematically unfair, the disparities are certain to contribute to transboundary disputes.

The water supply system in Nogales, Arizona, is well managed overall, and services have been upgraded to correspond to the population increase (which has been far smaller on the American side of the border). Two small, private water companies serve a few users; the Nogales Water District supplies most water customers in the city. These systems supply water users with reliable and continually available water at constant pressure.

Residents of Nogales, Sonora, by contrast, have only limited access to a public water-supply system that is, moreover, unreliable. As a result, they are often forced to find alternative means of supply. As of January 2000, 15 percent of the population in Nogales, Sonora had no water service provided to them at all, and only 39 percent of the population was provided with water service 24 hours a day.[35] As a result, many residents must purchase their water from water vendors. Private water purveyors, who fill their trucks (or pipas) up at wells on the valley bottom and serve established routes in the city, are the primary vendors of water. Wealthy residents store the water that augments their piped-in supplies in 1,850-gallon rooftop cisterns. In poorer colonias not served by piped-in water (or when neighborhood spigot supplies are interrupted), truck-delivered water is commonly stored in 55-gallon drums that have been scavenged from local industries or dumps. Many of these drums, which have warning labels printed only in English, formerly contained toxic chemicals.[36]

Concern about water pollution, in addition to delivery problems, induces consumers in Nogales, Sonora to purchase large quantities of costly bottled water. Ambos Nogales experiences considerable inequity in the price and supply of water. The poorest people, who live in colonias and store water in 55-gallon drums, pay the highest proportion of their incomes for water.[37] In addition, because many people must expend time and effort in arranging deliveries, in arranging to be home when deliveries are scheduled to arrive, and in carrying water from stores, from neighborhood spigots or from sources on the Arizona side of the border, the true cost of water is not reflected in the price paid per gallon.

At issue, fundamentally, is whether such striking disparities in water experience are acceptable among close neighbors whose lives and welfare are intertwined; it would seem that these conditions would naturally be perceived as unjust and unfair. Unfortunately, the higher relative expenditure of Mexican consumers is likely to widen, rather than narrow, the service disparity because, while water vendors may be useful in providing or enhancing system responsiveness and flexibility, money spent to purchase water from private purveyors is not invested in public water supplies and does not lead to upgrades of the municipal supply system. The Mexican government's plan to attract industry to the border by offering low wage rates, utility costs and taxes impedes any rational user-pays water-supply and sewage collection and treatment system. The rapid development of unplanned housing in challenging terrain requiring extensive and expensive engineering would create strain on any self-financed water system. The lack of control over hookups to the water supply system compounds this problem; some 36 percent of the connections to the system are illegal and therefore yield no revenue.[38]

Borders Marginalize Residents' Interests in Policy

Border residents' concerns may be marginalized during policy design, as domestic policy-makers tend to regard border regions as peripheral in policy-making processes. Even post-Nafta, the U.S. Mexico border zone is far from the national capitals in both nations – and from the decision-making structures, political patronage and financial support levers located at those centers of power. Consequently, border-area problems frequently are assigned a low priority or are simply not addressed.[39] National and state policies, therefore, are often at odds with border needs and priorities. Water managers on both sides of the border face separate sets of laws, institutions and decision-making processes that are unresponsive, complicate the problems they face or impede domestic or cross-border cooperation.

For example, Arizona's water laws are written with Tucson and Phoenix, the two largest metropolitan areas, in mind. The Arizona Groundwater Management Act mandated the establishment of Active Management Areas (AMAs) in areas of critical groundwater overdraft. Even though the Santa Cruz groundwater basin extends into northern Sonora, the boundary of the Santa Cruz AMA stops at the international border. Therefore, while Nogales, Arizona is included in Tucson's AMA, Nogales, Sonora is not.

Within the AMAs, users are subject to specific restrictions. AMAs regulate per-capita water use, rather than placing absolute pumping limits on municipalities in Arizona. Per-capita water use in Nogales, Arizona, has been much higher than in Tucson and has exceeded the limits within the AMA – in part because the measure does not take into account the roughly 40,000 daily crossings by commuters, shoppers and others from Mexico. Under AMA mandates, Nogales, Arizona may be obligated to cease implementing the informal measures it has used in an effort to ease water problems across the border. For instance, several Sonoran businesses located near the border possess decades-old connections to the Nogales, Arizona municipal water-supply system. Spigots in Sonoran city parks, and access to private supplies provided to neighbors, friends and family in Nogales, Sonora by residents of Nogales, Ariozona, all use small amounts of water. During the prolonged drought of 1989, the City of Nogales ran a fire hose from a hydrant on the Arizona side of the border over the fence in order to fill pipa trucks in Nogales, Sonora.

Federal laws administered by the U.S. Environmental Protection Agency (EPA) have a tendency to ignore circumstances along the border. For example, EPA enforces a moratorium on the construction of new sewer lines to waste-treatment plants that have exceeded their capacity, and in 1991 such a moratorium was placed on new connections in Arizona to the Nogales International Waste Water Treatment Facility. This prohibition was very irritating to residents in Nogales, Arizona because the municipality has very little control over the international facility. Since it was constructed by the IBWC in 1951, enlargement of the waste-treatment plant has routinely fallen behind its required capacity, especially during storm events. In addition, the 1991 floods caused sewer lines to break in Nogales, Sonora, contaminating surface waters that then flowed through Nogales Wash into Arizona. To minimize the consequent public health threat, IBWC pumped millions of gallons of water per day from the Nogales Wash to sewers that led directly to the treatment facility, whose capacity was far surpassed.

Similarly, EPA has enforced laws holding large plant in the border region to strict standards for pretreatment of heavy metals in waste streams that flow into the plant. But Nogales, Arizona officials have no control over the pretreatment practices of Mexican industries; furthermore, they would not have to meet such strict standards on a smaller plant that only served their jurisdiction's needs. Reducing the degree of cooperation with Mexico in waste treatment is, therefore, a tempting alternative to solving the problems encountered through the imposition of federal regulations. As previously mentioned, a second waste-treatment plant, one that would receive only influent from Mexico, has been proposed. This is a solution that would allow Nogales Arizona to avoid limitations on new connections and to meet the less stringent federal regulations for smaller facilities. However, costs to the city of Nogales, Arizona – and to the spirit of international cooperation in Ambos Nogales – would be heavy. Construction of a 15-kilometer sewer trunk line through the city would be very expensive and disruptive to downtown traffic and commerce. Moreover, the more fundamental issues of flooding and contamination, whose resolution requires binational cooperation, would not be addressed by these expenditures.

The U.S. has consistently opposed proposals for separate wastewater treatment plants in the Ambos Nogales region for several reasons. Were the pipes or pumps to a separate Mexican facility to fail, the impact on Nogales, Arizona would be severe. In addition, if Mexico were to construct a facility of sufficient capacity to divert a portion of their waste stream from the existing ITWP facility and use the effluent for irrigation or to replenish the Los Alisos basin on the Mexican side of the border, some of the effluent that now replenishes the aquifer and maintains the riparian habitat downstream from the plant (in Arizona) could be lost. At the present time, plans to build a separate facility are on hold until badly needed water supply infrastructure improvements on the Mexican side of the border have been completed.

The needs of Nogales, Sonora, have also fit poorly with the agendas of the highly centralized Mexican federal system and the practices of the state of Sonora. Constructing and operating water systems for Nogales, Sonora is the responsibility of federal and state agencies, so minimal responsibilities are assigned to local authorities. The Sonoran state water and sewer commission has descended into a state of low-level equilibrium: Water and sewer rates are quite low, and there is both difficulty in collecting fees and considerable resistance to raising them to more appropriate levels due to the poor service that is offered. Although rates rose sharply in 1993, inadequate record keeping makes it very difficult to determine who has paid and who has not. (See Spilled Water, this volume).

Investment of Mexican federal funds in border water and sewer projects has increased, but has not kept in step with pro-growth industrialization policies and lags far behind the growth in demand that has occurred as a result of the dramatic increase in population in Nogales, Sonora (an increase of approximately 220,000 people from 1990 to 2000). Environmental degradation in Mexico City has attracted most of Mexico's public attention, and the border is quite remote from Mexico City.[40] The federal government has fostered community self-help projects through which residents of colonias receive technical assistance in laying government-supplied water and sewer lines, but the new pipes tie into the inadequately sized and poorly maintained water and sewer lines that are the responsibility of the state, increasing the overall burden on this antiquated infrastructure. As a result, water supply service becomes more unreliable and sewer breakages and overflows increase.

Borders Obstruct Grassroots Problem Solving

In addition to leading to government policies that are unresponsive to border interests, political boundaries can also impede bottom-up, grassroots problem solving attempts. Nogales demonstrates that, in fact, the two influences are not unrelated: the maze of regulations, complex and unwieldy institutional frameworks and lack of official interest constrict and frustrate community-based solutions. The experience of Ambos Nogales in attempting to seek approval and financing for a large water supply and distribution project (the "Acuaférico") highlights both the promise of the Border Environment Cooperation Commission/North American Development Bank (BECC/NADB) institutions created by NAFTA, and the institutional roadblocks to implementation of the environmental infrastructure development process they were designed to engender in the border region.[41] The technical proposal for the Acuaférico was submitted to BECC in mid-1995, and BECC commissioners certified the project in January 1996, after a heated public meeting attended by approximately 500 residents.[42] Subsequently, NADBank's Institutional Development Cooperation Program provided assistance to the local water utility to develop a water-line survey and information system. While NADB represents a prospective direct lender and has served as investment banker for the state government in Sonora, the funding process for the Aquaferico was both difficult to arrange and very slow. As of late 1998 – almost three years after BECC certification was achieved – a $9 million loan for Phase I of the project was still under negotiation between NADB and the private contractor for the project. Despite the difficulty of securing funds through NADB, the acutely needed project is now under construction – but only as a result of direct financial support from the Mexican government.[43] In view of Nogales' acute need for additional solid-waste treatment capacity, NADB authorized additional assistance for a needs assessment to complement the Acuaférico in August 1998.[44]

However, the NADB financing component for the Acuaférico project itself was still "under financial analysis" as of September 2000.[45]

Although border residents have strong incentives to work toward common solutions, they lack sufficient control to implement whatever cooperative agreements they might negotiate. It is clearly in every resident's interest to decrease the water supply and sewage disposal gap in Ambos Nogales. For Sonorans, reliable water delivery and sewage retrieval services would substantially enhance their quality of life; for Arizonans, better water and sewage systems in Sonora would make it easier to control contaminants that flow across the border into the United States and represent an issue of growing concern.[46]

Improved water supply management and better information would benefit both sides of the border. Both cities are sinking wells and moving into new areas to acquire water supplies without coordinating with one another. The border creates a dividing line where issues of national sovereignty dominate over the common interests and shared resources of the border communities. Throughout the early twentieth century, governments in both the United States and Mexico supported commercial crop production, which, in the Ambos Nogales border region, relied on using both groundwater resources and the waters of rivers such as the Rio Grande and the Santa Cruz. In the U.S., various agricultural interests acquired "prior appropriation" rights to surface and groundwater, and Arizona continues to rely upon the prior appropriations doctrine. In Mexico, water rights have always been vested in the federal government, and those rights have historically been allocated in accordance with the balance of power between the communal agate sector (land owned by the Mexican government to which communities posses usufruct rights) and large commercial landholders.[47] Currently, the Santa Cruz AMA keeps track of surface and groundwater rights and issues well permits on the Arizona side of the border in accordance with to water rights holdings.[48] At the same time, the Mexican federal government has been permitting the drilling of wells on the Sonoran side of the border. Even though the aquifer is a shared resource, the two countries do not interact with one another to determine how this resource should be used or allocated.

This situation may now be beginning to change. Groundwater issues along the border are being handled by the two nations on a case-by-case, reciprocal consultation basis. An information exchange effort and a binational report development endeavor were both begun in 1995. The initial report produced under the program, "Binational Data Base for the El Paso-Ciudad Juarez Transboundary Aquifer," will serve as a basis for future bilateral studies for the evaluation, use and conservation of transboundary water resources. Similar efforts began for the Santa Cruz River aquifer and those in the middle reach of the Rio Grande between Amistad and Falcon reservoirs in 1998.[49]

International agreements and treaties that represent the national interests of sovereign states often fail to properly serve the needs and preferences of border residents. Moreover, international agreements that depend on internal political process for their implementation may fail to fully achieve desired goals precisely because they do not sufficiently take into account the local interests that ultimately determine the extent to which statutes are implemented. National and international institutions rarely have sufficient incentive to attend to the realities of the field. Instead, high-level policy-makers are rewarded for setting ambitious goals, even when they do not provide the appropriate understanding, tools or capacity at the local level to enable the achievement of those goals.

In response to national and international policies that are indifferent to local needs, citizen and nongovernmental groups are beginning to demand a legitimate voice in environmental and social policy formation. People's desire to influence the condition of the environment in which they live is especially problematic for border residents, who are thrice handicapped: They are usually situated at a distance from the capital or regional center; their most favorable trading market is often foreign instead of domestic and some of the local authorities with whom they have to work or contend are in another country.[50]

A wide range of non-governmental environmental organizations has emerged in Mexico since the signing of the NAFTA agreement. The trend in decision-making within recent decades in both Mexico and the U.S. has moved toward increasing openness and public accountability. In Mexico, however, sufficient resources to support public participation are lacking. Reliable data on water quality and availability is also lacking, obstructing both binational coordination of water policy and public participation in domestic and transboundary policy-making processes. Trans-border networking among Mexican and U.S. NGOs has intensified in recent years, but the level of NGO and public participation is far lower in Mexico than in the U.S. Groups north of the border have greater expertise, are better organized and funded, and have a longer and more active history of participation in bureaucratic policy-making arenas. Grassroots groups have proliferated on both sides of the border. However, a greater amount of leisure time, higher income levels, more extensive interconnections among groups and the longer tradition of activism in the U.S. have allowed U.S. groups to become engaged in policy-making processes to a far greater extent than their Mexican counterparts. In addition, Mexican NGOs are severely restricted by the federal government, which does not grant legal standing to non-governmental organizations. They are further constrained by an absence of government funding and a relative lack of foundations with sufficient resources to fund the actions of non-governmental organizations.[51,52] Participants in policy-making processes in the border region report that U.S. groups such as the Border Ecology Project, the Texas Center for Policy Studies and Arizona Toxics Information, have had more influence on BECC policy-making than have Mexican organizations.[53] While innovative binational groups have materialized in support of specific regions or ecosystems (such as the Sonoran Desert Alliance, the Sky Island Alliance and the Rio Grande Alliance), these transnational endeavors are faced with many challenges. The asymmetry in resources, the difficulties of working within the various levels of government in not one but two nations and the concerns of smaller Mexican groups or partners that they will be dominated by the larger, wealthier and more powerful U.S. groups all represent impediments to the creation and success of cross-border alliances.[54]

The predominance of U.S. NGOs is also mirrored in the probability that they will subscribe to and participate in BECCNet. BECCNet is an Internet-based discussion list that was established by BECC to provide another venue for announcing meetings, distributing and receiving public comment, and allowing individuals to carry on a dialogue with BECC officials in which they can air their concerns, BECCNet also affords NGOs with a forum in which to organize around environmental or social issues and coordinate their actions.[55] This site represents an important public participation and interaction forum that eliminates or diminishes the time limitations and agenda-setting processes that routinely serve to constrict debate.[56] The enormous potential to assist in the formation of transboundary alliances, share critically needed information, enhance the power of individual organizations and facilitate coordinated action among individuals and groups that is embodied in electronic communication systems has been demonstrated along the U. S. Canadian border.[57] However, this potential has not yet been realized in the U.S-Mexican border region through the use of BECCNet. While U.S. groups have indeed used BECCNet to promote their perspectives, magnify their advantages and strengthen their role as voluntary policy consultants to BECC, Mexican activists rarely make use of BECCNet, a fact that both reflects and contributes to their relative disadvantages.[58]

Economic factors reinforce the potential to agree on water management and other matters in Ambos Nogales. The two cities' economies are solidly interdependent. For a example, Mexican visitors fund much local public expenditure in Nogales, Arizona, as a large proportion of city and county revenues are obtained from sales taxes: Approximately 40 percent of Nogales, Arizona's sales tax revenue comes from the 50,000 Mexican consumers who cross the border to shop in Arizona on a typical day.[59] Ambos Nogales is the gateway through which nearly half of the winter vegetables consumed in the U.S. arrive from agricultural areas in Mexico.[60] In Nogales, Arizona, dozens of warehouses process and store agricultural produce.

A common culture, fortified by transboundary social interactions, reinforces the material links of this commercial relationship. Not only money, commodities and services, but friends and family members flow freely to and from home bases in Mexico and the United States. A common language buttresses these binational linkages. More that 80 percent of the residents of Nogales, Arizona speak Spanish, and conversations commonly switch back and forth from Spanish to English. Police, firefighters, and disaster-rescue operations regularly cross the boundary line in emergencies. Public health officials have developed lines of communication through which equipment, diagnoses, and sometimes even patients are exchanged. Government and academic researchers exchange information and interact professionally.

Prior to NAFTA, the formal agreements authorizing joint action on water resources on the part of Mexico and the United States were seriously flawed,[61] in that they did not take advantage of existing informal linkages and networks that bridged national differences and they did not permit sufficient public input to ensure that decisions reflected border values. Although NAFTA's environmental side agreement fails to address these shortcomings,[62] the creation of the Border Environment Cooperation Commission does provide for community participation in decision-making processes. However, this participation has intrinsic limitations that will be discussed later in this chapter.

IBWC, which was the agency most directly involved in border environmental issues prior to NAFTA, received its water mandate through the 1944 treaty. IBWC was designed to facilitate joint action while at the same time protecting national sovereignty. It thus consists of separate Mexican and U.S. sections. Although the two sections take actions jointly, each develops its negotiating position through domestic political processes. Each section and its commissioner represent and operate under national jurisdiction only, and have responsibility solely to their own government. The Mexican section operates as part of Mexico's Foreign Ministry; the U.S. section operates as part of the State Department. In essence, each section operates on behalf of its federal government as technical advisor on border water issues and as field-level operative for the construction and management of water-related projects.

IBWC's priorities, as well as the constraints under which it must operate, typify past institutional arrangements in the border region. Since its establishment, IBWC's responses to flooding, drainage and sewerage problems in Nogales have never transcended engineering works such as the channelization of washes or the construction of waste-treatment plants. Due to the protracted political process involved in realizing these facilities, they were frequently outdated by the time construction had been completed. Crises persist in the region because by-the-book engineering solutions do not address fundamental planning problems or the lack of capacity of local water utilities. For example, the IBWC has chosen to deal with surface water flooding and human exposure to contaminated water in the Nogales Wash, which runs through the center of town, by channelizing and covering the wash. This, however, does nothing to discourage the disposal of toxic or hazardous wastes. Furthermore, the covered water channels have resulted in a social problem the engineers who planned them would scarcely have anticipated: They have been used as a conduit for unofficial immigrants and day shoppers and have become home turf for the juvenile gangs that prey upon them.

Because of an inability to devise a permanent solution that addresses the causes of the pollution problem in Nogales Wash, the IBWC has for many years attempted to reduce the levels of dangerous waterborne pathogens by adding chlorine to the wash on the Mexican side of the border. However, because the chlorinated water flows over the border into the United States, treating the water in this manner is considered a discharge of a pollutant into waters of the United States. As such, the discharge requires a National Pollution Discharge Elimination System (NPDES) permit in order to comply with the Clean Water Act (CWA). In January 2001, the IBWC was ordered to bring the organization into compliance with the CWA by submitting an NPDES permit application to the EPA within 30 days.[63] The IBWC was also ordered to work with the EPA toward the development of a permanent solution that will alleviate the need for chlorination.

In relationship to facilitating grassroots participation, actions taken by the EPA under the 1983 La Paz agreement have been only marginally superior to those of the IBWC. The La Paz agreement, designated as the “Agreement Between the United States of America and the United Mexican States on Cooperation for the Protection and Improvement of the Environment in the Border Area,” forms the cornerstone of government-to-government working relations. It calls for cooperation in the discovery of solutions to mutual problems and it designates the EPA and its Mexican counterpart, the *Secretaria de Medio Ambiente Recursos Naturales y Pesca* (prior to December 2000 SEMARNAP; now SEMARNAT) as coordinators. In keeping with the terms of the agreement, topical working groups were established and meet regularly to deal with transboundary issues such as air and water quality, natural resource preservation and use and solid and hazardous waste treatment and disposal. These working groups are permitted, but not obligated, to include representatives from state and local governments in their meetings.

Although it provides important new protocols for binational cooperation, the La Paz agreement is implemented only through formal channels, and border residents and environmentalists alike have been especially critical of the general lack of public representation and participation in decision-making activities.[64] From 1983 to 1990, no state or local officials were appointed to any of the topical working groups and, while a few subnational government members are now included, no nongovernmental organizations are represented. The protocols for the BECC institution, established under the terms of the NAFTA accord, embody requirements that citizens must be provided with information and that community support for border infrastructure projects must be ensured. While these protocols represent important political advances in the border region, the local consultation process is inherently restricted. For example, the public is not engaged by BECC during the design phase of infrastructure projects; public involvement only occurs after alternatives to proposed projects have already been rejected. Moreover, public meetings may not allow for active public participation. When this is the case, they may signify little beyond acquiring support for projects that have already been planned and rubber-stamping decisions that have already been made. Finally, project sponsors may not solicit or encourage the involvement of steering committees and members of the public during the construction and operation phases of a project.[65] Ensuring meaningful public participation requires that public involvement starts at the inception of the process and continues throughout the life of the project. It also requires that public participants have relevant information and technical assistance at their disposal so that they may accurately evaluate the merit of alternatives and the effectiveness of project operations.[66] Public participation and access to information are further restricted by article 16 of the La Paz agreement, which provides that both counties must agree to release to third parties any or all technical information gathered. When either country can unilaterally prevent the disclosure of joint technical data, it is not possible to develop a system that can effectively disseminate information.[67]

Finally, Ingram, Blatter and Levesque (2001) point out that water has many meanings for people beyond the utilitarian, rational, individualistic notion of water as a commodity to be controlled, engineered, sold and consumed, which has formed the foundation for water policy-making during the modern era. They also assert that unresolved equity, environmental and political problems demand a broader understanding of the meanings of water and that this type of broader understanding is necessary in order to overcome the limitations inherent in modernist approaches.[68] Doughman's (2001) research in the U.S.-Mexican border region demonstrates that various groups see water as an integral part of the cultural and ecological identity of communities, and as a resource that helps to form life in the border region. Although BECC acknowledges the importance of water for community building in its discourses, its use of a modernist, technologically oriented approach to water management continues to reflect a rational, utilitarian and managerialist perspective.[69] While an enthusiasm for the price allocation and market commodification of water currently dominates policy discourse in both Mexico and the U.S., such a modernist approach to water may incite conflicts within and between the two nations along several lines of division: urban/suburban versus rural, indigenous peoples versus majority populations, and environmentalists versus advocates of economic development.[70]

Improving Upon Contemporary Transnational Initiatives

As the Ambos Nogales case study illustrates, national boundaries commonly traverse those of ecological systems and the actions of one nation often affect resources that are shared with neighboring nations. This may not only render holistic resource management difficult or impossible, it may also engender conflict among or between nations. Watersheds and water resources offer a complex and important illustration of the problems that can arise in border regions. Although the U.S.-Mexican border continues to be troubled by water-related problems in specific locales, an examination of its history demonstrates that nations may peacefully settle disputes through cooperation and compromise. The Ambos Nogales study examines a region in which there is a potential for both conflict and cooperation over transnational problems of inadequate and inequitable water supply, surface and groundwater pollution, cross-border water transport of pollutants, flash flooding and riparian habitat preservation. The study demonstrates that adopting a binational approach to the management of border area problems offers the potential for overcoming the major divides introduced by political boundaries and for resolving some of the conflicts they may engender.

During the past decade, Mexico and the U.S. recognized the need to create new institutional arrangements that treat border watersheds and shared resources in a holistic manner. They also recognized the need to include subnational and nongovernmental actors in transboundary environmental decision-making processes. These understandings resulted in the formation of BECC and NADB, binational institutions that have dramatically transformed policy-making processes along the U.S.-Mexican. border. The innovations they have incorporated have helped to democratize policy processes within the border region. They have institutionalized greater public participation in decisions impacting communities and shaped the evolution of more traditional institutions for binational cooperation, such as the IBWC. Through the auspices of BECC and NADB, a more ecologically sound and sustainable approach to infrastructure development has begun to evolve in the border region. However, the innovative approach they have engendered contains intrinsic flaws and has not yet managed to overcome the array of problems inherent in cross-border environmental cooperation. The U.S.-Mexican border continues to separate problems and solutions, create perverse economic opportunities that directly increase stress on natural resources, aggravate perceived inequalities, marginalize residents' interests in policy and obstruct grassroots problem solving. The environmental realities of Ambos Nogales, and the organizational realities of the binational institutions that have been created in an attempt to address U.S.-Mexico transboundary environmental issues, illustrate both the challenges and the opportunities represented by borders.

While the Ambos Nogales case study demonstrates the importance of adopting a holistic approach to bi-national environmental cooperation, it also demonstrates that comprehensive transborder environmental management in the Ambos Nogales area has been impeded by a lack of the kinds of informational, technological and financial resources local communities need to diagnose, analyze, understand and resolve environmental problems at the grassroots level, where these problems are experienced most intensely and where the drive to correct them is greatest.

Although great differences exist in terms of their historic and current capacity, effectiveness and influence, both national and locally-based nongovernmental environmental and social organizations in Mexico and in the U.S. are now beginning to play an increasingly important role in the formation of environmental policy in the border region. If environmental problems along the border are to be treated in the most effective manner possible, governments in both the United States and Mexico must create the means to empower grassroots actors to act effectively on their own behalf. Successful bilateral management of water resources will involve increasing the capacity of grassroots actors, particularly on the Mexican side of the border, to mobilize and to operate effectively in the political arena. Governments must also find ways to create and foster bi-national linkages among grassroots actors in both nations and among grassroots groups and the government representatives and agencies involved in environmental decision-making in the border region.

Endnotes

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[2] A. T. Wolf and J. H. Hamner, Department of Geography, University of Alabama, Tuscaloosa, Alabama. *Trends In Transboundary Water Disputes And Dispute Resolution,* http://www.gci.ch/GreenCrossPrograms/waterres/middleeast/wolf.html
[3] See, for example, S. P. Mumme, "Clearing the Air: Environmental Reform in Mexico," *Environment,* December 1991, 6.
[4] *U.S. Statutes at Large* 59 (1945): 1219. Further details may be found in A. E. Utton, "Mexican International Waters," in R. E. Beck, ed., *Waters and Water Rights,* vol. 5, part 9 (Charlottesville, VA: The Michie Company, 1991) chapter 51.
[5] The mean annual flow of the Colorado River was greatly overestimated, however. See C. W. Stockton and G. C. Jacoby, "Long-Term Surface Water Supply and Streamflow Levels in the Upper Colorado River Basin," *Lake Powell Research Project Bulletin,* no. 18 (Los Angeles: Institute of Geophysics and Planetary Physics, University of California, 1976); and C. W. Stockton and W. R. Boggess, "Augmentation of Hydrologic Records Using Tree Rings," *Improved Hydrologic Forecasting: Why and How* (Pacific Grove, Calif.: American Society of Civil Engineers, 1980), 239-65.
[6] The full acronym is IBWC/CILA. CILA stands for the Comisión Internacional de Limites y Aguas, which is the Mexican section of the binational commission.
[7] The National Water Commission reports that, all along the border, towns and cities can adequately treat less than 35 percent of the sewage generated and that nearly a third of the population live in dwellings that are not connected to the sewer system. G. Thompson, "Chasing Mexico's Dream Into Squalor," *The New York Times on the Web,* February 11, 2001. http://www.nytimes.com/2001/02/11/world/11BORD.html.
[8] D. M. Liverman et al. "Environmental Issues Along the US-Mexico Border. Drivers of Change and Responses of Citizens and Institutions." *Annual Review of Energy and the Environment* vol. 24. (1999).
[9] Of this total, approximately 21,000 reside in Nogales, Arizona while 350,000 reside in Nogales, Sonora. Data from Nogales Chamber of Commerce website, http://www.nogaleschamber.com/ambosnogo.html
[10] T. Sprouse and L. Farrow, note 1 above.
[11] D. T. Patten, J. C. Stromberg and M. R. Sommerfeld (n.d.) *Water and Riparian Resources of the Santa Cruz River Basin: Best management Practices for Water and Resource Quality. Final Report, SCERP project Number: WQ93-12.* http://www.scerp.org/scerp/projects/WQ93-12.html
[12] On an annual basis, the facility contributes 32 percent of the Santa Cruz's flow downstream of the plant. Duncan Patten, director, Center for Environmental Studies, Arizona State University, Tempe, personal communication with the authors, December 1993.
[13] D. T. Patten, J. C. Stromberg and M. R. Sommerfeld, note 11 above.
[14] Arizona Department of Water Resources (ADWR), *Third Management Plan for the Santa Cruz Active Management Area.* Phoenix: Arizona Department of Water Resources, 1999, as cited in T. Sprouse and L. Farrow, note 1 above.
[15] M. Davidson, *APF Reporter* Vol. 19, no. 1 (1998). Miriam Davidson, a correspondent for the Arizona Republic, has been examining public health and environmental issues in the town of Ambos Nogales with the assistance of a grant from the Alicia Patterson Foundation. http://www.aliciapatterson.org/APF1901/Davidson/Davidson.html)
[16] T. Sprouse and L. Farrow, note 1 above.
[17] G. Sjöstedt, ed., International Environmental Negotiation (Newbury Park, Calif.: Sage Publications, 1993).
[18] R. DeVito and J. Wambsganss, "Maquilas and NAFTA: Implications of a Free Trade Microcosm," *Journal of Borderlands Studies* 8, no. 2 (Fall 1993): 105-20.
[19] J. Dougherty and D. Holthouse, "The New World Border: The Maquiladora Industry Has Transformed Nogales Sonora," Tucson Weekly, 11/19/98. http://www.tucsonweekly.com/tw/11-19-98/feat.htm.
[20] G. Thompson, note 7 above. Minimum wages vary in Mexico in relationship to the type of job. Beginning January 1, 2001, the minimum wage in Mexico was set at 40.35 pesos, or about $4.21 per day, an increase of about

6.5 percent from the former rate. Associated Press; The San Diego Union-Tribune (Dec. 22, 2000) "Mexico sets small increase in country's meager minimum wage." http://home.earthlink.net/~surferslim/mexwage.html

[21] G.B. Frisvold and M.F. Caswell (2000). "Transboundary water management. Game-theoretic lessons for projects on the US-Mexico border." Agricultural Economics 24, 101-111.

[22] S. A. Mier, *Final Report: Evaluation of HRSA Sanitarian Assignment in Nogales, Arizona, Executive Summary,* 1996. http://158.72.105.163/borderhealth/mier.htm#issues. According to Mexico's census figures, the population of Nogales, Sonora in the year 2000 stands at 159,787. Unofficial estimates of the actual population, however, range from 200,000 to 400,000.

[23] J. Dougherty and D. Holthouse, note 19 above.

[24] G. Thompson, note 7 above.

[25] Jim Robinson 1999, as cited in T. Sprouse and L. Farrow, note I above.

[26] United States Environmental Protection Agency, *US-Mexico Border XXI Program, Framework Document.* Washington, DC: United States Environmental Protection Agency, 1996, as cited in Sprouse and Farrow, note 1 above.

[27] The IBWC estimates the useful life of water supply and wastewater removal systems to be approximately thirty years. Water losses from breaks and leaks in the Nogales, Sonora system are estimated to be at 51.2 percent of the total volume and CAN reports 7000 leaks in the system annually. T. Sprouse and L. Farrow, note 1 above.

[28] Fundación México-Estados Unidos para la Ciencia, The United States-Mexico Foundation for Science, "Water and Health at the U.S.-Mexico Border Science, Technology and Policy Issues," *Proceedings from the Workshop that took place at El Colegio de la Frontera Norte, Tijuana, Baja California June 23-25, 1997.* http://www.fumec.org.mx/water_health/background.html

[29] J. Dougherty and D. Holthouse, note 19 above.

[30] D. M. Liverman et al, note 8 above.

[31] In 1993, a class-action lawsuit against the owners of five maquiladoras in Matamoros, Chihuahua, was filed by eight families in Brownsville, Texas, who alleged that groundwater contamination due to the solvents used in the U.S.-owned firms was responsible for the birth of their anencephalic children. The rate of anencephaly in Brownsville is reported to be three times the national average, with 126 cases reported from 1980 to 1992. J. Dougherty and D. Holthouse, "Nogales Is An Environmental Nightmare. Nature respects geographic boundaries, not political ones." *Tucson Weekly,* November 19, 1998. http://www.tucsonweekly.com/tw/11-19-98/feat.htm.

[32] S. A. Mier, note 22 above.

[33] D. M. Liverman et al, 1999, note 8 above.

[34] S.A. Mier, note 22 above.

[35] United States Environmental Protection Agency. (2000). "Finding of No Significant Impact: Nogales, Sonora Water System Improvements." http://www.epa.gov/region09/water/nogales/waterfnsi.html

[36] M. Davidson, note 15 above.

[37] H. Ingram, N. Laney and D. Gilliland. (1995). Boundary Waters: Bridging the U.S.-Mexican Border. Tucson, AZ: University of Arizona Press.

[38] B.J. Morehouse, R. H. Carter and T. W. Sprouse, "The Implications of Sustained Drought for Transboundary Water Management in Nogales, Arizona and Nogales, Sonora," *Natural Resources Journal* 40,4 (Fall 2000): 783-817.

[39] D. M. Liverman et al, note 8 above.

[40] P. Ganster. "Sergio Reyes Luján: Mexico's Environmental Leader," *Mexico Policy News* 9 (Fall 1993): 23-25.

[41] H. M. Ingram and S. M. Levesque, "The NAFTA Institutions and Beyond".

[42] D. M. Liverman et al, note 8 above.

[43] H. M. Ingram and S. M Levesque, note 41 above; D. M. Liverman et al, note 8 above.

[44] NADBank, 20 October 1998. *NADBank News* 2:23, http://www.nadbank.org/; Border Environment Cooperation Commission, Projects, 20 November 1998, http://cocef.interjuarez.com/; D.M. Liverman et al, note 8 above.

[45] Border Environment Cooperation Commission and North American Development Bank, see note ** above.

[46] H. Ingram, N. Laney and D. Gilliland, note 37 above.

[47] D. M. Liverman et al, note 8 above.

[48] Arizona law provides that waters "of all sources, flowing in streams, canyons, ravines or other natural channels, or in definite underground channels... belong to the public and are subject to appropriation and beneficial use..." However it has not been clear whether the language of the law applied to groundwater or only to surface water. J. D. Leshy and J. Belanger, 1988, "Arizona law where ground and surface water meet," *Arizona State Law Journal,* 20, 657. A 1953 court decided that the prior appropriation doctrine did not apply to groundwater, which meant that

senior surface water rights could be negatively impacted by groundwater pumping with no recourse for the surface water right holders. This legal separation of surface and subsurface water rights has significantly affected the Santa Cruz and San Pedro watersheds. R. J. Glennon and T. Maddock, III, 1994, "In search of subflow: Arizona's futile effort to separate groundwater from surface water," *Arizona Law Review,* 36(3), 567. While a 1988 court decision did grant surface water rights holders protection from depletion caused by groundwater extraction, a 1993 case provided that surface water was linked only to groundwater that flows adjacent to or directly below a body of surface water, a ruling that ignores the fact that groundwater pumping at a distance away from a body of surface water can interrupt or redirect flows that would eventually reach the river.

[49] *IBWC Commission Report 1998.* http://www.ibwc.state.gov/ORGANIZA/BIENRPRT/95_98_Org_Report/95_98_org_report.html

[50] P. Orianne, *Difficulties in Cooperation Between Local Authorities and Ways of Solving Them,* Study no. 6, Local and Regional Authorities in Europe (Strasbourg, France: Council of Europe, 1973), as cited in C. G. Alger, "Bridging the Micro and the Macro in International Relations Research," *Alternatives* 10 (Winter 1984-85): 319-44.

[51] H. M. Ingram and S. M Levesque, note 41 above.

[52] To encourage a higher level of participation on the part of Mexican environmental NGOs and community-based organizations, the C.S. Mott Foundation and the Ford Foundation have supported a series of annual meetings on the border environment (Encuentro Annual Sobre El Ambiente Fronterizo), tailored to the needs of nongovernmental and community-based organizations and aimed at capacity building. Nearly 80 Mexican border groups attended the inaugural session, which took place in March 1998. This both confirms the rapid growth and vitality of the Mexican sector and suggests a greater future influence in environmental policy-making processes in Mexico. D. M. Liverman et al, note 8 above. See also H. M. Ingram and S. M Levesque, note 41 above.

[53] S. Graves, "Structuring Public Participation in a Binational Institution Citizen Activism and BECC Policymaking," *borderlines* 53, 7, 2 (February 1999). See also H. M. Ingram and S. M Levesque, note 41 above.

[54] D. M. Liverman et al, note 8 above. See also H. M. Ingram and S. M Levesque, note 41 above.

[55] H. M. Ingram and S. M Levesque, note 41 above.

[56] P. Doughman, "Discourses and Water in the U.S.-Mexican Border Region," in J. Blatter and H. Ingram, (Eds.), *Reflections on Water New Approaches to Transboundary Conflicts and Cooperation,* Cambridge, MA: MIT Press, (2001); BECC (Border Environment Cooperation Commission), *BECC Project Certification Criteria,* Ciudad Juárez, Mexico: Border Environment Cooperation Commission, (1996). See also H. M. Ingram and S. M Levesque, note 41 above.

[57] S. M. Levesque, "the Yellowstone to Yukon conservation Initiative: Reconstructing Boundaries, Biodiversity, and Beliefs," in J. Blatter and H. Ingram, (Eds), *Reflections on Water New Approaches to Transboundary Conflicts and Cooperation,* Cambridge, MA: MIT Press (2001). H. M. Ingram and S. M Levesque, note 41 above.

[58] S. Graves, note 52 above. H. M. Ingram and S. M Levesque, note 41 above.

[59] A. Hughes, Rural Health Office and Arizona Telemedicine Program, Arizona Health Sciences Center, *Connecting Arizona's Enterprise Communities. Strategic Plan and Resource Guidefor Telemedicine and Internet Connections,* (1998), Tucson, Ariz: University of Arizona. http://zeki.radiology.arizona.edu/ruralhealth/AROp1.htm.

[60] J. Dougherty and D. Holthouse, note 19 above.

[61] These include the 1944 treaty (see note 3 above) and related law creating the IBWC, and the La Paz Agreement of 1983, also known as the Reagan-de la Madrid accord.

[62] "North American Agreement on Environmental Cooperation Between the Government of the United States of America, the Government of Canada, and the Government of the United Mexican States," in *Message from the President of the United States Transmitting North American Free Trade Agreement Supplemental Agreements and Additional Documents,* 103rd Cong., 1st sess., 1 November 1993, H. Doc. 103-160. For a critique, see M. E. Kelly, *NAFTA's Environmental Side Agreement: A Review and Analysis* (Austin, TX: Texas Center for Policy Studies, September 1993). See also D. Magraw, "NAFTA's Repercussions: Is Green Trade Possible?" *Environment,* March 1994. 14.

[63] The *Administrative Order to Comply with the Clean Water Act: Docket No. CWA-309-IX-01-08* was sent to the attention of John Bernal, U.S. Commissioner International Boundary and Water Commission, U.S. Section, El Paso, TX, and was dated January 26, 2001. H. Kitching "Wash is international problem, IBWC manager here says," *Nogales International,* February 8, 2001; H. Kitching, "Supervisors back down on wash help resolution," *Nogales International,* February 8, 2001.

[64] Mumme, note 3 above.

[65] S. Graves, note 53 above. See also H. M. Ingram and S. M Levesque, note 41 above.

[66] H. M. Ingram and S. M Levesque, note 41 above.

[67] M. Kelly, *Facing Reality: The Need for Fundamental Changes in Protecting the Environment Along the U.S./Mexico Border* (Austin, Tex.: Texas Center for Policy Studies, 1991). See also H. M. Ingram and S. M Levesque, note 41 above.
[68] J. Blatter, H. Ingram and S. L. Levesque, "Expanding Perspectives on Transboundary Water," in J. Blatter and H. Ingram, (Eds.), *Reflections on Water New Approaches to Transboundary Conflicts and Cooperation,* Cambridge, MA: MIT Press, (2001).
[69] P. Doughman, note 56 above.
[70] R. Perry, J. Blatter and H. Ingram, "Lessons from the Spaces of Unbound Water," and M. R. García-Acevedo, "The Confluence of Water, Patterns of Settlement, and Constructions of the Border in the Imperial and the Mexicali Valleys (1900-1999)," in J. Blatter and H. Ingram, (Eds.), *Reflections on Water New Approaches to Transboundary Conflicts and Cooperation,* Cambridge, MA: MIT Press, (2001).

Changes in Trade Policy and Wastewater Emissions for a Border Watershed

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Introduction

The North American Free Trade Agreement (NAFTA) is the first regional trade agreement to formalize a trade and environment agenda. Have the changes in trade policy due to the NAFTA helped solve environmental problems along shared borders of NAFTA countries? This paper provides an answer to this question for assisting in policy assessment in addition enhancing the trade and environment literature by studying empirically transboundary water pollution in a dynamic setting with asymmetries between the U.S. and Mexico. The existing theoretical trade and environment literature investigates static impacts of transboundary pollution (Copeland and Taylor, 1997) or domestic pollution in a dynamic context (Chichilnisky, 1994). The empirical literature is static and concerns pollution within a country not transboundary pollution [(Anderson and Blackhurst, 1992), (Grossman and Krueger, 1992)].

While there exists trade analyses of Mexico, most are at an aggregate level using computable general equilibrium analysis that does not clearly connect the trade changes to actual pollution effects at the border affecting both countries over time [(Beghin et al., 1993), (Roland Holst et al, 2000)]. Grossman and Krueger (1992) consider the impact of environmental regulation on the composition of value-added generated in Mexico's maquiladora sector and the composition of U.S.-Mexico trade. The existing studies of transboundary pollution have not made clear connections to trade policy changes and impacts these changes might have to pollution over time and space. Missfeldt (1999) provides a review of the transboundary pollution literature. This paper is significant since there has been little empirical work that investigates the trade and environment interface using economic models with scientifically sound environmental linkages for the damage functions and pollution variables.

The U.S.-Mexico share almost 2,000 miles of an international border that stretches from the Pacific Ocean in the west to the Gulf of Mexico in the east. More than half of this boundary (1244 miles) is delineated by the Rio Grande. For the past three years, the Rio Grande has been named the most polluted river in North America. Transboundary wastewater contributes to the pollution in the river. Transboundary wastewater pollution concerns water-borne waste that crosses international political boundaries as a result of natural water flow. The source of this pollution is from treated and untreated wastewater emissions from cities lining the Rio Grande. Two neighboring cities, Ciudad Juarez (Mexico) and El Paso (U.S.) at the beginning of the Rio Grande's border reach, are similar to cities along the entire stretch of the border with continuous population growth and less than complete sewerage. The flow of the river here is dominated by wastewater flow (TNRCC, 1994). Upstream of these two cities a significant portion of the flow is withdrawn for irrigation purposes. Ciudad Juarez lacks any municipal treatment plant so domestic and commercial sewage flows in an open sewer that seeps into the floodplain of the Rio Grande. Both El Paso and Ciudad Juarez lack complete sewerage for residents living in colonias that are unsewered and rely on the Rio Grande for their water supply and use if for recreational swimming. Public health effects from waterborne illnesses are beginning to be documented in these areas (Lopez and Byrne, 1996). The environmental impacts consist of habitat degradation

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and public health effects from untreated and uncollected sewage in border waterways that serve as recreational waters and as a source of drinking water.

To maintain water quality in the shared waterway, coordination of wastewater treatment efforts by the U.S. and Mexico may be explored as a remedy. The potential for coordination is linked to economic activities such as trade that gives rise to the emissions affecting water quality in the waterway. One major change in economic activity between the U.S. and Mexico is the increase in international trade brought about by the NAFTA. Both sides seek to improve their economic activity through trade. El Paso and three other cities along the Rio Grande in Texas have the four lowest per capita incomes in the U.S. In the case of El Paso, which has a concentrated textile industry, one aspect of NAFTA entails removing a U.S. quota on imported cotton. The quota has been a quantity restriction on cotton imported from other countries in order to support the U.S. industry with a higher price for cotton than the world price. The U.S. cotton industry has been plagued by a number of pest problems and supply has not been terrific for consistent supply to the textile industry such as in El Paso. The ability to obtain cotton from other sources like Mexico would be ideal. The import quota serves to insulate the domestic cotton market from other countries. Once the quota is eliminated, more can be supplied by Mexico to satisfy the demand for cotton from the U.S. clothing industry. One reason why Mexico can meet this demand is because it does not have the boll weevil pest problem that the U.S. does and production sites are close to the U.S. In fact, cotton acreage in Mexico is a few miles across the border from the clothing industry in Texas. Both countries benefit since more is supplied at a lower price and Mexico is able to earn trade revenues.

Due to scarce fresh water resources, wastewater would be an attractive alternative to use as an input to produce the cotton. The possibility of using pollution such as reclaimed wastewater as an input to producing a traded good, creates an incentive to internalize the environmental externality of wastewater in the border waterway. Demand for Mexico's cotton creates a demand for reclaimed wastewater to be used to produce cotton. The proximity of cropping areas to urban areas means delivery of reclaimed water for irrigation is possible. Mexico's actions of reclaiming wastewater for cotton production affects the pollution in the shared border waterway between the U.S. and Mexico. If wastewater is reclaimed, it is not emitted to the waterway (directly or via the floodplain). Mexico is thereby helping improve water quality in the shared waterway by reclaiming wastewater and earning trade revenues.

The preceding border story can be translated into the costs and benefits involved in handling wastewater problems in this setting and used in a model that explores possible strategies for pollution control under the following options:

1) Trade liberalization and bilateral cooperation in pollution control
2) Trade liberalization and unilateral pollution control
3) restricted trade and bilateral cooperation in pollution control
4) restricted trade and unilateral action

Cooperation for pollution control may consist of a mutual target of stock pollution levels both countries agree to or institutional arrangements for bilateral decisions of each country's wastewater emissions. Institutions such as the North American Development Bank and the Border Environmental Cooperation Commission established under NAFTA are carrying out cooperation in terms of bilateral funding and decisionmaking, respectively, of environmental improvement projects along the border as well as technology transfer and shared pollution monitoring responsibilities between the U.S. and Mexico. Financial resources are designated for projects that are proposed for bilateral benefit such as in the case of mitigating wastewater discharges into the Rio Grande. These resources are seen as helping deal with environmental problems beyond what trade revenues could do. The watershed examined here is one among many where cooperation means deciding on how much to abate through the environmental projects approved and funded by the binational institutions.

This analysis will highlight how significant these NAFTA institutions are in handling wastewater problems by identifying the difference between independent action by each country (noncooperative solution) and cooperative action (cooperative solution) of the binational institutions jointly deciding how much pollution to abate through border environmental projects. The strategies for dealing with wastewater under each of the four scenarios listed above will be defined in terms of the cost and benefit incentives for pollution control and the resulting impact on water pollution in the river.

Although full cooperation is considered the optimal equilibrium [(Maler, 1992), (Barrett, 1992)] compared to noncooperation, the net gains are asymmetric between countries and this study explores these asymmetries empirically. The empirical analysis investigates what each individual country's marginal benefits and marginal costs are that make the cooperative case more attractive than the noncooperative case.

Model

The model is interactive and dynamic. It is interactive because more than one decisionmaker is included (a game theory model). Game theory enables us to present the nature of the problem of bilateral cooperation over investment in wastewater treatment for each border city (in the U.S. and in Mexico) in the presence of a dynamic phenomenon like water pollution in the river. With cooperation, both countries objectives are summed up and constrained by the equation defining the stock of pollution. In order to determine where the two countries will end up as a result of unilateral action for the transboundary wastewater problem, solutions to the noncooperative game are explored and compared to cooperation. Without cooperation, each country concerns itself with its own decision of weighing benefits and costs from wastewater control. In either case, each country's decision is constrained by what is happening in the waterway that can be depicted by a differential equation of the pollution.

The decisionmakers in this bilateral transboundary pollution game are the public resource management agencies for each country's border city in charge of addressing wastewater emissions. In the empirical application of the model there is a public resource agency for each country sharing a U.S.-Mexico border waterway into which both countries discharge wastewater emissions. It is plausible for the agencies to set the level of wastewater treatment and reclamation for agricultural use due to the history of bilateral treaties (in 1906 and 1944) with a formal hierarchy of allocation of potable water through centralized distribution to the urban setting and reclamation of wastewater for agricultural and landscape (golf course) use (Mumme, 1999). The agricultural sector is supportive of the resource agencies' actions to provide irrigation water (Chavez, 1999).

The objective of the resource management agency in each country is to choose pollution control strategies through the three types of emissions that maximize the discounted stream of net benefits over an infinite planning horizon. The three types of emissions indicate implicitly the level of wastewater treatment the resource management agency chooses. The choice of treatment as a function of emissions is a realistic choice variable for a public resource agency handling wastewater emissions. The objective is subject to the pollution dynamics in the waterway. It is possible to characterize the cooperative and noncooperative pollution control strategies.

Each country chooses the amount of different wastewater emissions overtime that equate marginal costs and marginal benefits. The marginal units are of interest in order to account for incremental changes in costs and benefits due to an increase or decrease in the amount of pollution. The different wastewater emissions are T = treated wastewater, U = untreated wastewater, and R = reclaimed wastewater. The distinction between treated, untreated and reclaimed wastewater emissions means an implicit choice of a level of treatment for wastewater. There are integrals to calculate the net benefits which subtracts the costs of abating pollution, TC, and damages, D, from the pollution from the benefits of production that results in some emissions, π. Mexico earns benefits from the possibility of trading cotton too, denoted by the term A(R).

The U.S. earns benefits from the textile production that is directly tied to the cotton produced by Mexico reclaiming wastewater. The U. S. and Canada have removed import quotas on cotton and lowered tariffs on textile and apparel items from Mexico (gradually the preferential tariffs will become zero) according to updates to the rules of origin of a product within the NAFTA countries (James and Umemoto, 2000). The tariff under U.S. customs laws Item 807 of the Tariff Schedules of the U.S. have been changed (U.S. Customs Service, 1997). Though the rules of origin have been criticized for their protectionist effects amongst the trading partners, especially by Krueger (1999), in principle, they can lead to an improvement in efficiency by reversing the trade-diverting effect of a tariff preference on the final good [(Panagariya, 2000),(Ju and Krishna, 1998)]. Goods assembled in Mexico from source materials made in the U.S. are treated preferentially, since they are only subject to duties on a portion of the product's value added during assembly in Mexico. The duty is assessed upon the full value of the imported item less the cost or value of such products of the U.S. (U.S.C. 1202). Hence, cotton textile production takes place in the U.S. and then has the potential to be shipped to Mexico for assembly. In the case of cotton denim blue jeans, cotton from the U.S. is woven into denim and dyed and cut into pieces for assembly (sewing into pants) in Mexico. The apparel is then reimported into the U.S. under tariff item 807. A separate finishing stage of the jeans apparel industry in the coproduction relationship between the U.S. and Mexico has shown evidence of remaining competitive with the rest of the world's textile and apparel production, specifically from Asia (James and Umemoto, 2000).

The NAFTA further induced change for an industry already on the move to focus on minimizing the labor costs for the labor-intensive finishing processes (Abel and Phillips, 2000). Throughout the 1990's there has been an expansion of what the finishing stage includes. For example, the labor and water-intensive stonewashing for dying cotton destined for blue jeans apparel has become part of the finishing stage. Abel and Phillips (2000) looked at the relocation of El Paso's garment stonewashing industry and observed various reasons for relocation apart from rules under NAFTA and environmental consideration. While in 1993 there were greater than 25 stonewashing finishing apparel businesses consuming 5% of El Paso's total water demand (5.2 million gallons per day), in late 1990's, there were less than six (1.2 million gallons per day) (Abel and Phillips, 2000). Many have moved to locations southwest of Ciudad Juarez. Pretreatment requirements placed on the industry in El Paso have had a lasting impact on the industry's attention towards treating water emissions and participating in wastewater reuse strategies and water savings at the new locations in Mexico. For example, the projections that the Hueco Bolson aquifer will be overdrawn by 2025 has led to implementing strategies for water and wastewater reuse for industries including the textile and garment sector (El Paso Municipal Code 15. Abel and Phillips (2000) provide a qualitative discussion of the expansion and contraction of the stonewashing industry and the environmental impact of the industry in El Paso. Their study documents that relocated stonewashing plants set up their own wastewater treatment in Mexico. For example, in Torreon, where several stone washing finishing plants have moved, there are 15 wastewater facilities to receive the pretreated wastewater from the stone washing plants and other industries in order to reuse the water to irrigate green spaces (Abel and Phillips, 2000). They did not find that the industry shifted to take advantage of less strict environmental rules. It is important to take into account both the trade revenues and wastewater pollution abatement costs associated with the various stages of cotton textile and apparel to account for the border watershed impacts. The movement in the industry can be seen as alleviating the pressure on the border's scarce water resources and fostering more wastewater treatment and reuse technology on both sides of the border (Abel and Phillips, 2000).

These textile trade changes are taken into account in the model with a shift over time in the U.S. textile benefit term to be shared with Mexico. This is due to a change in the reimportation laws under NAFTA of finished products, the ability to finish the cotton apparel in Mexico and reimport it into the U.S. leads to further benefits and wastewater treatment efforts by Mexico. Both benefits and costs are functions of the different types of emissions.

Both countries face the dynamics of pollution occurring in the river that is expressed as a differential equation of how pollution enters and changes in the river. Pollutants in wastewater emissions are a stock that persists in the waterway once discharged. Equation (3) indicates the water quality equation for the model. The total pollution in the river changes according to the difference between the amount that flows in minus the amount that flows out. The equation contains a component of what is in the river, the degradation of the pollutant, the inputs from each country in different forms (treated, untreated). The amount that is reclaimed is diverted from the wastewater treatment plant after treatment for reuse; reclaimed emissions never enter the waterway (R_S, R_M never enter the river pollution equation (3)).

U.S. Objective

$$(1)\quad \max_{T_S, U_S, R_S} \int_0^{\infty} e^{-rt}[\pi_S(T_S(t), U_S(t), R_S(t)) + F(A(R(t))) - TC(T_S(t), R_S(t)) - D_S(P(t), U_S(t))]dt$$

Mexico Objective

(2)

$$\max_{T_M, U_M, R_M} \int_0^{\infty} e^{-rt}[\pi_M(T_M(t), U_M(t), R_M(t)) + A(R_M(t)) - TC(T_M(t), R_M(t)) - D_M(P(t), U_M(t))]dt$$

Constraint of Pollution in the River

$$(3)\quad \dot{P}(t) = Z + \beta_0 Q(t) + \alpha P(t) + \beta_1 T_S(t) + \beta_2 U_S(t) + \beta_3 T_M(t) + \beta_4 U_M(t)$$

where P(t) equals the stock of accumulated pollutants, $\alpha P(t)$ equals the rate of pollutant decomposition proportionate to the existing stock, Z is an intercept accounting for background pollution in the river and floodplain feeding the river, Q is water flow from upstream, β_0 is the pollutant concentration of the upstream flow, and $\beta_1, \beta_2, \beta_3, \beta_4$ are parameters of the pollutant concentrations in the treated (T_S, T_M) emissions from the U.S. and Mexico respectively and untreated (U_S, U_M) emissions from each country entering the waterway directly or via the floodplain. Reclaimed flows $R_i(t)$ do not enter the waterway. Instead they are diverted from the treatment plant to be reused. From equation (1) it is clear that P will increase as T_S, T_M, U_S, U_M increase. Due to scarce fresh water resources in the area, wastewater that receives treatment can augment water supplies for irrigation and non-potable uses.

The preceding three equations can be used to characterize all four scenarios that are of interest to compare. For example, for the case of cooperation with trade liberalization, both equations (1) and (2) are summed up to represent the cooperative, joint decisions by both the U.S. and Mexico to maximize net benefits of pollution control subject to the pollution dynamics from the wastewater emissions. Both the cotton revenues and textile revenues from having changes in trade policy due to NAFTA (the elimination of the cotton quota and the reduction in the tariff for reimported goods) are included in the sum of net benefits to represent trade liberalization. Alternatively, if the countries are making decisions on their own, the U.S. would be focused on maximizing its benefits in equation (1) subject to pollution dynamics of equation (3) and Mexico, independently, would be focused on maximizing its benefits in equation (2) subject to equation (3). With trade liberalization and noncooperation, the terms, F(A(R(t))) for the textile revenues the U.S. can earn from production based on cotton imports from Mexico and A(R(t)), the revenues Mexico earns from producing cotton with reclaimed wastewater and trading the cotton to the U.S. are included as trade benefits for the cooperative and noncooperative games. When there is no trade liberalization, both terms are set to zero, since trade restrictions would prevent the possibility of these revenues being generated for both cooperation and noncooperation.

In order to explore the magnitude and asymmetric differences between the U.S. and Mexico, it is necessary to numerically simulate this model by calibrating it with parameters from available data that helps to estimate realistic functional relationships of trade revenues from textile and cotton production, costs of wastewater treatment, public health damages and pollution dynamics. This simulation provides a sensitivity analysis of how the cooperative and noncooperative strategies for wastewater treatment change with changes in model parameters that indicate changes in international trade and changes in environmental damages. Fernandez (2001) provides a complete description of the derivation from the three equations above of the mathematical system of equations for all four of the simulations as well as the empirical estimation of parameter values.

Data

Calibration of the model is based on existing data for costs of wastewater treatment and reclamation, water quality measures, epidemiological surveys of illnesses associated with wastewater pollution and the economic value of production of traded goods for transboundary pollution in the Rio Grande waterway that is the U.S. – Mexico border between El Paso, Texas and Ciudad Juarez, Chihuahua. By using such data, it is possible to provide realistic solutions to pollution problems that the public resource management agencies for each border municipality faces.

Table 1 Parameter Values

Parameter	Description	Value	Std. Error
α	Decay rate	0.002	
β_1	TSS concentration in treated emissions (U.S.)	5 mg/l	
β_2	TSS concentration in untreated emissions (U.S.)	800 mg/l	
β_3	TSS concentration in treated emissions (Mexico)	5 mg/l	
β_4	TSS concentration in untreated emissions (Mexico)	900 mg/l	
z	intercept in state equation	0.22	
π_S	benefit function for U.S.	1.38×10^6	1.17
π_M	benefit function for Mexico	1.37×10^6	.92
C_S	cost function for U.S.	2.03×10^{-5}	$.15 \times 10^{-7}$
C_M	cost function for Mexico	1.73×10^{-5}	$.06 \times 10^{-7}$
D_{1S}	damage function for U.S.	4318	
D_{2S}	damage function for U.S.	13893	
D_{1M}	damage function for Mexico	299.45	
D_{2M}	damage function for Mexico	862.23	

The state equation (3) defines the change in the index of pollutants in the Rio Grande over time. Total suspended solids (TSS), a measure of the organic and inorganic solids, serves as the index of pollutants. The aim is to express the relationship between the existing concentration of TSS in the waterway and the wastewater emissions added to the floodplain and waterway in each period. The concentrations of TSS for treated and untreated emissions from both countries are referenced from water quality data from the 1992-93 bilateral monitoring project along the Rio Grande (IBWC, 1994). The concentration for the reclaimed wastewater emissions is obtained from measures of reclaimed flows in El Paso and the proposed reclamation plans for Ciudad Juarez [(EPWUPSB, 1992),(IBWC, 1994)]. The intercept and decay term α are obtained with information from a dynamic and spatial analysis of the volume of the reach of the river and floodplain around El Paso and Ciudad Juarez and the change in P from upstream and downstream of the river reach. The choice of TSS is useful since it not only can be tied directly with all types of wastewater emissions entering the waterway, but also with public health effects that are considered environmental damages from the transboundary pollution.

The benefits function consists of the monetary figures for value added from commercial and industrial production in El Paso and Ciudad Juarez. I have estimated the parameters by regressing total emissions on value added for available years. The coefficients π_S and π_M in the benefits functions are estimated for the U.S. and Mexico respectively by regressing each country's value added for aggregate production on each country's sum of weighted wastewater emissions [(INEGI, 1995), (U.S. Dept. of Commerce, 1996)]. The coefficients for each type of emissions are the concentrations of TSS.

Revenues from the export of cotton by Mexico to the U.S. constitute the additional component of Mexico's net benefits when trade is liberalized and the quota on cotton is removed. The parameter, A, in the benefit function of reclaimed water for cotton production, $A(R_M)$, is obtained through a cotton production function that identifies how much water is used to produce cotton (Schulthies and Williams, 1992). To arrive at a figure that indicates the value of marginal production per unit of reclaimed water used as an input, net benefits per hectare are divided by the amount of liters of reclaimed water per hectare used to produce cotton. Dividing \$1366.66/HA by 104.88 l/HA, gives a value of net benefits: \$13/liter or 13R. The cotton production function includes inputs besides water (reclaimed water), such as labor and seed. The labor input will be useful for an additional result of the model which explores the amount of employment created by reclaiming water for cotton production.

Textile revenues from the additional cotton that are represented in the U.S. net benefits as F(A(R)) are estimated through regressing 1990-1996 data from the United Nations Commodity Trade Statistics for textile values derived from imported cotton on the quantity of cotton and indirectly reused water as described in A(R) estimation. The tariff rates between Mexico and the U.S. are also taken into account.

The parameters in the cost function for wastewater treatment in each country are obtained with data from existing facilities in El Paso and projections on future facilities in Ciudad Juarez. There are 18 year projections of fixed and variable costs for wastewater treatment and water reclamation from 1992-2010 provided by the El Paso Public Utilities Authority, Texas Water Development Board, and Junta Municipal de Aguas y Sanamiento de Ciudad Juarez [(EPWUPSB, 1992),(JMAS, 1994)]. All monetary values of costs are in constant 1992 million dollars. The data for the U.S. consist of existing treatment expenditures for the projected volume of industrial and domestic sewage over time as well as adding new treatment units for unsewered neighborhoods called colonias (EPWUPSB, 1992). The costs also include pretreatment costs for enforcement and monitoring and source reduction at industrial sites. Estimates of costs for Mexico are from projections for plants to be constructed to treat wastewater emissions flowing in an open canal from the municipal domestic and industrial sources. Currently Ciudad Juarez has no wastewater treatment [(Degremont, 1995), (JMAS, 1994)]. The costs of reclaiming the water are also included since this consists of an extra stage of treatment at the treatment plant to reuse the wastewater emissions.

Valuation of damages is accomplished using an epidemiological survey of residents in six residential areas, colonias, that are unsewered without water connections adjacent to the Rio Grande around El Paso and Ciudad Juarez to delineate the relationship between human exposure to TSS levels through water supply for drinking and washing as well as recreational use and the incidence of gastrointestinal illnesses, angina, respiratory illnesses, and pneumonia [(Lopez and Byrne, 1996),(Lopez, 1995)].

Total suspended solids serve as an indicator of pathogens and water-borne viruses causing public health problems. The data consist of water quality measures in shallow wells used for water supply and water quality measures from the river used for bathing and swimming. The wells are shallow and draw water from the Rio Grande floodplain, which is contaminated with waste (Lopez and Byrne, 1996). Since organically dense wastewater harbors waterborne pathogens and viruses that lead to gastrointestinal illnesses and other public health problems, it is possible to estimate the frequency and duration of illnesses with pollutant levels in the wells and area of swimming. The epidemiologists estimated relationships between ambient pollution and illnesses in a dose-response manner (Lopez and Byrne, 1996).

A unit cost of the physical damage that included medical care expenditures and lost wages for the percentage of population with the illnesses is applied to the estimated relationship. Monetary values of the damages are found through a method to assign the costs of illness. The cost of illness assigns a unit cost to the physical damage to convert it into monetary terms (Freeman, 1993). The unit cost includes medical care expenditures and lost wages from people not working due to the illnesses.

There are two sources of public health damages for the analysis. The first source is the stock variable, P. The second source is the flow variable of untreated emissions, U. The damage associated with P arises from well water supplying potable water for residents of the unsewered colonias on either side of the Rio Grande (Lopez, 1995). The correlation between TSS and illness is estimated according to the following equations which express the change in incidence (percentage) of morbidity induced by changes in TSS concentrations. The coefficient γ in $PI_P = \gamma P^2$ is estimated by regressing PI_P (percentage of illnesses correlated with the stock pollutant) on P^2 (quadratic stock pollutant) using four observations of different TSS levels and percentages of illness. Thus, $\gamma = 1 \times 10^{-2}$.

The damage linked to U originates from exposure to water pollution in the river through recreational fishing and swimming. The coefficient b in $PI_U = b(\beta_\eta U^2)$ is estimated by regressing PI_U (percentage of illnesses correlated with the flow pollutant) on $\beta_\eta U^2$ (weighted quadratic untreated emissions). The β_η term where η=2,4 indicates the TSS concentrations of untreated emissions from the state equation (1) for the U.S. (β_2) and Mexico (β_4), respectively. Two observations of different TSS levels in the untreated emissions are used in the regression which yields $b = 2.8 \times 10^{-2}$.

Parameters γ and b are used to calculate a dollar value of illnesses associated with pollutant levels, according to the cost of illness technique (Tolley et al, 1994). The equation for the dollar value of illnesses in the U.S. from the stock pollutant is

(22) $D_{1S} = (m + w)t\gamma$.

The D_{1S} term is the parameter in the damage function for the dollar value of public health damages. The m term refers to the dollar amount of medical expenditures per person for illnesses reported in the survey (respiratory problems and angina). The w term refers to the lost wages per person associated with missing an average of four workdays due to illness (Tolley et al, 1994). The t term refers to the total number of people with the illness, calculated by multiplying the percentage of illnesses times the total population of the colonia. By substituting D_{1M} for D_{1S}, equation can also be used to calculate the damages from the stock for Mexico.

The same procedure is used to calculate a dollar value of illnesses for the U.S. and Mexico, associated with the flow variable U. The following equation shows terms for calculating the damages for the U.S.

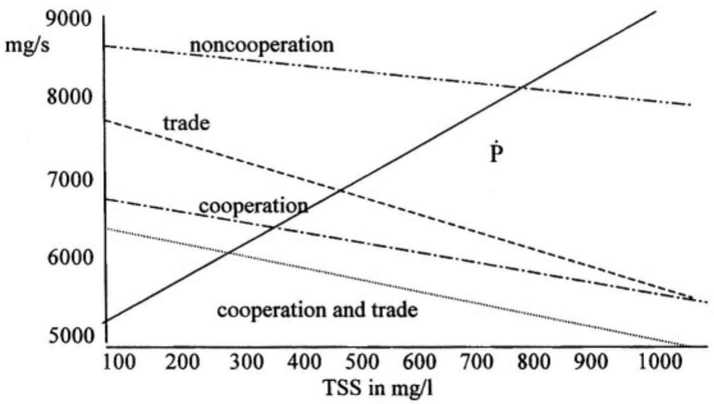
(23) $D_{2S} = (m + w)tb$.

By replacing D_{2S} with D_{2M}, Mexico's damages can be calculated.

Results

The system of equations are numerically calibrated and solved to find the paths of wastewater emissions over time under the four different cases of with and without trade and with and without bilateral cooperation over pollution control. Graph 1 shows aggregate emissions of both countries for both games with and without trade liberalization. Trade liberalization with bilateral cooperation yields the lowest steady state of pollution of 290 mg/1 TSS. This is 21% less pollution than the case of bilateral cooperation, 42% less than the noncooperative case with trade liberalization and 65% less than the noncooperative case in the absence of trade liberalization. The steady state of each of the four scenarios of Graph 1 is the intersection of the state equation for the rate of change of water quality in the river that follows a 45 degree line, $\dot{P} = 0$, and the change in aggregate emissions for both countries. The steady state is an important basis of comparison according to the logic of finding a steady state flow of emissions and its relationship to pollution stock. Trade liberalization lowers the steady state for both the noncooperative and cooperative games given the opportunity costs of lost trade revenues from reclaiming. Aggregate emissions decline faster in the noncooperative game with trade and approach the level of emissions in the cooperative game at high concentrations of TSS (TSS=1000 mg/1). So bilateral cooperation for pollution control makes a difference. And so does trade.

Graph 1. Aggregate Emissions and Steady States of Pollution



In order to illustrate the separate results for Mexico and the U.S. beyond just the aggregate results for both depicted in Graph 1, it is necessary to resort to a table instead of a graph that summarizes what would be a messy graph from about 10 different lines to watch intersect.

Table 2 indicates differences between the U.S. and Mexico. The reduction in emissions due to trade liberalization is recorded in percentage units at two concentrations of TSS pollution for each country under the noncooperation and cooperation scenarios. Note that there are two percentage values listed for each box. The number on the lefthand side of each box indicates the percentage for the case where the textile revenues are earned by the U.S. only and the cotton revenues are earned by Mexico. The number on the righthand side of each box indicates the percentage of emissions reductions when textile revenues are earned by Mexico instead of the U.S., due to a shift in the industry to move operations to Mexico.

Table 2 Reduction in Emissions from Trade Liberalization

Scenarios with trade liberalization	Reduction in emissions at TSS=200 mg/l		Reduction in emissions at TSS=900 mg/l	
Mexico, noncooperation	5%	9%	60%	76%
Mexico, cooperation	25%	36%	31%	48%
U.S., noncooperation	10%	-2%	21%	8%
U.S., cooperation	14%	0%	18%	3%

With trade liberalization, Mexico emits 5% less emissions than in the absence of trade liberalization at a pollution concentration of TSS = 200 mg/1 and 60% less at a higher stock of pollution, TSS = 900 mg/1. The addition of trade revenues from cotton produced with reclaimed water means Mexico reclaims more water and emits less untreated and treated emissions to the waterway. With the addition of textile revenues for Mexico, once the stonewashing cotton textile operations move from El Paso to Mexico, the reduction in emissions is 9% at TSS=200 mg/1 and 76% at the higher TSS=900 mg/1, when public health damages are apparent. Cooperation and trade liberalization with cotton trade revenues result in reduced emissions for Mexico of 25% at TSS = 200 mg/1 and 31% less than in the absence of trade liberalization at TSS = 900 mg/1. With the addition of textile revenues for Mexico under this cooperation and trade liberalization scenario, reductions in emissions are 36% at TSS=200 mg/1 and 48% at TSS=900 mg/1.

The noncooperative strategy for the U.S. with trade liberalization where more textile revenues are generated from importing Mexican cotton grown with reclaimed wastewater results in a 10% reduction in emissions at TSS=200mg/l and a 21% reduction in emissions at TSS=900 mg/1. The noncooperative strategy for the U.S. with trade liberalization where Mexico earns the textile revenues yields 2% more emissions than without trade liberalization at TSS = 200 mg/1. This is due to the public good nature of water quality in the waterway and the ability of the U.S. to act strategically. Since Mexico is emitting less and it is the only one that earns trade revenues from reclaiming, the marginal cost of emissions for the U.S. is lower and therefore, it will emit more at this concentration of TSS. However, at the higher concentration of TSS = 900 mg/1, the U.S. reduces emissions by 8%. With cooperative pollution control and textile revenues for the U.S. with trade liberalization, the U.S. reduces emissions by 14% at TSS=200 mg/1 and 18% at TSS=900 mg/1. The cooperative strategy for the U.S. with trade liberalization yields less emissions than without trade liberalization at TSS = 900 mg/1, but at the lower level (TSS=200 mg/1), the loss of textile revenues for the U.S. means lack of incentive to curtail emissions.

The model in the study provides results of the effects of trade liberalization on employment in producing the traded crop, cotton. The same information about the cotton production function used to calculate the trade revenues from reclaiming wastewater, A(R), includes the labor input quantity that is useful here. Since a Leontief fixed proportions relationship exists in the two inputs of reclaimed water and labor for cotton production, it is possible to obtain the level of employment generated through the use of reclaimed water in cotton production (Schulthies and Williams, 1992). The employment levels for both games with and without trade liberalization are calculated as follows. The fixed proportions of 104.88 liters/HA of reclaimed water and 26 laborers/HA are used. Dividing the amount of reclaimed emissions by the fixed proportion of 104.88 liters/HA, yields the amount of total HA in cotton production. The amount of land in cotton production is then multiplied by 26 people/HA to obtain the total amount of employment in cotton production with and without trade liberalization for the noncooperative and cooperative games. Cooperation results in more people employed in cotton production as the stock pollution increases. There is a slight increase with trade liberalization and cooperation. Approximately six more people are employed for every 100 mg/1 increase in the stock pollutant.

Conclusions

The empirical analysis yields meaningful results. First, trade liberalization provides economic incentives for Mexico and the U.S. to treat and reclaim wastewater and reduce transboundary pollution. The ability to use the reclaimed wastewater to irrigate tradable agricultural crops yields revenues.

Second, trade liberalization also increases welfare through improvement in public health, water quality and employment opportunities. The crop production activity generates new employment opportunities. Third, the transboundary pollution is controlled through trade liberalization and cooperation. Cooperation in pollution control guarantees emissions are reduced dramatically. This is a useful result for determining the significance of international environmental institutions created by NAFTA. Fourth, strategic behavior for pollution control occurs in the noncooperative game with asymmetric trade benefits. The free riding that the U.S. pursues strategically under noncooperation when the trade revenues are exclusive to Mexico only occurs at lower levels of the stock of pollution, not at higher levels where public health damages are a disincentive for the U.S. to free ride. The inclusion of empirical measures of asymmetric environmental damages as well as costs and benefits makes the gains from cooperation and trade liberalization more pronounced.

The policy implications are that any policies such as aspects of NAFTA which have the effect of removing quotas on traded goods such as cotton, can offer enough revenues to encourage reclamation of wastewater. Prior to NAFTA limited investment in wastewater treatment exacerbated environmental problems. NAFTA has brought attention to the environmental damage at the border in the form of institutions that are focused on environmental infrastructure such as wastewater treatment. Cooperation in handling wastewater pollution does matter and therefore institutions like the BECC and NADBank do play a significant role in manifesting the wastewater treatment resources.

The public resource management agency, JMAS, in Ciudad Juarez, Mexico, is currently pursuing wastewater reclamation for irrigation of tradable crops such as cotton as a means of offsetting costs of the wastewater treatment plant that is due to be online by the end of 2001.

The game theory simulations provided in this analysis represent one watershed along the border. In order to investigate other changes in trade policy and links to other types of environmental quality in other settings along the border, it is imperative to encourage more empirical research to link economic activities to binational incentives to address environmental problems along the shared border.

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The Geography of Water Transfers and Urbanization in Baja and Southern California

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> Water and population growth are physically linked, irrespective of whether water is supplied to induce or to accommodate growth. Water is essential for new [urban] development, whether water be from existing developed supplies (conserved, reclaimed recycled or not) or from new acquired supplemental supplies. Land and air uses associated with growth can degrade water quality, affect the amount of runoff and even influence climate (Weatherford 2000, 1)

The relationship between water and urban growthare complex and differ in every geographic context. For example, one finds a rapidly expanding urban population and economy along the U.S.-Mexico border even though clean water resources are limited. Today, economic development and urban expansion along the U.S.-Mexico border not only place a tremendous demand upon scarce water resources, but also threaten local drinking water quality with pollutants from agricultural, urban and industrial activities.

To enable economic growth and development, politicians and water agencies have promoted water transfers -- sometimes hundreds of miles – between perceived areas of "lesser need" to perceived areas of "greater need," as in the case of the Colorado River in the United States or the Lerma River in Mexico. This practice results in the formation of hydrocommons, a geographical linkage that connects one region to other regions through the transportation of water over long distances. Yet the existing literature and environmental assessments of water transfers tend to focus only on one region: the sending region or the river basin that sends water. As my research demonstrates, a geographical approach to hydrocommons construction and management must include a focus on how regions are connected. My analysis is drawn from a case study examining transbasin water diversions from the Colorado River to the Tijuana-San Diego metropolitan region. By examining the geography of water transfers, urban growth, and degraded border water quality, I argue that water resources problems exist in both sending and receiving regions of the hydrocommons.

The findings presented here are based on fieldwork undertaken in Tijuana and San Diego between 1997-2000. To carry out the study, I employed three field research techniques: participant observation, document analysis and field interviews. Participant observation entailed observations of meetings, public forums and work groups concerning water, storm water and wastewater management for these two cities. My document analysis consisted of reviewing four categories of water organization communications: public forums, persuasive communications[1], water resources reports, plans and studies. Finally, I conducted fifty-two focused, open-ended formal interviews with scientists, engineers, government officials and environmental representatives in the United States and Mexico.

[1] Examples of persuasive communications are maps, geographic information systems utilized to persuade other stakeholders or the public, lawsuits, organizational comments made at stakeholder proceedings, and organizational press releases.

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After reviewing the literature on water transfers, this paper examines the geography of water imports for the Tijuana-San Diego metropolitan region. I analyze the complex physical and institutional relationships between water transfers, urban growth and degraded border water quality caused in part, by long distance water transfers to the Tijuana-San Diego metropolitan region, a binational urban center located in the westernmost part of the U.S.-Mexico Border. It is my goal to move beyond the "water importation and urban growth controversy", and focus upon water quality problems which are emerging in regions which not only send but also receive imported water. In essence, this paper answers the question: What are local land use development implications, and more importantly the localized water quality impacts of imported water to the Tijuana-San Diego metropolitan region? This question is of utmost importance in water scarce regions (i.e. the U.S.-Mexico border, Western United States, the Middle East) as cities continue to grow and expand not only in terms of population and physical space, but also in political and economic power. This urban growth may encourage even more water imports, but it is also in these urban centers where political mobilization questions the need to increase water imports.

What is a Hydrocommons?

Before discussing the Colorado River hydrocommons that exists along the border between California and Baja California, it is important to understand water transfers. In the United States, water transfers are understood as the process of moving water supplies through a complex of water storage and distribution systems from areas of lesser need to areas of greater need (Water Education Foundation 1996). Water transfers may occur either within a watershed (intrabasin), or beyond the natural watershed boundaries (transbasin diversions).[2] Water transfers can occur between agricultural users, or between agricultural and urban users. Water supply agencies and politicians in Tijuana and San Diego cite that transbasin water transfers as advantageous because the transfers assure a long term, reliable water supply that meets the demands of the growing urban binational economy and metropolitan region population.

According to Weatherford (1990), once a transbasin water diversion or transfer is made the sending and receiving basins/watersheds are linked. This linkage (made via the transfer) erases the natural boundaries of both sending and receiving basins. When transbasin water transfers are established by conveyance systems such as storage reservoirs and aqueducts, the receiving basin becomes dependent upon the sending basin for water. In addition, the sending basin is no longer self-contained because water is diverted beyond its natural basin boundaries (Weatherford 2000). Areas downstream of the diversion now receive less water. Consequently, the sending region's water quality and aquatic ecosystems downstream of the diversion are altered. In essence, transbasin diversions "cause hydrologic basins to be reshaped, breached and bonded by hydraulics resulting in hybrid basins" (Weatherford 1990, 3). These hybrid basins, which are tied together by man-made plumbing, are known as hydrocommons (Weatherford 1990; 2000).

Weatherford (1990, 10) has chosen to use the term hydrocommons because he recognizes that "water resources cannot be managed by attending to water alone." For management

[2] An early transbasin water transfer in the Western U.S. occurred in the early 1900s, when the City of Los Angeles Department of Water Resources was successful in diverting water from the Owens River (located East of California's Sierra Nevadas) via a 260 mile long aqueduct to the City of Los Angeles. In this case, the City of Los Angeles purchased thousands of acres of land within the Owens River watershed to obtain water rights so that Owens River water could be diverted and transferred to Los Angeles (Water Education Foundation 1996).

purposes, water is part of a large commons through which it moves. This commons is composed of water, air, land and organic matter --- elements that are interrelated via complex biogeochemical processes. Geographers also recognize that urbanization, economic development and even personal lifestyle are human elements of the commons that are supported by the flow of water. A crucial element of Weatherford's argument is that when interbasin transfers connect two basins or commons, then this connection (or the creation of the hydrocommons) alters elements in both basins or commons. Hence, the creation of the hydrocommons results in altered hydrology, geomorphology, water quality, ecosystems, economies, and even land use patterns in both the sending and receiving watersheds/basins. Given that interbasin water transfers can and do modify numerous elements of the commons in the sending and receiving basins, Weatherford (1990; 2000) supports the notion that water resources policy must incorporate all elements of the commons (i.e. multi-resource and multi-purpose planning (See Wescoat 2000)). In addition, the linkages, or the geographic scope of the hydrocommons, must be addressed in water resources policy.[3]

Figure 1 details transbasin diversions that support urban water demand in Southern California and Baja California. San Diego imports between seventy-five to ninety percent of its water from the Sacramento River Basin, approximately 600 miles north, and from the Colorado River, approximately 240 miles to the east (Laru pers. com. 2000). The City is negotiating to increase its current supply of water through agricultural to urban transbasin water transfers from Imperial Valley, California (City of San Diego Manager's Report, March 24 1999). During times of drought, Tijuana exports up to ninety-five percent of its water supply from the Colorado River, and is seeking to increase its allocation of Colorado River water (Ganster, Sweedler and Clement 2000). At present, both cities are working together to investigate the possibility of constructing a binational Colorado River aqueduct to accommodate the rapidly growing economic and residential water needs in the Tijuana-San Diego Metropolitan region.

A hydrocommons-based analysis (and even a hydrocommons based policy in water resources management) in the western part of the U.S.-Mexico border region can be beneficial, because the region's primary waterways are not large river basins, such as the Río Grande River basin in the eastern part of the border. Instead Southern California's and Northern Baja California's primary waterways are a hydrocommons or a network of manmade canals and aqueducts which divert the Colorado River to agricultural fields in Imperial Valley and Mexicali, and west to expanding urban regions such as Los Angeles, Tijuana, Ensenada and San Diego. The total amount of transbasin diversions range between six and eight million acre-feet each year (Michel 2000a). These transbasin diversions, along with other diversions within the Colorado River Basin, are a significant cause of water and land- based environmental degradation problems along the U.S.-Mexico border. Currently laws and governmental organizations in the United States do not adequately address the links between transbasin diversions, water quality, and habitat destruction. In Mexico, umbrella organizations at the federal and municipal levels do manage in conjunction water supply and quality; however laws and infrastructure planning rarely address the links between transbasin diversions, water quality and habitat destruction.

Colorado River Transbasin Diversions for San Diego

As shown in Figure 1, San Diego's source of Colorado River water comes from the Colorado River aqueduct, an aqueduct owned and operated by Metropolitan Water District of

[3] In California, the CALFED process proposes to fulfill these two requirements. For more information see Michel (2000b).

Southern California (MWD).[4] San Diego County Water Authority is the water supply organization that buys water from MWD, and subsequently sells this imported water to various water districts and cities in the San Diego region. In 1998, San Diego County Water Authority imported approximately 433,000 acre-feet of water from MWD (Laru pers. com. 2000). This imported water is a blend of State Water Project water from the Northern California Bay-Delta estuary, and the Colorado River. According to the City of San Diego Manager's Report, dated March 24, 1999, The City of San Diego has received several unsolicited offers for water transfers from Central Valley, Northern California, and the Colorado River basin. One main issue for San Diego is conveyance of imported water supplies. How can San Diego transport and store the imported water? How will conveyance be financed?

San Diego actively supports an increase in water supplies because local government officials cite that San Diego's population will increase from 2.8 million in 1999 to 3.6 million in 2015 (San Diego County Water Authority 1999). In addition, water supplies need to be long term and reliable to support San Diego's 87 billion dollar economy (San Diego County Water Authority 1999). By 2015, San Diego County Water Authority[5] officials estimate that San Diego's growing economy and population will nearly double the region's demand for water supplies to 868,700 acre-feet per year (San Diego County Water Authority 1999).[6] One key provision of San Diego's plan to increase its water supply, is for Imperial Irrigation District (IID)[7] to transfer or sell Colorado River water directly to the San Diego County Water Authority. The San Diego County Water Authority Board of Directors approved this agreement in 1998 (San Diego County Water Authority 1999). The agreement proposes to transfer 200,000 acre-feet per year for an initial term of 45 years. San Diego County Water Authority may increase the water transfer amounts to a total of 300,000 acre-feet, and renew the water transfer agreement for an additional 30 years (San Diego County Water Authority 1999).

The San Diego County Water Authority-Imperial Irrigation District water transfer represents San Diego's move to obtaining its own water imports besides those it now receives

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[4] Metropolitan Water District of Southern California (MWD) was formed in 1928, pursuant to California's Metropolitan Water District Act or law. MWD represents approximately 240 cities and unincorporated areas, and serves seventeen million people in six counties of Southern California (Littleworth and Garner 1995; Metropolitan Water District of Southern California n.d.).

[5] San Diego County Water Authority is a water wholesaler selling imported water to 23 member agencies (San Diego County Water Authority 1994).

[6] This doubling of demand is in part due to a common paradigm in western water resources policy known as "build to demand." In this type of water resources planning, the water resources agency estimates future growth in a region, and then estimates the increased demand to support this growth. The next step is to build water supply infrastructure to meet that perceived demand. Historically, numerous water resources agencies such as California's Department of Water Resources and the San Diego County Water Authority have not encouraged discussion of water resources limits (i.e. that there is a limited supply of water resources available to a region). One of the reasons why there seems to be no limit is due to the availability of interbasin transfers to augment urban water supplies. Consequently, since the assumption that there is no limit, then managing demand has not been a crucial element of water resources planning. Managing demand or demand management, focuses upon the demand side of the equation, and examines how demand can be minimized via more efficient use of water, water conservation techniques and water reclamation. For more discussion of the build to demand paradigm in the Tijuana-San Diego metropolitan region see Michel (200a), Chapter 6.

[7] Imperial Irrigation District provides water for agriculture and cities in Imperial Valley, California. All the water IID receives, approximately 2.77 million acre-feet per year, is diverted from the Colorado River which is managed and operated by the United States Bureau of Reclamation (Imperial Irrigation District 1996a; 1996b).

from Metropolitan Water District of Southern California (MWD).[8] At present, all of San Diego's imported water is supplied by MWD. By 2015, San Diego County Water Authority proposes to reduce MWD imports by twenty-five percent (San Diego County Water Authority 1999). However, even with its own water supplies from IID, San Diego is still dependent upon MWD to transport the water from the Colorado River. At present, the only way for San Diego County Water Authority to transport IID water is through the Colorado River aqueduct, an aqueduct owned and operated by MWD.

Negotiations for the wheeling rate, (transport fees) of IID water with MWD have been problematic at best. San Diego wants to keep costs down on the transportation fees and claims that MWD's wheeling rate is yet another example of MWD over-charging their customers *(San Diego Daily Transcript,* 20 May 1998). On the other hand, MWD which has built, financed, and maintains the aqueduct and water treatment facilities, asserts that San Diego should pay for these services in the wheeling or transportation rates. As a result of these tense negotiations concerning use of MWD's aqueduct, San Diego looks south to work with Tijuana, and build a second aqueduct which would transport IID water transfers and Tijuana's increasing Colorado River water allocations to the San Diego-Tijuana metropolitan region.

Colorado River Transbasin Diversions for Baja California and Tijuana

Tijuana's current annual allocation of Colorado River water is 63,834 acre-feet (Comisión Nacional del Agua (CNA) 1999). This water is delivered by the Río Colorado-Tijuana Aqueduct, an aqueduct operated and maintained by the State Water Service Commission or the Comisión de Servicios de Agua del Estado (COSAE). The water organization which delivers water to Tijuana's water users (imported and locally developed water supplies), is a state agency, the Comisión Estatal de Servicios Públicos de Tijuana (CESPT). This agency provides both water and wastewater services to Tijuana and Rosarito Beach (a community approximately sixteen miles south of Tijuana).[9]

Like San Diego, Tijuana seeks to increase its water supplies to support a growing economy and population. By 1999, Tijuana's population grew to 1.2 million people, and by 2010 Baja California's State Water Agency estimated the population to be well over two million (Comisión Estatal del Agua (CEA) 1999). Tijuana's rapid population growth rate poses for CESPT a tremendous challenge to provide potable water for all city residents. This is an especially difficult task since state and municipal local agencies receive little or no financial income from the federal government (Carter 1999). It is estimated that by 2004 water rationing will start for Tijuana (San Diego Dialogue 1999). According to a local newspaper, Tijuana has

[8] Critics cite that San Diego's need for independence from MWD is resulting in water transfer deals, which force San Diego county water users to pay more for water. The IID water transfers indeed support this assertion. IID pays the U.S. Bureau of Reclamation $12.50 per acre-foot of Colorado River water. If the IID-San Diego County Water Authority transfers are approved, IID will sell water to San Diego County Water Authority for $200 per acre-foot of water, and increasing to around $306 per acre-foot of water. Based upon other agriculture to urban water transfers in California (Central Valley Project water for example), critics state that San Diego should pay between $ 165 to $ 185 per acre-foot of water. One critic estimates that for the initial forty-five year, 200,000 acre-foot contract, San Diego ratepayers will spend $1.1 billion dollars more than they should be paying for water (Erie 1997).

[9] However, the state agency in charge of the aqueduct, Comisión de Servicios de Agua del Estado (COSAE) does not operate the aqueduct until Tijuana runs out of local surface and groundwater supplies, usually in years with drought conditions. This action saves the state from paying expensive energy costs associated with pumping water over the mountains between Tijuana and the Colorado River. In addition, the current aqueduct is in poor structural condition, and there is significant water loss from the aqueduct as it delivers water from the Colorado River to Tijuana.

Figure 1


California
Major Urban Water Conveyance Facilities
Southern California and Baja California
Oroville Dam and Reservoir
Sacramento
Delta
San Francisco
Nevada
California Aqueduct
Los Angeles Aqueduct
Arizona
Colorado River Aqueduct
Los Angeles
San Diego
Tijuana
Colorado River Aqueduct
Morelos Dam
Baja California Norte
MILES
0 40 80
0 64 128
KILOMETERS
Source: SANDAG 1998

four options to solve its water shortage problem First, Tijuana may retrofit and modernize the existing aqueduct (González Delgado 1999). Second, the city may construct a second aqueduct. Third, it may construct desalinization plants, and fourth the city may use wastewater reclamation as a supplemental source of water. (González Delgado 1999).

The Tijuana-San Diego Binational Aqueduct

The government-sponsored proposal to build a binational aqueduct for the Tijuana-San Diego metropolitan region has its roots in the Border Water Council. The Border Water Council was formed in 1998 and was designed as a forum for water agencies in Tijuana and San Diego to discuss binational solutions to water resources management in the Tijuana-San Diego metropolitan region. At present, the primary impetus of the Border Water Council is to investigate the possibility of a constructing a binational aqueduct to deliver water from the Colorado River to the Tijuana-San Diego metropolitan region.

There is a second, private proposal by two Mexican businessmen for a Tijuana-San Diego binational aqueduct. Francisco Molina, director of the Mexican development company EMTEC, and Gastón Luken Aguilar, chairman of the board of Proxima Gas propose building a binational aqueduct and power plant in Mexico (San Diego Dialogue 1999). This aqueduct would have a capacity of 525,230 acre-feet per year, with up to 300,000 acre-feet of IID water for San Diego, and 225,230 acre-feet of water for Tijuana (San Diego Dialogue 1999). The total cost of the aqueduct-power plant project is estimated at 800 million dollars (González Delgado 1999).

Despite the two proposals, a binational aqueduct faces political and legal challenges in both Mexico and the United States. In addition to North American Free Trade Agreement (NAFTA) and federal environmental assessment requirements, it is unclear as to how other Colorado River Basin states will react to yet another aqueduct or "straw" which will draw water from an already over allocated Colorado River. At the 1997 Public Officials for Water and Environmental Reform Conference on California Water Policy, the "second" aqueduct for Southern California question was posed to water agency representatives from Nevada and Arizona. Both representatives stated an emphatic "no" to a second aqueduct. However, through Minute 301, the International Boundary and Water Commission is conducting with Border Water Council representatives a joint study for Colorado River water supply options – commonly referred to as the binational aqueduct study (Michel 2002). Concerning the IID water transfers, San Diego County Water Authority faces two legal hurdles. The first is the completion of an environmental impact report, and public review process, as required by the California Environmental Quality Act. In addition California's State Water Resources Control Board (SWRCB) and U.S. Fish and Wildlife must review the transfer and proposed environmental mitigation. The SWRCB must examine third party impacts or economic consequences to rural communities sending water to San Diego. Farmers and other local business owners in Imperial Valley assert that the IID water transfers will result in fallowing of agricultural land, and a subsequent decline of Imperial County's local economy that depends upon agriculture (Rossman 2001). Finally, the SWRCB and U.S. Fish and Wildlife will evaluate environmental impacts of the water transfers (Water Education Foundation 1996). One key environmental issue is how the water transfers will impact salinity levels in the Salton Sea National Wildlife Refuge – a topic I will address in the next section.

Concerning agricultural to urban water transfers from the Mexicali Valley to the Tijuana, it is unclear if and how these transfers will occur. At the national level, the 1992 National Waters Law initiated the process to transfer the adminstration of water use from the National

Water Commission (CNA) to irrigation district users (Calleros 2002). At the state level, the State Water Commission (Comisión Estatal del Agua, CEA) and the State Commission of Water Services (Comisión de Servicios de Agua del Estado, COSAE) are the two state agencies which are the strongest supporters of a second aqueduct for Tijuana. According to the COSAE State Hydraulic Plan, the 1992 National Waters Law allows for the sale of irrigation water rights. In COSAE's discussion of water transfers, neither third party nor environmental impacts are addressed. CEA officials, however, support the water transfers, but remain quiet on how the transfers will occur (Author interview).

In this section, I detailed the status of Colorado River transbasin diversions to the Tijuana-San Diego metropolitan region and the status of the binational aqueduct proposal. In the next section, I discuss environmental consequences of transbasin diversions occurring within the hydrocommons along the California-Baja California border. For the most part, environmental impacts to the sending region are of primary concern to water resources scholars and practitioners. This article also will discuss review those impacts and also the environmental impacts to the receiving region of the above detailed proposed water transfers - the Tijuana-San Diego metropolitan region.

Colorado River Hydrocommons Connections and Environmental Impacts -- The Sending Region, the Colorado River Delta and Salton Sea[10]

The Colorado River Delta and Upper Gulf of California

According to Anderson (1999), four linked wetland regions in Baja California and California need immediate restoration attention. These wetland regions which are linked through migratory bird routes along the Pacific Coast, are the Klamath Basin, the San Francisco Bay-Delta estuary, the San Joaquin Valley, and the Río Colorado (Colorado River) Delta region. The latter delta, also known as California's "Other" Delta (the other delta besides the San Francisco Bay-Delta estuary) is a wetland ecosystem that to date has largely been ignored by policy makers in the California and to a certain extent in Baja California. Like the Bay-Delta estuary, the Río Colorado Delta has been dramatically altered by transbasin diversions from the Colorado River (Morrison, Postel and Gleick 1996).

One hundred years ago the Colorado River Delta, or the Río Colorado Delta, was the largest and most diverse desert wetland system in North America (Anderson 1999; Morrison, Postel and Gleick 1996). This delta spanned an enormous area, more than 150 miles long and 100 miles across (Bates et al. 1993), and is represented in Figure 2. Aldo Leopold described the region as one of hundreds of green lagoons, awesome jungles, and lovely groves (Leopold 1966). The Delta supported between 200-400 plant species in various habitats from forests, to grasslands, to tidal wetland marshes and estuaries (Morrison, Postel and Gleick 1996). Geese, doves, pelicans, egrets, sea turtles, bobcats, jaguars, tropical birds and deer thrived in the Delta (Bates et al. 1993). In addition, nutrients, sediment loads and fresh water from the Colorado River supported not only the Delta wetland habitat, but also the diverse and productive Upper Gulf of California marine ecosystem. Mexico's Upper Gulf of California or the Sea of Cortez

[10] The author understands that the geographic scope of the sending region is the entire Colorado River Basin and its tributaries. In this article I focus upon regions impacted by transbasin diversions, known as the problem regions. Problem regions in hydrocommons are usually the mouth or end of the river, or as in the case of the Colorado River, the Delta where little to no water flows from upstream sources. The entire Colorado River hydrocommons is quite large and complex, including water resources management of upper basin states and municipalities such as Denver, Colorado.

Figure 2

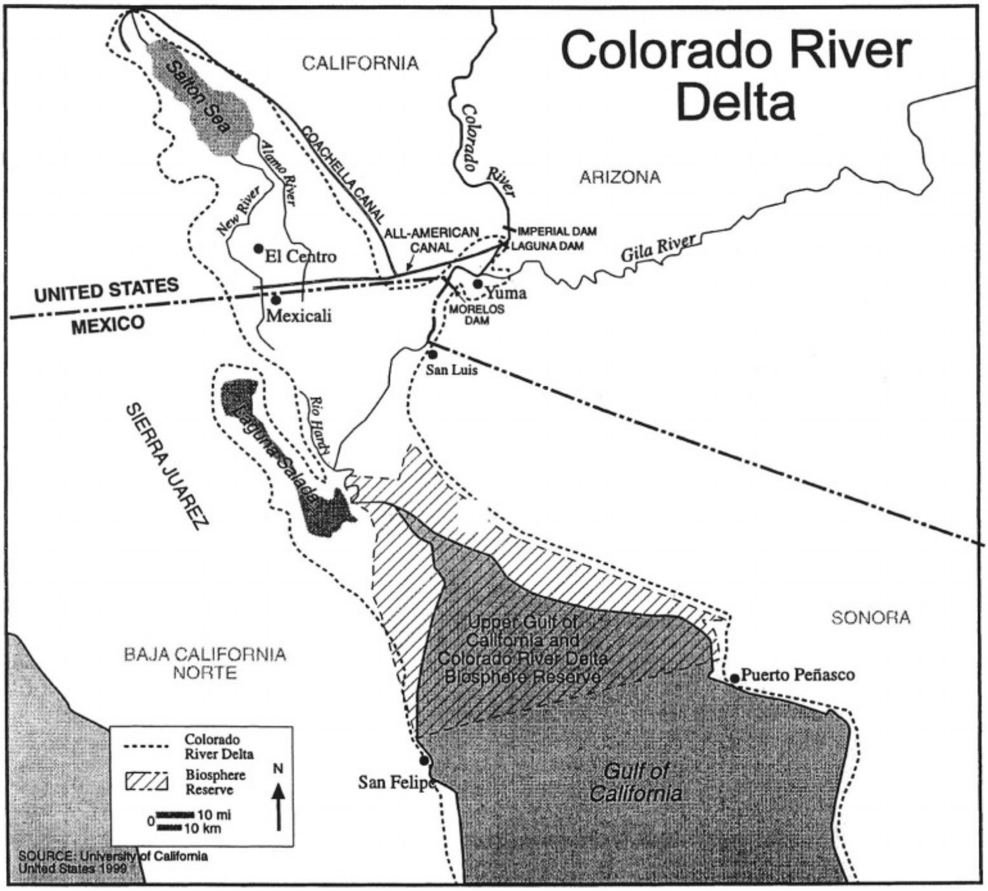

Illustration by Andrea Kaus and Sophia Habl, reproduced with permission from UC Mexus, taken from Alternative Futures for the Salton Sea.

was once a place of special biological richness and a seemingly limitless source of fish for food, commerce and sport (Vincent 1999, 1).

In 1999, Colorado River transbasin diversions in the U.S. and Mexico have reduced dramatically the natural flow of water, silt and nutrients to the Colorado River Delta and the Upper Gulf of California. Except for rare high flood years (for example in 1983 and 1998), the entire flow of the river is diverted and used (Glenn et al. 1996; Morrison, Postel and Gleick 1996, 22). The reduced Colorado River flows have desiccated the Delta and the Upper Gulf estuaries. In addition, freshwater wetlands and riparian habitat supported by the natural flow of the Colorado River have diminished considerably (Glenn et al. 1996).[11] Today wetland habitat exists but only where agriculture drainage water is discharged or where there is groundwater flow.

Due to the amount of wetland habitat that has been lost, a number of species that depend upon the Colorado River Delta and the Upper Gulf ecosystem are now threatened or endangered. One group of threatened species are migratory birds which depend on the Delta wetlands and Sea of Cortez as a major breeding habitat region. The Delta and the Sea of Cortez is considered by avian biologists as an important link in the Pacific Flyway system (Anderson 1998; 1999). The Pacific Flyway system shown in Figure 3, includes numerous wetland regions such as the Colorado River Delta, the Salton Sea and Northern California's Bay-Delta estuary. These wetlands host migrating waterfowl as they travel along the west coast of North and South America. It is estimated that the Colorado River riparian vegetation in Mexico has the potential to support 120,000 resident and migratory waterfowl (Luecke et al. 1999).

Not only wetland ecosystems, but also marine ecosystems have been impacted by the diminished Colorado River flows into the Upper Gulf of California. Local fisherman and local biologists in the Gulf of California assert that the sharp decline in Gulf shrimp and commercial fish fisheries is due in part to the lack of nutrient-rich water inflow from the Colorado River into the Gulf of California.[12] In addition, Colorado River transbasin diversions has resulted in a severe reduction in numbers of two significant marine species. The first is the vaquita (or little cow), the world's most endangered porpoise. The vaquita's range is the Delta and Upper Gulf of California. This porpoise grows to about four feet in length and feeds on small fish and squid. Very little is known about the vaquita since it is believed that only a few hundred remain. Certain scientists assert that the sharp decline in Northern Gulf of California fish populations (the vaquita's food source) is to blame for the near extinction of the vaquita. This sharp decline is caused by over-fishing in the Gulf, and insufficient Colorado River fresh water flows entering the Gulf (Vincent 1999a).[13]

The second indicator species is the totoaba, a large silver-blue fish found only in the Gulf of California. As in case of young salmon that use Northern California's Bay-Delta estuary as a nursery, biologists have found that the shallow waters and dense sea grass vegetation of the Río Colorado Delta-estuary provide breeding and nursery habitat for the totoaba. Totoaba spend approximately the first year of their life in the Río Colorado Delta-estuary feeding on crustaceans

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[11] Some of the wetland loss can be attributed to conversion of wetlands to agricultural use (Water Education Foundation 1999).

[12] According to Glenn (1998) increased fresh water Colorado River flows has resulted in increase in shrimp catch as far south as the coast of Guyamas.

[13] One Mexican biologist has witnessed the vaquita feeding in the Delta during low tide. This biologist now asserts that the vaquita depends upon young fish and shrimp, which breed and grow in the Delta estuaries *(San Diego Union Tribune,* June 17, 1998). If this observation is true, then the vaquita's survival is dependent upon increased Colorado River flows to the Delta.

Figure 3

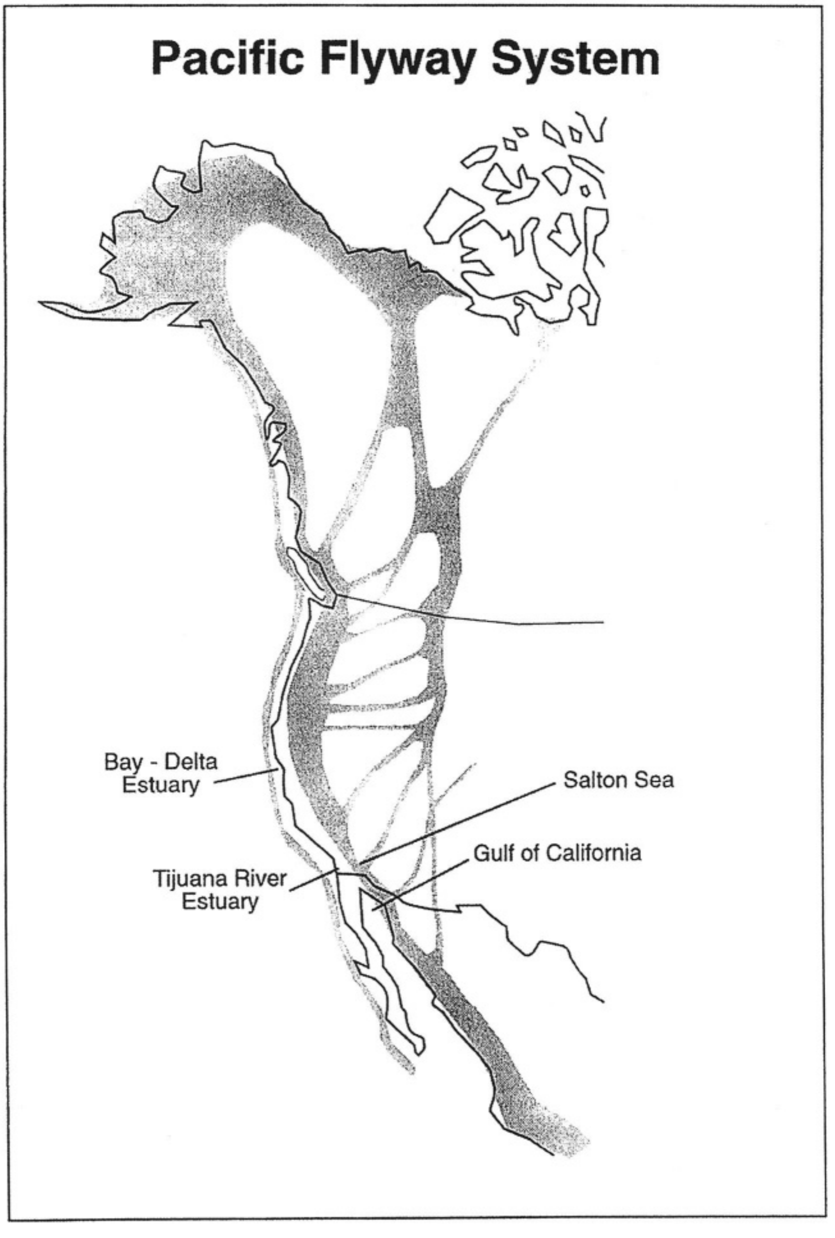

Illustration by Andrea Kaus and Sophia Habl, reproduced with permission from UC Mexus, taken from Alternative Futures for the Salton Sea.

and small fish. After the first year, the totoaba spends most of its adult life in the deep waters of the Gulf of California. The totoaba can grow up to 2 meters in length and weigh 140 kilograms (Morrison, Postel and Gleick 1996, 23). Each year, mature totoaba return to the Delta to breed and lay eggs. Today the fish is on the verge of extinction.

At the Universidad Aútonoma de Baja California in Ensenada (UABC, Ensenada),[14] fisheries biologists have constructed possibly the last breeding and nursery habitat available for the totoaba. In the early 1990s, the Mexican government recognized that the totoaba was heading for extinction. Subsequently, UABC fisheries biologists were sent out to the Gulf to capture and breed seven adult totoaba. These totoaba now live in two large seawater tanks at UABC, Ensenada. Twice a year the biologists raise the temperature of the tank water. This rise in temperature sparks breeding behavior, resulting in thousands of totoaba eggs. The eggs are hatched, and young totoaba spend between four months to a year growing in nursery tanks at UABC, Ensenada. During the first year of the totoaba fishery project, three totoaba survived the hatching and rearing process. In 1999, I witnessed hundreds of young totoaba in the nursery tanks. UABC biologists have relayed to me that the survival rate now is much higher because they are learning from past mistakes and presently provide better nursery conditions for young totoaba. When the biologists receive approval from the Mexican government, the totoaba are trucked from Ensenada across the Baja Peninsula and released into the Upper Gulf of California.[15]

In addition, Mexican national government officials now recognize that the Colorado River Delta is key to the environmental health of the Lower Colorado River Basin and the fisheries in the Gulf of California. In 1993, the Mexican government set aside 2.3 million acres of water and land within the Delta and the Upper Gulf as an United Nations Biosphere Reserve (Vincent 1999a; Water Education Foundation 1999). The Biosphere, portrayed in Figure 2, encompasses over 400,000 acres within its core zone, limiting activities to research, small-scale shell harvesting and limited ecotourism (Water Education Foundation 1999). For the manager of the Biosphere Reserve and conservation biologists in the U.S. and Mexico, the major goal of the reserve is to obtain fresh water flows from the Colorado River.[16] What is rarely recognized in the negotiations for Colorado River water, is the environmental consequences of transbasin diversions to the Delta and Upper Gulf of California. As noted above, California is attempting to reduce its water allocation amounts, but this reduction of allocation is done so that other states in the Colorado River Basin can increase water use to their full allocation apportionment designated in the 1922 Colorado River Compact. In Colorado, the Denver Water Department will need an additional 100,000 acre-feet to serve anticipated growth in the next forty years. Nevada will be diverting its full entitlement by 2007 *(San Diego Union Tribune,* 19 October 1999). Along the border of the Californias, the cities of Tecate, San Diego, Tijuana, Rosarito Beach and Ensenada are counting on increased Colorado River diversions as the next source of water to support each city's anticipated growth.[17] However, as argued by Morrison, Postel and Gleick (1996), since

[14] Ensenada is located on the west coast of the Baja California peninsula 60 miles south of Tijuana.

[15] This information on the totoaba was provided to me during a tour of the totoaba fisheries facility at UABC, Ensenada, October 22, 1999.

[16] How much flow is the question. Because the Delta is located within an arid desert region with intermittent precipitation and hence river flow patterns, a report sponsored by the Environmental Defense Fund suggests a perennial flow of 32,000 acre-feet, with a flood flow (once every four years) of 250,000 acre-feet (Luecke et al. 1999).

[17] In comparison with water use of IID (3 million MAF), the amount of imported water these cities hope to receive is small (300,000 – 400,000 AF). However, the reader must note that the agriculture to urban transfers is not new

Mexico receives less than ten percent of Colorado River flows, it is unrealistic and inequitable for Mexico to assume all the responsibility of restoring ecosystems in the Río Colorado Delta and the Upper Gulf of California. As indicated by the above discussion on the totoaba fishery and the Delta Biosphere Reserve, Mexico has taken localized steps to slow down the degradation process. Restoration can only be accomplished with international cooperation and agreement. As is being done in the CALFED process for Northern California's Bay-Delta estuary, all Colorado River water users need to take responsibility for downstream environmental consequences in the Río Colorado Delta ecosystem.

<u>The Salton Sea</u>

As I have stated before, the Colorado River Delta encompassed an enormous desert wetland desert ecosystem, up to as much as 3,000 square miles (Anderson 1999). Today due to transbasin diversions, there exist wetlands in California which are part of the Delta wetland ecosystem. The largest and most biodiverse wetland/marine ecosystem in the United States, is the Salton Sea (See Figure 2), a terminal saline lake located thirty five miles north of the U.S.-Mexico border and ninety miles east of San Diego. The Salton Sea is connected to the Colorado River Delta by riparian or wetland corridors along the Colorado, Hardy, New and Alamo Rivers (Cohen, Morrison and Glenn 1999). Both the Salton Sea and the Delta support similar habitats, such as low desert, riparian woodlands, wetlands and hypersaline marine habitat (Cohen, Morrison and Glenn 1999).

The Salton Sea was created in 1905 when Colorado River flood waters destroyed the headworks of a canal which served Imperial Valley farm cooperatives (Pomento 1998). The result of this flooding was that the Colorado River changed its course and flowed north into the Salton basin for approximately two years. Today the Salton Sea and its wetland habitat encompasses 380 square miles, and has an average depth of approximately thirty-one feet (Cohen, Morrison and Glenn 1999). In addition, the Salton Sea has been created by and is still the product of Colorado River water. The Salton Sea receives Colorado River water diversions that are first used for irrigation by the Imperial Irrigation District. After irrigation use, the agriculture drainage or return flows are then deposited into the Salton Sea. Besides agriculture wastewater, via the New and Alamo Rivers, the Salton Sea receives municipal and industrial wastewater from Mexicali, Mexico. The Salton Sea does receive some freshwater from groundwater flows and seepage from irrigation canals and drains. However, for the most part the Salton Sea acts as an agricultural and municipal wastewater sump (Pomento 1998). The estimated total amount of water inflow to the Sea is 1.35 million acre-feet (Cohen, Morrison and Glenn 1999).

Agricultural and municipal wastewater flows sustain the Salton Sea, but at the same time these flows threaten to kill the Sea's aquatic and avian life. Scientists have identified four categories of pollutants, which threaten the Salton Sea ecosystem: salinity, nutrient loading, selenium and pesticides. According to Cohen, Morrison and Glenn (1999, 15), "annual inflows to the sea contain four million tons of dissolved salts, 15,000 tons of nutrients and such as nitrogen and phosphorous and variable levels of selenium, other metals and pesticide residue." Pollutant concentrations increase over time because "the only outflow for water entering the Sea

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water per say, but diverted agriculture water transferred to urban regions. In addition, this small amount could restore the Delta. I am not stating that Tijuana and San Diego should assume the complete responsibility for restoring the Delta, yet at some point, all users of the Colorado River hydrocommons must recognize the binational water quality and wetlands problems emerging along the border of the Californias.

is through evaporation." To restate, the evaporation process reduces fresh water in the Sea, and consequently increases pollutant concentrations of salts, nutrients, selenium and pesticides (Cohen, Morrison and Glenn 1999, 15). At present the Salton Sea's salinity levels are 44 parts per thousand, and is increasing by about .5 parts per thousand each year (Vincent 1999b). According to an article written by the *San Diego Daily Transcript* (21 March 2001) the Salton Sea's salinity levels are more than twenty-five percent saltier than the Pacific Ocean.

The Sea's hypersaline and nutrient rich water support huge numbers of marine invertebrates, which in turn feed large numbers of fish species, which in turn nourish waterfowl populations. The fish species which inhabit the Salton sea are non-native, a result of government efforts to initiate recreational fishing at the Sea. Marine species such as sargo, orangemouth corvina, gulf croaker were introduced during the 1950s (Pomento 1998). The most common fish in the Sea, the tilapia, entered the Sea from agriculture drainage ditches. The tilapia, introduced by Imperial Valley farmers, was for control of aquatic weeds in irrigation ditches (Pomento 1998; Cohen, Morrison and Glenn 1999).

The Salton Sea and nearby crop lands provide a mix of habitat and food sources for a high diversity of waterfowl. Each year over one million birds representing 380 species (five of which are endangered) spend some time at the sea (Pomento 1998). These species include the Yuma Clapper Rail, peregrine falcon, brown and white pelicans. Scientists assert that the Salton Sea habitat is not the only reason for the large numbers of migratory bird population present at the Sea. In essence approximately ninety percent of wetland habitat in Southern and Central California and the Colorado River Delta has been destroyed (Anderson 1999; Salton Sea Restoration Authority n.d.). Subsequently, since so much wetland habitat has been destroyed, the Salton Sea has evolved into a critical wetlands breeding ground for migratory birds that travel the Pacific Flyway (McNaughton 1998; Cohen, Morrison and Glenn 1999; Anderson 1999). One scientist noted with irony that the Salton Sea is now flooding with agricultural wastewater (diverted from the Colorado River) and creating wetland habitat, while the Colorado River Delta wetlands are drying up due to lack of water (McNaughton 1998).

The Salton Sea has a rich aquatic ecosystem, and high levels of avian biodiversity. However this ecosystem experiences large-scale mortality events for both fish and waterfowl species. Periodically massive fish die offs occur, resulting in up to a million fish deaths (Cohen, Morrison and Glenn 1999; Vincent 1999b). The causes of the die offs are not yet fully understood by scientists and government officials (Vincent 1999b). Some believe that the most common cause of die off is eutrophication.[18] Eutrophic conditions in the Salton Sea result in reduced levels of dissolved oxygen available for fish, and hence each year during warm weather conditions, thousands of Salton Sea fish die due to lack of dissolved oxygen available, or a condition commonly referred to as hypoxia. Another cause of widespread fish mortality is temperature change. The most common fish in the Salton Sea, the tilapia is a nonnative fish (from Africa), and sensitive to water temperatures below 55 degrees Fahrenheit, and hence subject to mass die offs during the cold winter months (Cohen, Morrison and Glenn 1999). Tilapia die offs are also caused by disease outbreaks. These outbreaks weaken the fish, and in turn allow for other diseases such as botulism to penetrated the fish tissues (Bloom 1998). In the

[18] Eutrophication occurs when large amounts of nutrients from agricultural wastewater enter the sea, which in turn initiate a rapid increase of plant and phytoplankton growth in the Sea. Algal respiration and decomposition of dead algae and plankton leads to diminished levels of dissolved oxygen (DO) available for all aquatic species including fish.

case of botulism, the disease spreads beyond fish to waterfowl populations that prey upon diseased fish.

The most disturbing mortality event at the Salton Sea is the recent advent of waterfowl bird die offs. In 1992, more than 150,000 eared grebes died at the Sea within a three month period. In 1996, more than 20,000 birds, representing 64 species including 1,996 endangered brown pelicans and 8,000 white pelicans (fifteen of the North American white pelican population), died of avian botulism. In 1998, another 17,000 birds representing 70 species died from Newcastles disease and avian cholera (Bloom 1998). U.S. Fish and Wildlife response to these bird die offs has been localized responses such as care and rehabilitation of sick birds, and the incineration of dead birds.[19]

As with the fish mortality events, scientists and Fish and Wildlife officials are unsure as why the bird die offs occur. Many believe that one cause of the avian botulism outbreak is that the botulism is transmitted to birds from dying tilapia. Another theory is since so much wetland habitat has been destroyed in Southern and Baja California, most migratory birds are forced one small region of the Salton Sea, whereas in previous years the birds could inhabit other different wetland sites such as the Colorado River Delta. According to Vincent (1999b) crowding birds into scarce, even diminishing wetland resources raises the risk of exposing more birds to rare diseases (such as Newcastle disease). For example, in March 1998, over 26,000 American white pelicans were observed at the Sea (Cohen, Morrison and Glenn 1999). These large numbers may represent between 20-25% of the total North American population of the species, and hence and maybe at particular risk, especially when birds disperse and travel south (Vincent 1999b). Other researchers believe that selenium and pesticides found in agricultural wastewater discharged into the Salton Sea weaken bird immune and reproductive systems, and given cumulative and interactive effects, pollutants could be another cause of Salton Sea bird die offs and reproductive failure. Each year over 6 million pounds of pesticides are applied to crops in Imperial Valley (Cohen, Morrison and Glenn 1999). U.S. water quality laws, most notably the Clean Water Act do not regulate water pollution from agricultural runoff.

As with the Río Colorado Delta, the amount of water flowing into the Salton Sea is likely to decrease. As stated before water agencies in Southern California are currently negotiating to reduce California’s Colorado River water use from 5.3 to 4.4 million acre-feet. In addition, due to efforts to restore Sacramento and San Joaquin Rivers Delta, an increase of imported water from Northern California’s Bay-Delta estuary to Southern California is unlikely. These two events are spurring changes in water use policy and practice in Southern California. One policy change that may reduce Salton Sea water inflows is the water transfer agreement between Imperial Irrigation District (IID) and San Diego County Water Authority. As stated above, in this agreement IID will sell conserved water to San Diego. Essentially conservation measures would reduce the volume of fresh water present in agricultural run off entering the Salton Sea. This fresh water dilutes the concentrations of salts and pollutants present in agriculture wastewater flows entering the Sea. Wastewater inflows to the Salton Sea originating in Mexico may decrease. Baja California’s Comisión Estatal del Agua plans to expand its wastewater treatment capacity in Mexicali, and this water will be reclaimed for industrial processes and urban landscaping (Comisión Estatal del Agua (CEA) 1999).

[19] One grim addition to the Salton Sea National Wildlife Refuge is an incinerator to cremate dead birds. This incineration prevents further spreading of disease amongst waterfowl. In 1997, Fish and Wildlife management of the disease outbreak has resulted in the Service to go $350,000 over its budget allocated for Salton Sea (Bloom 1998).

Given these anticipated changes in water management in U.S. and Mexico, Cohen, Morrison and Glenn (1999) estimate that inflows to the Salton Sea may decrease from 1.35 to about 0.8 million acre-feet. As water inflows are reduced, the salinity, nutrient and other pollutant concentrations (selenium and pesticides for example) in the Sea may increase. At present, increasing levels of salinity in the Salton Sea are threatening an important food source for the birds, brine shrimp. The increase of pollutant concentrations in the Sea could result in a further weakening of fish and waterfowl immune and reproductive systems. Increases in both salinity and pollutant concentrations is likely to increase waterfowl moralities. In addition, the Sea's elevation will decrease and the lake bed will be exposed. Exposure of hypersaline lake beds (as have occurred in the case of Owens Lake and the Aral Sea) have resulted in an increase of wind blown salts, dust and other air pollutants. These air pollutants could adversely affect both human and animal populations in the Salton Sea region (Cohen, Morrison and Glenn 1999; Vincent 1999b).

In January 2000, federal officials warned that the sea's ecosystem will die unless 9.4 million tons of salt are pulled from the lake each year (2001). Since the IID-San Diego water transfers will result in less fresh water entering the Salton Sea, IID maybe responsible for mitigating the environmental impacts of the transfers. Imperial Irrigation District could render the transfer null and void, if the cost of mitigation is more than $15 million per year *(San Diego Daily Transcript,* 21 March 2001). San Diego County Water Authority officials cite that the Salton Sea is dying, and it might be too late to save the Sea. Meanwhile, due to the massive bird die offs, the Audubon Society listed the Salton Sea as one of the ten most endangered wildlife refuges in the United States *(San Diego Daily Transcript,* 21 March 2001).[20]

In this section I have detailed the geography and environmental conditions of the Río Colorado Delta, a delta encompassing wetlands and marine ecosystems in both California and Baja California. Mexico has responded with localized projects in the sending region of the hydrocommons. Yet Mexican solutions cannot include United States receiving regions of the Colorado River hydrocommons as part of the solution to Río Colorado Delta ecosystem restoration. The primary reason for this lack of incorporation of U.S. receiving regions (and their responsibility for the consequences of their transbasin diversions), is simply that the "other" Delta of the Californias is for the most part located in Mexico. In addition, U.S. states receiving Colorado Water allocations have been unwilling to recognize the need for environmental water allocations for endangered wetland ecosystems such as the Colorado River Delta and the Salton Sea. Yet this attitude may change, due to adverse environmental impacts which occur in receiving regions of Colorado River hydrocommons. In Southern California, an awareness of environmental impacts due to transbasin diversions is emerging from water pollution and coastal

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[20] Details of the IID-San Diego County Water Authority water transfer agreement (land fallowing, return flow changes) and environmental mitigation are currently being analyzed in the Environmental Impact Report as required by CEQA. This report has not been completed at the time of publication. However, one key element of the agreement may incur a international water conflict. One method proposed to free up water for the transfer is the lining of the All-American Canal in Imperial Valley. This conservation method has been approved by the International Boundary and Water Commission and will be funded by the State of California. The lining will save IID an estimated 100,000 acre-feet per year. However, water from the all American Canal has seeped into an aquifer, and most of the aquifer is located in Mexico. For decades, farmers in the Mexicali Valley have used this groundwater for irrigation agriculture. The lining will reduce a significant amount of recharge for the aquifer, an estimated 800,000 acre-feet each year. Farmers in Mexicali Valley strongly oppose this lining and continue to bring up the topic in binational forums and conferences. For more information see (Calleros 1991; Hayes 1991; Calleros 2002).

water protection stakeholders, and it is this water quality component of hydrocommons construction that I detail in the following section.

Colorado River Hydrocommons Linkages and Environmental Impacts:
The Tijuana-San Diego Metropolitan Region or the Receiving Region

> A San Diego-Baja aqueduct study is a good idea. But dare we hope that the worthies studying the idea will plan what to do with the water after it has been flushed into Baja's sewers? And ours too, for that matter. This year for the first time in decades, I have not needed medical attention for infected sinuses and ears. Because this year, for the first time in decades, I have not gone into our ocean. Cleaning up the water we already have should be of first importance. (Editorial, *San Diego Union Tribune,* September 17, 1999)

This editorial elucidates a concern often not thought of concerning hydrocommons construction and management. What are the land use and water quality impacts of the diversion to the region that receives the transbasin diversions? This analysis is often overlooked in natural resources policy debates. A geographical approach to hydrocommons management examines the complex political, economic and environmental flows or interactions for all regions. Given this geographical approach, if there are environmental consequences in the receiving region exacerbated by transbasin diversions, should not these impacts in the receiving region be a consideration in proposals, such as the Tijuana-San Diego binational aqueduct?

The most obvious link between an increase in water imports and water quality is that water supply increase may result in an increase of wastewater flows (Gunnerson 1991; Osann and Young 1998). In Mexico, because state and federal level hydraulic plans evaluate both water supply use and wastewater discharges, the correlation between developed water supply and wastewater discharge data is easy to plot. Guzman (1998) reviewed the water supply and wastewater discharge data for Tijuana. His analysis revealed that between 1984 and 1999 Tijuana's developed water supply nearly doubled. This increase of water supply has contributed to a threefold increase in wastewater discharges and threefold increase in uncontained wastewater flows (Guzman 1998).

In San Diego, there is much discussion as to the cumulative amount of water imported to Southern California, yet there is little discussion concerning the cumulative loads of wastewater deposited into Southern California's coastal region. One 1998 study analyzed the four largest municipal wastewater treatment facilities discharging into Southern California's coastal waters. A noticeable trend is the ninety percent wastewater flow increase for San Diego's Point Loma Wastewater Treatment Plant. The study cites that population growth patterns, regional industry types and numbers, presence or absence of water reclamation programs, and inland discharge sources account for differences among the plants (Raco-Rands 1998, 4). An increase in developed water supply was not cited as a possible cause of increased wastewater discharges.

Table 1 provides an initial analysis linking water imports, City of San Diego water supplies, City of San Diego urban population numbers and wastewater flows. As the reader will note there is a positive correlation between water imports and Point Loma's wastewater flows. However, the reader must also note that the service areas, land use types and populations served for each agency listed in Table 1 are not the same.[21]

[21] In fact numbers from San Diego County Water Authority can be misleading because water imports for San Diego County not only support urban uses but agricultural uses. Hence, I have included City of San Diego usage.

Table 1
Links Between Water Supply, Urban Growth and Wastewater Discharges

Year	SDCWA Imports (AF)	City of SD Total Water Supply Deliveries (AF)	City of SD Population	MWWD Wastewater Discharges (MGD)
1974*	337,757	153,671.7	1,358,000	102
1980	309,826	175,667.4	1,862,004	132
1990**	674,016.1	236,491.0	2,498,000	185
1998	433,490.1	210,936.9	2,690,255	194

AF: Acre-Feet MGD: Million Gallons Per Day
Sources: Ganster 1998; Laru pers. com. 2000; City of San Diego Metropolitan Wastewater Department National Pollution Discharge Elimination System (NPDES) Permit Annual Reports, San Diego Regional Water Quality Control Board.
* 1974 is the first year MWWD filed an NPDES permit for wastewater discharges from the Point Loma Wastewater Treatment Plant
**1990 reflects a drought year, hence a large increase of water imports

Although wastewater flow volumes have increased in Southern California, the amount of certain pollutants discharged have decreased. In 1971, these four plants released nearly 600 metric tons of copper and chromium (Raco-Rands 1998). By 1996 the plants discharged approximately 6.5 metric tons of chromium and 49 metric tons of copper. Between 1971 and 1996, oil and grease discharges decreased by 76 percent (Raco-Rands 1998). The study cites that increased source control, land disposal of biosolids, sludge dewatering, and technological advances in primary and secondary treatment methods account for the reduction in contaminant mass emissions (Raco-Rands 1998). Again there is no discussion of whether water conservation methods have contributed to a decrease of pollutants discharged (Osann and Young 1998).

An increase of wastewater flows entails a need for more and larger pipelines to collect and convey the wastewater to a municipal wastewater treatment plant. Citizen activists in both cities charge that the planning process does not address the need to increase daily sewage capacity and the need for more maintenance on sewer lines (More pipelines entail more inspections, cleaning and replacement of pipes.) (*The Beacon,* Thursday July 22, 1999). According to the lead water quality activist Donna Frye:

> You can only fit so much stuff into a pipe. San Diego is building projects and adding users. Where you had a single family home, you now have a condo building; where you had a mom and pop store, you now have a mini-mall. Poor planning is the culprit, and we are dealing with the problem after the fact. When looking at a pipe which is fifty years old, over capacity and in poor structural condition, the answer to the question: "Should we have repaired our pipes earlier?" is self evident. *(The Beacon* Thursday July 22, 1999)

The problems surrounding wastewater infrastructure and urban expansion leads us to question relationship between imported water and urban growth? According to Reisner (1993),

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Remember MWWD discharges reflect not only discharges from City of San Diego, but also fifteen other municipalities or wastewater districts outside San Diego's city limits.

Gottlieb (1988), Worster (1985) from a historical perspective cities, like Los Angeles and San Diego, could not grow without a growing supply of imported water. For example, Tijuana's rapid population growth rate (5.8 percent each year) has also been accompanied by a two-fold increase of developed water supplies between 1984 and 1999 (Guzman 1998). On the other hand, Southern California Metropolitan Water District's cites that aggressive conservation measures resulted in the Southern California's population increasing by 2.8 million between 1987-97, without an increase of water supplies (Hubbell pers. com. 1999). Water agency representatives state that they simply supply water. Furthermore, since the agencies do not conduct land use planning, they do not encourage urban growth or sprawl in San Diego County.

Given these conflicting points of view on the links between urban water and growth, the more appropriate question to ask is does an increase of water imports encourage an expansion of urbanized land use? In both cities, urban centers are not only growing in population numbers, but also in square miles of urbanized region. The amount of urban expansion, does differ. According to Ojeda's (2000) biogeographical analysis, in 1938 the city covered 17.35 square miles. By 1994, the city had extended to 121.45 square miles for 1,035,415 residents (Ojeda 2000; Ganster 1998). San Diego's urbanized region can best be estimated by the total square miles of urban infrastructure. San Diego's Metropolitan Wastewater District's sewerage service area which encompasses the City of San Diego and fifteen cities and districts, is 450 square miles (City of San Diego, Metropolitan Wastewater Department (MWWD) n.d.).[22] Within this service area, MWWD serves approximately 2,000,000 residents. Given these numbers, Tijuana's urban population density is approximately 8,500 persons per square mile. San Diego's is 4,444 per square mile. Hence, San Diego's urban consumption of land is two times greater than that of Tijuana.[23]

One can clarify the imported water urban sprawl link controversy by asking a simple question. What is the intended use of the imported water? If the use of the imported water is to build more residential and industrial units in regions that were previously not urbanized, then yes, imported water supports urban consumption of land. According to document analysis of local newspapers and economic development publications, San Diego's local political and business leaders support the notion to use imported water supplies to build more homes, and high tech/tourism based economies.[24] In terms of the Imperial Irrigation District (IID)-San Diego County Water Authority transfers, a staff member of the State Water Resources Control Board states that San Diego's politicians intend to build new homes with the IID water. This use of water is problematic as the staff member asks "What happens after the transfer contract expires, and IID decides to sell this water to another water user?" In Tijuana, land use planners are preparing for tremendous growth along major highways to the east and the south. One planner relayed to me that he would like to see more centralized urban development in Tijuana.

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[22] If one examines the map of MWWD service area, one can see that even this geographic representation of urbanization in the San Diego region is incomplete. MWWD does not service urban regions in the north part of San Diego County, a region that is rapidly growing in terms of urban growth and expansion, especially for cities such as Oceanside.

[23] In fact the trend towards low density urban sprawl will continue in San Diego. According to the 1999 San Diego Association of Governments Cities/County Forecast, between 1995 and 2020 low density single family housing will increase by 201%. Multiple family housing will increase 42%.

[24] See for example: Editorial "Securing Water" *San Diego Union Tribune,* August 14, 2001 at B8; San Diego Association of Governments 1999; San Diego Dialogue 1999; Editorial "Working for Water," San *Diego Union Tribune,* September 4, 1998.

However, landowners along these highway corridors are lobbying for Tijuana's urban expansion (Graizbord pers. com. 1999).

Urban consumption of land are critical in terms of the region's water quality, simply because water quality scientists, the United States Environmental Protection Agency and coastal water pollution non-governmental organizations (such as the American Oceans Campaign, Heal the Bay, San Diego BayKeeper) assert that urban growth and it consequent land cover change, is probably the primary cause of nonpoint source pollution deposited in Southern California's and Baja California's coastal waters.[25] A recent Los Angeles times report articulates how nonpoint source pollution travels and enters coastal waters.

> A drop of rain plunks onto a sidewalk in downtown Los Angeles. Spilling over the curb, it whirls down the drain. Five hours later, after coursing 18 miles through the heart of the city, the storm water carrying every germ and chemical it encountered along the way splashes into the ocean at Playa del Rey. Everyday rain or shine, enormous quantities of potentially toxic wastes, from human sewage to garden pesticides to metal that flakes off roofs and car brake pads are washed onto the streets and yards onto the beaches in Southern California (Cone 1999).

Urban expansion and increasing population growth exacerbate urban polluted runoff in two ways. First increasing populations generate more contaminants. Second, when regions urbanize, there is an increase of impervious surface area. These impervious surfaces do not allow rainwater to be absorbed by vegetation or soils, and hence storm water runoff flows in greater velocities and volumes to surface waters (American Oceans Campaign 1997; San Diego Association of Governments 1997; Dallman and Piechota 2000). Pollutants such as copper (released from car brake pads), fertilizers, oil, bacteria and viruses are picked up by runoff, and discharged untreated to surface waters via the storm water conveyance system. Furthermore impervious areas such as asphalt or concrete greatly impede the natural pollutant filtration system when rainwater is allowed to percolate into the soil, or accumulate in wetland regions.

In essence as the surface area of impervious surfaces increase, there is an increase of urban runoff flows (Bay and Schiff 1996). As urban populations grow there is a greater concentration of nonpoint source contaminants that enter urbanized region's storm drains, rivers, streams and coastal waters. Between 1972 and 1995 Southern California's urban runoff has increased approximately by 1100 percent (Cone 1999). Table 2 summarizes the major pollutants found in Southern California's polluted runoff, and the amounts deposited in coastal waters.[26]

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[25] Nonpoint source pollution does not originate from a single source, rather it is human/animal waste, chemicals, oil and other substances that have collected on the ground, are washed off by water flows and eventually enter and pollute watersheds and coastal waters. Other terms for nonpoint source pollution are polluted runoff, urban runoff and storm water pollution.

[26] Polluted runoff is especially problematic for bay and estuary regions, which are semi-enclosed and poorly flushed out by tides. For the San Diego-Tijuana region, urban runoff is identified as a primary source of pollution for semi-enclosed water bodies such as the San Diego Bay, Mission Bay, the Tijuana River, Sweetwater River and San Diego River estuaries.

Table 2
Southern California
Runoff Pollutants -- Historical Increases[27]

Pollutant (in metric tons)	1972	1995	% Change
Copper	18	88	+389
Zinc	101	316	+213
Lead	90	39	-57
Nitrate	980	8,800	+798
Phosphorous	410	2,900	+607
Total Urban Runoff (gallons)	**63.9 billion**	**771 billion**	**+1,106%**

Source: Cone 1999, citing data from the Southern California Coastal Water Research Project (SCCWRP) Annual Reports.

According to the SCCWRP, estimates of mass emissions of pollutants listed in Table 2 can demonstrate significant variability due to: 1) that a small fraction of watersheds and runoff volumes are actually monitored, and 2) there exists tremendous variability in contaminant concentrations among various watersheds and storm events (Schiff 1996, 1). However, Schiff (1996, 21) points out that even when utilizing the lower end of pollutant mass emission estimates, pollutant emissions from urban runoff are substantial relative to other sources of pollutant emissions (such as those from power generating stations or even some municipal wastewater treatment plants).

Besides heavy metals, urban polluted runoff carries viral and bacterial pathogens. This public health concern is reflected in the quote from the *San Diego Union Tribune* editorial at the beginning of this section. Pathogens can afflict swimmers and surfers when polluted ocean water enters their ears, noses or mouths. Surfers exposed to pathogens risk contracting gastroenteritis, hepatitis, ear nose and throat infections, respiratory ailments, diarrhea, rashes and other illnesses (American Oceans Campaign 1997), In 1995, the Santa Monica Bay Restoration Project and the University of Southern California researchers conducted an epidemiological study to examine the health effects of swimming near storm drain outfalls in the Santa Monica Bay (Haile, et al. 1996). The study:

> ... compared individuals swimming at the outfall location, with those swimming 400 yards away, found substantial increases in experiencing fever, chills, ear discharges, vomiting, coughing and phlegm, respiratory diseases and gastrointestinal illness among those swimming directly in front of the outfall (American Oceans Campaign 1997, 9).

[27] This data reflects pollutant mass estimates from urban runoff, based upon sampling of urban runoff. For a discussion of how these estimates are calculated see Schiff (1996). Schiff (1996) notes that other elements need to be considered such as pollutant transport, contaminant fate, and biological impairment.

The study confirmed what surfers had been claiming for decades. There is an increased risk of illness associated with swimming near storm drain outfalls (the discharge outlets for polluted runoff).

This section discussed the links between imported water supplies, urban expansion and coastal water quality in Tijuana and Southern California. However, urban expansion and its consequent pollution from point and nonpoint sources, not only threaten coastal waters, but drinking water sources within the receiving region of the hydrocommons. Below is a discussion of local water supply contamination resulting from urban consumption of land. What is interesting to note is that certain local politicians and water agencies in the region assert that one remedy for contamination of local water resources, is an *increased reliance* on imported water supplies.

<u>Linking Water Imports with Local Surface/Groundwater Water Contamination</u>

Probably the greatest threat to Tijuana's local water supply is water pollution from industrial/urban point and nonpoint sources. One indicator of the concentration of pollutants in Tijuana's local supplies is the Tijuana River aquifer. This aquifer lies beneath the Tijuana River, a river that travels through the City of Tijuana. According to Guzman (1998) over 100 wells draw from this aquifer, producing an average of 5,000 acre-feet per year of water. After analyzing twenty well samples during wet and dry weather conditions, Guzman (1998) concludes that the aquifer is contaminated. Wells that demonstrate high levels of total dissolved solids, nitrates and fluctuating numbers of coliform are contaminated by uncontained wastewater flows. A second source of well contamination is the presence of heavy metals such as barium and silver, contaminants that originate from industrial, commercial, residential and automobile activities (Guzman 1998).

What Guzman did not address in his analysis is contamination from nonpoint sources found in Tijuana's polluted runoff flows. In 1996-97 rainy season, researchers from San Diego State University conducted an analysis of Tijuana's urban polluted runoff. From storm water samples significant amounts of zinc, copper and lead (all toxic heavy metals) were present. Other pollutants detected were cadmium, chromium and nickel (Gersberg et al. 2000, 36-39).[28] Given the study results and above discussion on Southern California's urban runoff pollution, it can be expected that as Tijuana's urbanized population and urbanized region grows, so will the amount of urban polluted runoff flows increase. Tijuana's main supply surface water reservoirs, Presa Rodriguez and Presa Carrizo are currently protected from urbanization and urban sources of contamination. However, irregular residential settlements or colonias are expanding from the west towards both these reservoirs. It is unknown as to how much the Tijuana River aquifer has been contaminated from urban polluted runoff.

Protection from urban nonpoint source pollution is not the case for San Diego's surface and groundwater supplies. Just southeast of San Diego, the Sweetwater River flows into the Sweetwater reservoir, a local supply source of fresh water for residents which reside in east San Diego, and suburbs such as National City, Chula Vista and Bonita Vista. Urbanization has started to encroach on land near the western part of the reservoir, and regions upstream the reservoir. According Dennis Bostad, the Director of Water Quality for Sweetwater Authority (the water supply agency which manages the Sweetwater Reservoir) runoff from urbanized area

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[28] For chromium, copper and lead residential land uses demonstrated the highest levels of these pollutants. This is surprising, since the assumption has been that export manufacturing plants or maquiladoras are the primary source of pollutants (Gersberg et al. 2000).

within the Sweetwater watershed causes a severe degradation of drinking water quality. This water quality degradation is caused by urban runoff flows during wet and dry weather conditions (Bostad pers. com. 1999). To illustrate his point Bostad referred to one indicator of drinking water quality for health and taste standards, the amount of Total Dissolved Solids (TDS), or an indication of the amount of salts present in drinking water supplies Table 3 summarizes the data Bostad (pers. com. 1999) presented to me:

Table 3
Salts Present in Drinking Water Supplies

Type of water	TDS parts per million (ppm)
Local surface waters (unaffected by urbanization)	200-250
Colorado River imported water	600-1000
Reclaimed water	1250
Urban runoff	2000-5000

As one can see from this chart according to Bostad and the Sweetwater Authority, the best water quality is from local surface water unaffected by urban pollution sources. In fact, Sweetwater blends its local water supplies with Colorado River water, to dilute the amount of TDS present in imported Colorado river water.[29]

Within the past decade urban development within the Sweetwater River watershed, posed a contamination threat to Sweetwater Authority's drinking water supply. As urban development continues to grow in the drainage areas which contribute runoff flow to the Sweetwater Reservoir, urban runoff will contribute continuous and increasing flows that are high in TDS or salts, and other contaminants such as heavy metals and viral/bacterial pathogens. Given the high concentrations of pollutants in urban runoff, the Sweetwater Authority constructed an urban runoff diversion system Sweetwater Authority, n.d.). The system completed in 1998 intercepts and directs a significant portion of urban runoff from the reservoir. Urban runoff, or high TDS water is diverted into PVC-lined holding ponds which form wetland marshes. Some of the urban runoff is allowed to percolate into an aquifer downstream, where it is treated using reverse osmosis demineralization (Sweetwater Authority n.d.). Some of the diverted high TDS runoff does not enter the aquifer and continues down the Sweetwater River, where it discharges and deposits its pollutants into the San Diego Bay. The urban runoff diversion system removes annually 535 tons of salts each year from the Sweetwater Authority water supply (Sweetwater Authority, n.d.).

However, even with the urban runoff diversion system, water quality within the Sweetwater River water, along with most rivers in the San Diego-Tijuana metropolitan region, continue to be threatened by urban development, or more specifically, land use development conducted with no consideration of downstream water quality impacts. At present many stakeholders (including the EPA and the SCCWRP) state that polluted runoff is primarily a beach or coastal water problem. However according to Bostad (pers. com. 1999), as urban development moves inland or upstream, the problem extends upstream to fresh water resources:

[29] Southern California Metropolitan Water District blends its Colorado River water with State Water Project water to reduce the high amounts of TDS present in Colorado River water.

> Historically what has happened is most of growth has occurred on the coast. So as the concentration of growth moves east [upstream], then that all the runoff ends up in higher concentrations at the coast. As growth continues to move east, that line of impact of runoff will move east or upstream also. Right now urban growth is impacting the beaches where people are absolutely upset about the conditions of the beaches. People in the county are not as cognizant of the impacts to the drinking water reservoirs located near the coast. But the same urban runoff problems occur at reservoirs with trash, bacterial contamination, and high TDS water runoff. Generally with all the reservoirs in our system in the county, many are attached to imported water supply, and if more and more growth is allowed upstream of these reservoirs, they could come under pressure from having impacts from urban runoff flows. Sweetwater is the only reservoir in the county right now which has an urban runoff diversion system. As they build in South County around Otay reservoir, and build in North County upstream of reservoirs there will be more pressures of urban runoff to drinking water quality in both places. It will happen more and more as growth continues.

In the San Diego-Tijuana metropolitan region land use planning rarely if at all takes into consideration protection of local watershed or coastal water quality. The concern of urban polluted runoff is more often than not ignored in the environmental assessment process (as required in San Diego by the California Environmental Quality Act) of urban development projects. Often the assessment will state that individually a development project can pose significant cumulative impacts in a watershed, but these impacts cannot be mitigated (City of Santee 1997). California's Regional Water Quality Control Boards and the California Coastal Commission have developed plans to address the cumulative impacts of urban point and nonpoint sources for the watershed and coastal receiving waters. However, there is immense resistance to these plans from inland communities (or communities upstream), the Building Industry Association and the County of San Diego. One planner I interviewed suggested that planning departments in this metropolitan region should map projected urban growth patterns not by each city/political jurisdiction (as it is commonly done in Tijuana and San Diego), but map urban sprawl in each watershed. Then he states, the public and land use planning decisionmakers can visualize the cumulative amounts of polluted runoff generated by urban development as it continues to expand upstream (Author interview).

In addition, water agencies in the San Diego metropolitan region need to expand their perception of water quality from that of simply imported water quality, and include water quality issues within local watersheds. As Bostad points out below, if urban development continues upstream, imported water reservoirs may be the next sites of contamination from urban polluted runoff. Bostad's solution to localized water quality problems encompasses an integrated vision of water resources management. Such a vision integrates imported water use, land use planning, and local watershed protection:

> Since the 1960s, we at Sweetwater have been making water quality improvements. Developing multiple barriers to water quality degradation. The treatment plant built in the 1960s is one type barrier, the other is going backwards into the watershed supply system, and that is why we have our urban runoff diversion system. Recently, we are taking more and more efforts to interact with the San Diego County planning department. We are trying to improve land use practices that may impact water quality.

> Our interaction with the County planning department has been less successful. I think there should be better communication between the County and water agencies. We need to impart a better way to express the value of source water management as an important tool for future land use planning and protection of water resources. I think part of the problem is that there is a mixed perception of local water and protection of local water resources. The City of San Diego, Helix, Sweetwater Authority, Oceanside and Vista are the only water supply agencies that have local supply reservoirs. As a result most of the people in the County perceive water quality from the perspective of imported water quality not local water quality. So I think it is real important that we get a better understanding of source water quality, and the reasons to protect local sources.
>
> The San Diego County Water Authority [the agency which imports water for San Diego County] for example has a different perspective. First they don't treat water. They don't have local reservoirs that they are protecting from urban runoff. Their perspective is one of imported water only, and that is going to change because they are developing programs for local storage. I think their perception that "We can put water in a reservoir that is not protected from urban runoff" is going to change because that water is going to require additional treatment, therefore it will cost more. Or if there is a situation where there is enough deterioration of that water that they put in a reservoir then perhaps they can't take it out and treat it one hundred percent, then they will have to blend it again. So there are other issues of loss of supply due to loss of local water quality, they will have to address in the future (Bostad pers. com. 1999)

It is at this point that my discussion of water quality impacts within the hydrocommons comes to full circle. I have discussed how imported water supplies can encourage, in part, urban growth and most definitely urban expansion. I have discussed how urban pavement of land and its by-product urban polluted runoff contaminates coastal waters and even local fresh water supplies. As Bostad implies above, part of the San Diego's local water quality problem is water importation. From a planning perspective, there is little to no consideration of the relationship between imported water, urban expansion and urban polluted runoff. This urban polluted runoff (which has resulted from imported water supporting urban expansion) degrades local water quality of not only locally captured drinking water, but ironically enough as Bostad states above, local imported water storage facilities. It is this connection which needs to be made between transbasin diversions, land use planning and water quality.

I end this section with a personal narrative of water importation and local water quality degradation. In August 1999, my parents who reside in Lakeside, a suburb seventeen miles east of San Diego, asked me to attend a public hearing on contamination of an aquifer that provides drinking water to Lakeside residents. The aquifer, known as the Santee-El Monte aquifer, an unconfined groundwater basin directly beneath the San Diego River. This aquifer provides water for three water districts.[30] Riverview Water District, my parent's local water supply district, uses

[30] This aquifer is known as the Santee/El Monte groundwater basin. At least eighty-three private, municipal or industrial wells are in operation in the Santee/El Monte Basin (Weinburg 2000).

local groundwater supplies to reduce the high cost associated with imported water.[31] The public hearing I attended was called because earlier that summer, well water samples tested for trace amounts of methyl tertiary butyl ether, a gasoline additive commonly referred to as MTBE. MTBE is an oxygenating agent added to gasoline for cleaner gas combustion, hence cleaner air. However, in California, cleaner air has meant contaminated drinking water. MTBE is leaking from underground storage fuel tanks, fuel pipelines and other sources, and is subsequently contaminating surface and groundwater sources. MTBE is a known carcinogen, and takes years to break down in water bodies (Lakeside Water District 1999).

Hydrological studies revealed that three gas stations (and their leaking underground storage tanks) located on or near the aquifer are the sources of well water contamination. At the August 11, 1999 hearing I listened to public health experts discuss MTBE, and why there is a cause for concern. I listened to a County of San Diego public health official who stated that the gas stations may be the cause of contamination, but that the gas stations were currently in compliance with environmental law (environmental law in terms of hazardous material storage). I listened to a hydrologist talk about the hydrology of the aquifer, and the different, yet expensive methods available to remove MTBE from groundwater supply. One resident asked the board of experts, “Why could you just not use legal action to get the gas companies to clean up the wells?” The representative from the County of San Diego said legal action to clean up the wells might be a possibility, but if you do that, then well the gas companies will pass on the costs to the Lakeside residents, and gas prices in Lakeside might increase.

At this point, a resident asked, “Why not shut down the wells and just rely on imported water?” In essence then Lakeside residents would not have to worry about local water pollution, not worry about higher gas rates, and still have safe drinking water. A heated discussion then ensued, because some residents did not want to have to pay higher costs for imported water. At present locally pumped groundwater from the Santee-El Monte groundwater basin is produced for the approximate cost of $65 dollars per acre-foot. Riverview Water District pays $550 dollars per acre-foot to buy imported water from San Diego County Water Authority (Phone interview with Riverview Water District, May 30, 2000). Approximately one month after the hearing, Riverview Water District shut down four wells due to MTBE contamination. The wells provided thirty-two percent of the District’s water supply. Riverview Water District is now forced to buy expensive water imports to replace its groundwater supply (Lakeside Water District 1999).

One would think that local politicians would take steps to prevent further contamination of the aquifer, but this is not the case. In August 2000, the County of San Diego approved a Riverway Specific plan for Lakeside’s section of the San Diego River. In this plan and most of the land on or adjacent to the San Diego River is zoned for heavy industrial use. The land zoned for industrial use lies within recharge areas of the Santee-El Monte groundwater basin, and lies within the zone of influence for active wells.[32] Representatives from local water agencies, Lakeside community residents and coastal clean water activists strongly objected to this zoning proposal. However, from my observations of public hearings and interviews of public officials, the County of San Diego elected leaders seem to be more preoccupied with tax generation from

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[31] In certain regions of the basin, groundwater quality reflects significant levels of nitrates and TDS, hence my parent’s local water supply agency, Riverview Water District, blends the groundwater with imported water to improve drinking water quality (Riverview Water District Public Hearing, August 11, 1999).

[32] Since the Santee-El Monte aquifer is an unconfined groundwater basin, there is interaction between surface water (in the San Diego River) and groundwater.

industrial economic activity in the San Diego River, than protecting local sources of water supply and coastal waters downstream. It seems that Lakeside's San Diego River and the Santee-El Monte aquifer water quality might become another casualty to urban development with no consideration to water quality impacts.[33]

In his book *Cadillac Desert,* Marc Reisner (1993) uses the Los Angeles urban growth machine case study, to explain the vicious cycle that occurs between water importation and urban growth. Essentially his argument is that if a city imports water and then grows (in urban population numbers and urban land expansion), this urban growth causes a demand for more water. Subsequently, there is yet another demand for more imported water, which results in more urban growth and so forth. I would like to add another component to this "vicious cycle" --- the degradation of water quality in the receiving region of the hydrocommons. From my standpoint, if a city imports water, then the city grows and expands, which then causes a demand for more water, which then results in more imported water and consequent urban growth/expansion. The city grows and eventually the first signs of cumulative water quality problems appear. Beaches start closing and surfers are getting sick from increasing levels of urban polluted runoff and raw sewage discharges. As urban pavement of land moves upstream, local water resources become contaminated by urban development and polluted runoff. This contamination of local water supplies forces local water agencies to either curtail urban growth near local water resources, or import water which then allows urban expansion without consideration of local water quality to continue. The Sweetwater Authority has tried with little to no success the former strategy, integration of water importation, urban planning and local water resources management. Lakeside may opt for the later -- water importation. When will this vicious cycle end in Southern California? More importantly, from my interviews with local politicians and water agency directors in Tijuana, it seems that Baja California's political and business leaders plan to follow Southern California's model of water importation, and consequent economic development and urban expansion.[34]

My argument is not that urban growth or development is essentially bad or wrong, but at some point we need to start asking the difficult questions concerning what are the local land use development implications, and more importantly the localized water quality impacts of imported water? Water quality activists, the U.S. EPA, and even local water pollution government officials all have told me that the best solution is to integrate in terms of governance: water

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[33] Information for this case study stems from my participation observation of land use planning hearings and document analysis associated with the Upper San Diego River Improvement Project or USDRIP between May and August 2000. Until recently, the USDRIP process has been primarily concerned with increasing industrial development in the Lakeside's portion of the San Diego River. Water quality impacts to the San Diego River and the Santee-El Monte Groundwater Basin were largely ignored in the environmental assessment process. In fact the County determined from its cursory water resources analysis, environmental effects from this project are not found to be significant to local water resources (County of San Diego Department of Planning and Land Use, 2000). The County staff reasoned in its environmental assessment, that if business owners in the region follow the law, then there will be no contamination of water resources. Lakeside residents countered that current users in the area do follow the law, and the groundwater is still contaminated. In addition, Lakeside residents, the local Chamber of Commerce, and even the Lakeside School District have requested that the County scrap the USDRIP plan and create a river park. The County ignored these requests, and at present a coalition of Lakeside residents are considering legal challenges to heavy industry uses, especially near wellheads.

[34] The link between water importation and local water quality degradation seems to hold true for Southern California and Baja California. However, I would not extrapolate this link to other regions in the U.S. or Mexico, since the relationship between water imports and land use varies geographically. Theoretically, one could make the same statement with a downstream city transporting water from upstream sources in the same watershed --- hence then the culprit would be "new" water not a transbasin diversion.

resources, land use planning, transportation planning and endangered species protection. In 1999, the County of San Diego's Smart Growth Coalition water resources working group started a discussion on the links between water supply, land use planning and water quality. However, representatives from this task force have are not optimistic. Most believe that local city politicians, land use planners, land development corporations and water import agencies in both San Diego and Tijuana will ignore this document, and hence continue to ignore the links between water importation, urban expansion and water quality.

Conclusion

The geography of water resources along the border between California and Baja California, demonstrates a network of manmade aqueduct and storage facilities utilized for water transfers. This hydrocommons transports Colorado River for agricultural uses in the eastern part of the Californias border region, and ultimately west to urban centers on the Pacific Coast. As with other urban regions in Baja California and Southern California, the Tijuana-San Diego metropolitan region is dependent upon water imports for the region's rapidly growing industrial and residential needs. Both San Diego and Tijuana seek to increase Colorado River water imports, and both cities are investigating the possibility of constructing a binational aqueduct to transport imported Colorado River water.

The hydrocommons, which supplies water to the Tijuana-San Diego metropolitan region, along with other transbasin diversions within the Colorado River Basin, has resulted in greatly diminished fresh water flows entering the Río Colorado Delta. The diminished fresh water flows has desiccated wetlands in the Delta which threaten species migratory waterfowl which visit the Delta and the Salton Sea to breed and rest. In addition, marine species in the Upper Gulf of California (vaquita and totoaba) are endangered by diminished Colorado River flows. In fact, the San Diego-Imperial Irrigation District water transfers are now at risk due to mitigating environmental impacts, most notably salinity increases, in the Salton Sea.

However, transbasin diversions not only adversely impact sending regions such as the Delta and the Salton Sea, but receiving regions. In Tijuana-San Diego metropolitan region, a region that imports up to ninety percent of its water supply, water imports do contribute to urban consumption of land. This urban expansion results in more contaminants, and second an increase of paved surfaces. As with any urbanized region, polluted runoff flows pick up chemicals and germs and discharges concentrated amounts of bacterial and chemical pollutants into rivers and coastal waters. In both Tijuana and San Diego, polluted runoff is the primary public health risk for surfers and swimmers in the region's surface waters. Finally, for rapidly urbanizing regions, nonpoint source pollution is threatening local water drinking water quality resources. Certain water agencies such as Sweetwater Authority ask for integration of water resources and land use planning. Other communities such as Lakeside, chose to shut down local drinking water resources, and import even more water. Tijuana's groundwater resources are now threatened by urbanization in river floodplains, which is expanding east to Tecate (the Alamar and Tecate Rivers are tributaries of the Tijuana River and are key groundwater recharge areas for the Tijuana River aquifer). As in San Diego, Tijuana's political leaders are not focussed on local source water protection, but increasing Colorado River imports. Given consideration of energy costs associated with long distance water imports, water importation may not provide a cost-effective, reliable and secure drinking water supply.

However, a change in perception and politics is occurring in Baja and Southern California. In Tijuana, the Instituto Municipal de Planeación (IMPLAN, Municipal Institute of

Planning), is working to create an urban river park for the Alamar River, located in the eastern section of Tijuana. This river park is an attempt to stop current plans (sponsored by the Mexico's National Water Commission) to channelize and urbanize the Alamar River floodplain. If successful, IMPLAN's urban river park will not only provide much needed green space for city residents, but also will enhance groundwater supplies beneath the Alamar River. East of Tijuana, environmentalists and local businesses have started the process to stop industrial park development in the Tecate River floodplain. Groundwater supplies beneath the Tecate River are of significant interest to the local economy since it provides the "special" water needed for Tecate beer. If this groundwater resource becomes contaminated, it is doubtful that Tecate beer will taste as good using imported Colorado River water (Michel 2001).

In Los Angeles water quality activists and watershed movements are just now starting to understand the connections between imported water, urban expansion and local water quality degradation. Watershed movements throughout the Los Angeles, Riverside and Orange Counties are starting to flourish, taking on the extremely difficult task of watershed restoration and protection in a highly urbanized region. These movements such as the Los Angeles & San Gabriel Rivers Watershed Council and California's Clean Water Action assert that Southern California's water pollution problem is not one limited to coastal contamination and beach closures. The problem is associated with land use planning without consideration to local water quality, a lack of ethic of care for watersheds in Southern California and imported water. Southern California's urban watershed movements are coordinating with watershed organizations in Northern California to limit or even reduce water imports from the Sacramento-San Joaquin Rivers Delta, as demonstrated by the below statement from a letter written by urban watershed and environmental justice groups to California's Governor Gray Davis:

> Water management decisions (especially those made without a connection to land use) can promote sprawl and can result in increased infrastructure costs to urban residents as well as increased concentrations of non-point source pollution in urban streams and waterways. Our communities already suffer from deteriorating infrastructure and polluting industries (Environmental Water Caucus 1999).

As indicated above, certain watershed groups are concerned with not only environmental impacts in the sending region, but the problem of urban expansion, urban polluted runoff and subsequent degraded surface and ground water quality of urban watersheds which receive water imports.

For years, environmental groups have been drawing attention to the plight of the Colorado River Delta, and the need to reduce water imports to restore Delta wetlands, and the Gulf of California marine ecosystems. What this case study elucidates is that political action to save the Delta, may emerge at the other end of the pipeline, the Pacific Ocean. Essentially, at the true end of the pipeline -- the ocean outfalls which discharge municipal wastewater and the storm drain outlets which drain onto Southern California and Baja California beaches -- another problem, coastal water contamination, is emerging due, in part, to increased water transfers along the border of Baja California and California. This problem of coastal contamination has sponsored action by not only beach protection groups, but also urban watershed movements in Southern and Baja California. In addition, coastal and urban watershed residents are starting to realize that cost-effective local drinking water sources have been destroyed or are threatened by urban development. As in the case of Lakeside and potentially the case of the Tijuana River aquifer, contamination of local drinking water resources probably has and will continue to force local residents to shut down local water supply production and rely upon expensive water imports. Given the perspective of the hydrocommons, and the physical interdependencies between water imports, wetland dessication, urban expansion and water quality, it is essential that water suppliers and users in the U.S. and Mexico re-examine management policies and social values concerning a priceless resource produced by healthy ecosystems: clean water.

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Restoring Instream Flows Economically: Perspectives from an International River Basin

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1. Introduction

The Rio Grande originates in the southern Colorado Rocky Mountains, flows through New Mexico, and forms the border between Texas and Mexico on its way to the Gulf of Mexico. Like many western rivers, the Rio Grande is both the dominant and limiting water resource throughout most of its watershed. Under dry conditions human claimants to basin water exceed the available supplies, and emerging demands for environmental protection (in the form of instream flows) further increase competition for access to scarce river flows. On top of this is overlaid explosive population growth, declining groundwater levels, and deteriorating water quality.

The upper Rio Grande from its headwaters to Fort Quitman, about 80 miles downstream from the cities of El Paso and Ciudad Juarez, meets the primary water needs of over one million acres of irrigated land in the U.S. and Mexico. In 1906 the U.S.- Mexico Water Treaty provided that a fixed but small portion of the river's annual flow be delivered to Mexico. Three decades later in 1938, the Rio Grande Compact was approved by the U.S. Congress, dividing the annual water flow among Colorado, New Mexico, and Texas. In developing the Compact, the three states considered likely future flow conditions, and the capabilities and limitations of storage facilities in order to craft an operating agreement for the river which protected the water uses existing at that time.

Conditions six decades ago could hardly have predicted the subsequent growth in the basin's demand for water. Since establishment of the Compact, regional population within the river basin in the U.S. and Mexico has experienced a more than five-fold increase (Peach and Williams, 1999) and new policies toward fish and wildlife habitat have created substantial demands for instream flows. While municipal and industrial water demands in the major basin cities, Albuquerque, El Paso, and Ciudad Juarez have historically been met by nonrenewable groundwater, such pumping is not sustainable at current withdrawal rates. El Paso is rapidly increasing its use of surface water, Albuquerque has plans to begin direct withdrawals of surface water, and the largest basin municipality, Ciudad Juarez, is projected to exhaust its current sole source of potable water within as little as a decade (Paso del Norte Water Task Force, 2001). Within this potentially difficult context we explore possibilities for binational cooperation to not

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only provide for not only future human water demands, but also to meet emerging demands for instream flows and river restoration.

2. Rio Grande Instream Flows

Protection and enhancement of instream flows is increasingly valued for ecological, esthetic , and water quality purposes. But provision of such instream flows typically must occur within a context of traditional, economically beneficial, and legally protected off-stream uses such as irrigation (Gillilan and Brown, 1997). Demands for instream flows within the upper Rio Grande basin are of three basic types. These include endangered species, habitat preservation and recovery, and water quality. Specifically, these concerns include depletion of instream flows and outright dewatering of the river channel, channelization and destruction of riparian areas, and water quality degradation from the concentration of salts, and from untreated sewage and runoff, and mining wastes. In response to these existing conditions, the Rio Grande is regularly identified by a national advocacy group as one of the United States' most "endangered" rivers (American Rivers).

Interstate and international agreements have long been used to establish water rights and obligations in the arid regions of North America such as the Rio Grande basin. While compacts and treaties effectively accommodated most existing and anticipated or desired future uses, the agreements could not anticipate the emerging social values governing many of today's new water demands. In particular, existing compacts and treaties do little to define responsibilities for meeting demands such as instream flows for protection of endangered species. As the U.S. Endangered Species Act is increasingly tested and applied, the need to accommodate instream flow demands consistent with existing compacts and treaties will grow. Binational arid region river basins, including the Colorado River (Pitt, et al, 2000) and the San Pedro River (Varady, Moote, and Merideth, 2000) in the U.S. southwest, and the Snake and Columbia Rivers in the Pacific northwest (Hamilton, Green, and Holland, 1999), each face the challenge of preserving and enhancing instream flows, particularly in downstream reaches.

The case of endangered species and instream flow protection for habitats in the central reaches of a river system is more complex. This is the case of interest in the upper Rio Grande Basin (see Figure 1). Serving over one million acres of irrigated land and the domestic and industrial needs of cities like Albuquerque and El Paso, the river represents the most significant surface water resource in that portion of the arid southwest. The major consumptive uses are in the San Luis Valley (Colorado), the Middle Rio Grande Valley (New Mexico), and below Elephant Butte Dam (New Mexico, Texas, and Mexico). The most sensitive habitat is the 100 river miles upstream from Elephant Butte reservoir (Burton), where irrigation activity may result in the near total dewatering of the river. While many species have been permanently lost from the Middle Rio Grande Valley (including shovel nosed-sturgeon, blue catfish, the American eel, and three minnow species), native aquatic life persists, including the endangered silvery minnow (U.S. Fish and Wildlife Service). The current study considers the impact of the existing Rio Grande Compact, and delivery obligations to Mexico on emerging habitat requirements as defined under the Endangered Species Act.

Most immediate, though perhaps also of least impact to the basin in and of itself is preservation and recovery of the endangered Rio Grande Silvery Minnow (*Hybognathus amarus*). As is typical of endangered species cases, restoring habitat for the particular species of concern is the specific legally mandated target, while restoration of broader ecosystem functions is the broader goal. For the silvery minnow itself, the paramount instream issue is one of

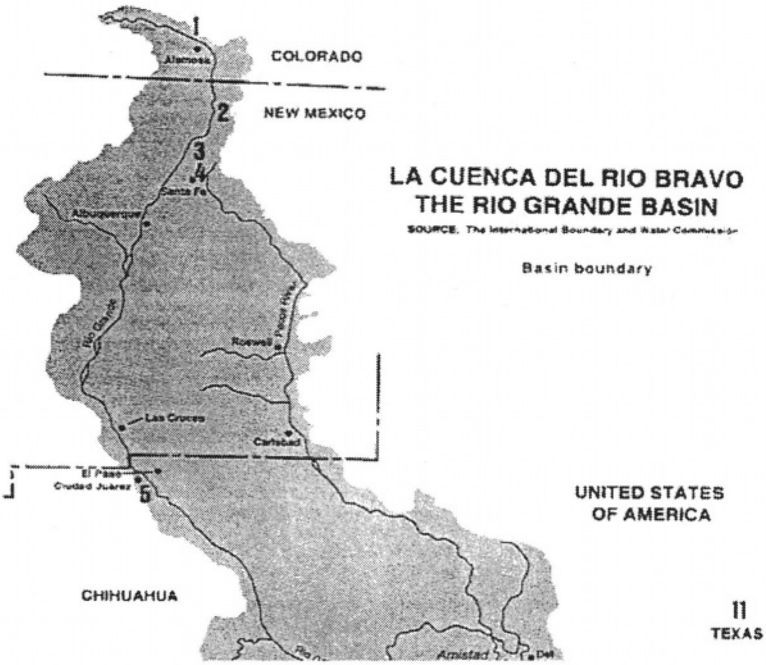

Figure 1. Río Grande Basin above Ft. Quitman, Texas.

maintaining river flows during peak irrigation periods in which the current river channel has a tendency to run dry (Burton, 1997).

For the upper Rio Grande, ecosystem function is largely defined by a self perpetuating wooded riparian corridor, the *bosque*. The cottonwood dominated *bosque* draws shallow groundwater replenished by instream flows. For regeneration, however, overland flows are required; such flooding has been largely eliminated due to upstream flood protection efforts. Thus preservation and regeneration of riparian habitat requires flows regimes which are generally not available today. Below Elephant Butte Dam there is little remaining habitat per se. In downstream reaches the river has been largely channelized, and instream flows occur only as requested by downstream water users. As a matter of course, instream flows are turned on and off in response to irrigation demands. There are emerging calls to restore some ecological function to these reaches. Such efforts would clearly require substantial changes to current water and flood plain management regimes. Nonetheless, the remaining *bosque* above Elephant Butte Dam is regionally significant in the U.S. southwest as the longest unbroken stretch of cottonwood dominated forest (Niemi and McGuckin, 1997).

Finally, instream flows are critical for their dilution value in maintaining acceptable water quality below Elephant Butte Reservoir. Water quality concerns are dominated (though not limited to) by salinity concentrations in river water, shallow groundwater, and nontributary groundwater. In general, as instream flows increase salinity levels decline; conversely, salinity levels can reach critical levels severely impairing crop production and violating water quality standards under very low flow conditions. Further, with increasing levels of good quality instream flow available as far downstream as El Paso/Ciudad Juarez, reliance on nonsustainable groundwater could be reduced through substitution of surface water. The quality of the water throughout the Rio Grande Basin is generally poorer in years of drought than in years of more abundant water supply. Because there is typically a progressive increase in total salt concentration of the river water from the upper to the lower end of the basin, the problem of quality is more critical to the downstream users than to those near the headwaters. In much of Texas and Mexico, the major problem during drought conditions is elevated salinity in the river, thus making river water less suitable and/or more expensive for irrigation and municipal uses.

3. Frameworks for Cooperation

Binational cooperation for enhancing Rio Grande instream flows must be considered in the context of the dominant binational water supply issues facing the United States and Mexico. These issues revolve around the dual problem of explosive population growth in El Paso/Ciudad Juarez, and declining groundwater resources for serving even the existing population. Overlain on physical scarcity is problematic water quality. Our premise is that the most promising opportunities for enhancing instream flows are those that can contribute to addressing these critical municipal water supply issues. Further, we seek to understand the conditions under which cooperative approaches might address the increasing demands for both municipal water supply and instream flow.

Le Marquand (1977) suggests that the potential for binational cooperation is greatest when several conditions are met. These include possibilities for integrated resource development, and symmetric control over a shared, common pool resource. Applying these conditions to El Paso/Ciudad Juarez, Mumme (2000) identifies both opportunities and impediments to cooperation. Integrated resource development is a possibility at many levels, but may be most promising in areas complimentary to cooperative management of groundwater resources. In particular, securing and delivering surface supplies of sufficient quality to meet user needs might be pursued cooperatively. Additionally, water treatment plants and management for municipal effluent could be jointly pursued to the benefit of both El Paso and Ciudad Juarez. The Hueco Bolson from which both El Paso and Ciudad Juarez draw, is physically a common pool resource, utilized on each side of the border. Mumme argues that control of basin water resources is dominated by the U.S. and is hence asymmetric. Control of the groundwater resource alone is less straightforward in the sense that each party can unilaterally utilize the resource by pumping from its own lands. In this sense symmetry exists with respect to groundwater resources, but not with respect to surface supplies. Institutionally, appropriation and use of groundwater is primarily by private property rights. This leads to the situation where there are no clear property rights to the resource as a whole, and there exists an incentive to prematurely deplete the resource to the detriment of all parties. It is helpful to describe the Hueco Bolson as an “open access resource” (Randall, 1981) where use of the physically shared resource is open to all. In this context, cooperative management could bring about substantial benefits if spillover effects between the uncoordinated uses of the resource are large. This may in fact be the case, noting that a groundwater gradient leading to flow from the U.S. to Mexico has been induced by past groundwater pumping (Hibbs, 1999). Cooperation in management of the shared aquifer would thus apparently be desirable.

Ostrom (1991) identifies four characteristics which create favorable conditions for cooperative management of common pool resources. First, the resource should not be depleted beyond recovery. The Hueco Bolson as a primarily nonrenewing aquifer cannot be expected to recover per se, but it does continue to function as a viable (and indeed for Ciudad Juarez as the sole) water supply source. Second, the condition of the resource should be measurable. Recent and ongoing work (e.g. Hibbs et al., 1998) has made important contributions to our understanding of resource conditions on both sides of the border; this mutual understanding is likely to enhance cooperative efforts. As part of the growing knowledge of the shared water supply conditions, predictability (Ostrom’s third condition) of future resource conditions, and responses to management changes, is also increasing. Finally, the resource is “localized” to the extent that potentially cooperating parties have the ability to evaluate and regulate the resource.

We suggest that an additional factor favoring cooperative approaches to management is the potential net benefit of cooperation. To cover the costs of developing and maintaining cooperative solutions, there must be substantial benefits which can potentially be achieved. In economic terms, possibilities for cooperation will be enhanced when Pareto optimal solutions differ substantially from outcomes derived from private solutions. In the case of a common pool resource, for example, the difference between the cooperative solution, the Pareto optimum, and the private solution, will hinge on the degree of spillover effects. A system with only weak spillovers will derive limited benefits from cooperative efforts; systems with substantial spillovers will enjoy potentially large benefits. Such benefits might be symmetric (both parties enjoy significant potential benefits from cooperative solutions), as would be predicted for economically optimal solutions to the classic common pool problem. Alternatively, benefits might be asymmetric (one party might stand to benefit greatly, while benefits might be nonexistent for the other party.) In this case, compensation might be offered as an incentive for cooperation, thus moving towards more symmetric benefits.

Identifying policy options which increase net system benefits is thus a useful step in identifying possibilities for cooperative solutions. To the extent that benefits of such policy options are symmetrically distributed, the likelihood of cooperation will be enhanced. If net benefits are unevenly or asymmetrically distributed, cooperative solutions, while less likely, may still be possible particularly if compensation is offered.

In the remainder of this chapter we seek to identify possible opportunities and barriers to binational cooperation in increasing instream flows in environmentally sensitive reaches of the upper Rio Grande. Two selected policy options are then developed and considered in the context of a previously developed integrated model of the basin (Ward et al, 2001). The model includes essential elements of the basin hydrology, institutions, and economic impacts in order to estimate the system benefits of alternative policy options.

4. Opportunities and Barriers to Cooperative Protection of Instream Flows

Endangered Species Protection

The Rio Grande Silvery Minnow was once common throughout the Rio Grande system, from its sole current habitat in central New Mexico downstream to the Gulf of Mexico. Today, the silvery minnow's occurrence is restricted to the hundred mile long reach above Elephant Butte Dam, about 5% of its original range. Its survival in this reach is threatened by periodic dewatering of much of this reach during the irrigation season. Additional threats include channelization; degraded water quality from municipal, industrial, and agricultural discharges; and competition and predation by introduced non-native fish species (Burton, 1997). Existing Mexican and downstream U.S. water rights would appear to provide some protection for these instream flows. Mexico's senior right may appear generally unimportant to the U.S. (it is less than 5% of median basin inflows), but it may provide limited benefits for endangered species in providing a senior baseflow. In particular, the junior water rights in Texas and southern New Mexico cannot provide upstream instream flows during low flow conditions. By requiring a baseflow for Mexico, it would appear that a small instream flow for the silvery minnow would be maintained.

In practice, the presence of Elephant Butte Reservoir downstream of the reach occupied by the silvery minnow allows for significant operational flexibility in the timing of flows reaching Elephant Butte. The situation is complicated by leakage from the main river channel, the importance of local return flows from irrigation, and a hydrologically connected aquifer. Indeed, a "low flow conveyance channel" was constructed precisely to bypass the leaky river channel in what is now the river reach harboring the greatest population of the silvery minnow. Maintenance options with the potential to significantly impact instream flow conditions are the currently under review (see U.S. Bureau of Reclamation, 2000). Water storage and flood control reservoirs in northern New Mexico which are operated, respectively, by the U.S. Bureau of Reclamation and the Army Corps of Engineers, add further complexity. As such, it is possible to dry up the Rio Grande mainstem for extended periods without compromising Compact or Treaty obligations. This was precisely the case in 1996, when irrigation withdrawals in the Middle Rio Grande Conservancy District dried up habitat of the silvery minnow (U.S. Fish and Wildlife Service). Based on historical flows, approximately 30% of years would produce even greater water scarcity at this reach than was observed in 1996. Instream flows in the middle Rio Grande are thus dependent on intra and interstate, and international institutions, as well as on the management actions of U.S. federal agencies.

Instream Flow and Habitat Restoration below Elephant Butte Reservoir

The Rio Grande below Elephant Butte is today largely a channelized water course serving primarily to convey water for offstream uses in New Mexico, Texas, and Mexico. Emerging demands for restoration, together with continuing concerns for water quality, suggest a range of opportunities and barriers to binational cooperation. Opportunities include impacts of reallocating existing flows from agricultural to municipal uses, potential future increases in allocations to meet the needs of the growing population, initiatives to reduce salinity levels through irrigation efficiency improvements, and habitat restoration projects. The concept of "piggybacking" on water transfers destined for growing municipal demands is identified by Ken Bixby of the Southwest Environmental Center as a key opportunity for restoring perennial instream flow below Elephant Butte Reservoir (Lardner, 2001). Current work on understanding impacts and alternatives to the existing 106 mile long canalization project in this reach include preparation of an environmental impact statement (EIS) on future construction and maintenance activities related to the project (Federal Register, 1999). Looking further downstream, Steve Harris of Rio Grande Restoration draws attention to the "forgotten river," the largely dewatered reach from below Fort Quitman to near the confluence with the Rio Conchas (Harris, 1999).

While growing downstream municipal demands suggest opportunities for river restoration, approaches to meeting these demands may threaten river restoration. Most immediately, the El Paso - Las Cruces Regional Sustainable Water Project is designed to provide for year-round withdrawals of surface water for municipal use, but in the completed EIS also includes provision of a 32 mile long aqueduct for conveyance of treated surface water to El Paso (Paso del Norte Water Task Force, 2001). Construction of such a bypass around the river channel to reduce river channel losses and water quality degradation would remove many of the opportunities for river restoration which arise from growing downstream municipal demands.

Continued regional urbanization also suggests conflicting impacts on the river corridor itself. Development may eliminate opportunities for restoration of wetlands and other aspects of a "natural" corridor. Conversely, restoration of such natural river features would provide flood control benefits which increase over time with continuing downstream population increases.

5. The Model

An integrated model of the Rio Grande Basin (RGB) was developed to bring the issues and impacts of hydrology, economics, and institutions within a single quantitative framework (Ward et al, 2001). The RGB model is used to estimate hydrologic, economic, and ecological impacts of a prolonged basin drought. Proposed alternative water management institutions for minimizing drought damages are simulated using the RGB model. The model is then further utilized to explore the sensitivity of assumed parameters of critical physical linkages (e.g., surface-groundwater interactions) to the estimates of drought damages.

The integrated framework provides a flexible environment for representing alternative drought-coping institutions. At the same time, the framework plausibly accounts for a set of physical interactions between uses (e.g., agricultural, municipal, instream, and environmental), storage (including groundwater), flows (including diversions, pumping from groundwater, and return flows), and various losses (including field, canal, and conveyance losses). Because of the importance of interstate and international water policy issues, relevant compacts and decrees, uses, storage, and flows must be represented.

The integrated model starts with the basic water supply, which includes all major tributaries, interbasin transfers, and hydrologically connected groundwater. Water demands (current and projected up to 40 years into the future) include agricultural water uses (representing from 86% to 98 % of surface, and 47% to 56% of groundwater use), municipal and industrial demands in Albuquerque and El Paso (the balance of the demand for consumptive use), recreation at the major basin reservoirs, and environmental demands for instream flow protection. Each component is represented in a yearly time-step over a forty year planning horizon.

The fundamental institutions governing water allocation throughout the basin are the 1938 Rio Grande Compact and the 1906 U.S. - Mexico Water Treaty. The Compact establishes schedules relating each states' obligation to the next on the basis of available water inflows to the state. The Treaty establishes an obligation that the U.S. deliver annually 60,000 acre-feet to the Republic of Mexico, except in "extraordinary drought."

Representing the Compacts

While intrastate water rights systems are typically classified as appropriative, riparian, or a hybrid of the two systems, interstate compacts can take many forms (Tarlock). Bennett and Howe provide one approach to classifying compacts by distinguishing between allocations based on fixed versus percentage formulas. In addressing the Upper Rio Grande Basin, it is useful to introduce a complementary approach to classification of the implicit water rights between the three states and Mexico.

We begin by thinking of water rights in economic terms as a type of water production function. For any given water right holder, the production function relates the actual water delivery over a given period (termed wet water) to the sum of river basin inflows. While the sum of all off-stream deliveries will increase roughly linearly with basin inflows (ignoring return flows and system losses), it is unlikely that a given water right holder will experience constant returns to basin inflows. Rather, the user (e.g a state or nation) may be allowed decreasing (junior right) or increasing (senior right) marginal returns to basin inflows. The case of constant marginal returns is that of a proportional right. This concept of linking seniority of water right to the nature of the marginal flows reserved with increased total flows offers insights into characterizing water rights implicit in compacts and treaties. This concept is particularly helpful where, as is the case with the Upper Rio Grande Compact, the text of the agreement provides little intuition as to the nature of the respective state water rights.

Allocations under the Compact and Treaty can be represented using a deterministic model. Central to the Compact are a set of supply indices specifying the proportion of inflows to one sub-basin that are to be passed to the downstream sub-basin. First, Colorado must deliver to New Mexico a minimum water volume based on the headwaters inflows. Let $\alpha_i(Z_i)$ and Z_i represent the supply indices and the headwaters flows, respectively, for Colorado, and let X_{Col} represent the implicit consumptive use allocated for Colorado. Then

$$(1) \qquad X_{Col} = \sum_i (1 - \alpha_i(Z_i))\ Z_i \quad .$$

Colorado may use from 40% to 80% of the total annual flows. Secondly, New Mexico must deliver annual flows to downstream of Elephant Butte Reservoir for water users in southern New Mexico, Texas, and Mexico. For northern and central New Mexico, consumptive use X_{NM1} is constrained by the supply index $\beta(\alpha_i(Z_i), Z_i)$ for these deliveries, giving

$$(2) \qquad X_{NM1} = (1 - \beta(\alpha_i(Z_i), Z_i))\sum_i \alpha_i(Z_i)\ Z_i + Z_{exempt}$$

where Z_{exempt} are tributary inflows (and San-Juan Chama imports) that can be fully consumed in northern and central New Mexico. The river reach of greatest concern for the silvery minnow lies downstream of (most of) these uses. The factor $1-\beta$ ranges from about 20% at high flow levels to a maximum of 43% at low flows. Deliveries to Mexico (X_{Mexico}) of up to 60,000 acre-feet must be made from the deliveries below Elephant Butte, giving the allocated use in Texas (X_{Texas}) and in southern New Mexico (X_{NM2}) as

(3a) $X_{Texas} = \gamma \beta(\alpha_i(Z_i), Z_i) \sum_i \alpha_i(Z_i) Z_i - X_{Mexico}$

(3b) $X_{NM2} = (1 - \gamma) \beta(\alpha_i(Z_i), Z_i) \sum_i \alpha_i(Z_i) Z_i - X_{Mexico}$

respectively, where γ=43% is independent of flows.

Table 1 shows the calculated total water allocated according to the Rio Grande Compact, given Mexican Water Treaty deliveries of 60,000 acre-feet to Mexico. Colorado use under the Compact shows diminishing marginal returns to inflows: as basin inflows increase, Colorado receives a smaller share of the marginal inflow. One interpretation is that Colorado holds a comparatively senior right to Rio Grande inflows. Conversely, Texas water rights are junior: increasing basin inflows leads to increasing marginal additions to its water rights. That is, Texas receives an increasing proportion of basin inflows only when total flows are high. Aggregate New Mexico water use under the Compact also shows increasing marginal returns to inflows.

The general pattern of water rights follows both the geography and history of the Basin. Early irrigation in the Basin was concentrated in the upper and middle reaches of the Rio Grande, while most uses downstream of Elephant Butte developed more recently. The Compact is thus consistent with the doctrine of prior appropriation, granting the most senior rights to those regions with the earliest water use. Also consistent with traditional western water law, no protection for instream flows is provided by the Compact.

6. Results

Two modest, incremental policies for instream flow protection and enhancement are examined in detail here. The specific policy issues which are raised focus on the distribution of water within a single irrigation district during shortage conditions, and within a single U.S. federal water project. Each policy proposal is consistent with the Rio Grande Compact, and the U.S.-Mexico Water Treaty. To evaluate the policies, each is first defined in terms of the RGB model, and hydrologic and economic impacts of each are estimated using the model. Historic river flows for the 1944-85 period, and projected future water demand conditions (Ward et al, 2001) are used. Model results on the level and distribution of impacts are then interpreted in terms of opportunities and barriers to cooperation.

The first policy seeks to enhance instream flows in a critical reach above Elephant Butte Reservoir to provide habitat protection for the endangered Rio Grande Silvery Minnow. The policy targets reductions in offstream diversions to the river reach of greatest concern for the silvery minnow. Only aggregate diversion reductions, required under low flow conditions by the Rio Grande Compact within the middle Rio Grande valley in New Mexico, are considered. The second policy seeks to enhance instream flows above El Paso and Ciudad Juarez, while providing for future municipal water needs, by allowing market based water transfers from upstream (including New Mexico) water users. The policy focuses only on water users below

Table 1. Water use apportioned by state under Rio Grande Compact, in 1,000 acre-feet per year, exclusive of tributary flows produced in New Mexico and Texas.

Total Inflow (Rio Grande at Del Norte, plus Conejos River near Mogote)	**Colorado Use** (Based on total Compact obligation at Lobados)	**New Mexico Use** (Between Otowi and Elephant Butte, from water delivered at Lobados)	**Texas Use** (Total delivery below Elephant Butte Reservoir; includes uses in southern NM)
300	240	26	34
400	315	37	48
500	380	52	68
600	439	69	92
700	493	89	118
800	541	111	148
900	585	135	180
1000	624	162	214
1100	660	189	251
1200	692	217	291
1300	720	248	332
1400	745	278	377
1500	767	308	425
1550	782	323	445
1600	789	334	477
1650	794	352	504
1700	794	360	546
1800	784	385	631
1900	784	399	717
2000	784	405	811

Elephant Butte Reservoir, and includes the participation of only U.S. water users. It is thus consistent with both the Compact and U.S. - Mexico Water Treaty.

Endangered Species Protection

Habitat vulnerability for the endangered silvery minnow is particularly acute in the river reaches immediately upstream from Elephant Butte Reservoir. While these reaches are critical habitat, they are also subject to complete dewatering. Maintaining instream flows is particularly difficult in these reaches, with large losses of river channel flows to the associated aquifers regularly occurring, particularly under low flow conditions. Irrigation diversions also play a significant role, however. One policy response to dewatering is to focus on the very high level of diversions to consumptive use in the region, while noting that much of the return flow to the river accrues below reaches which are prone to dewatering. Diversions could physically be reduced in these critical regions either through increases in irrigation efficiency, or through reductions in irrigation reductions and use. We consider the latter, but only in the case where central New Mexico water use is necessarily curtailed under the Rio Grande Compact. The required limits in New Mexico water use are applied first to agricultural users downstream of Socorro and the San Marcial gage.

Table 2 shows the impact of requiring that shortages be borne disproportionately by irrigated agricultural users in the region of greatest concern. We use the RGB model to estimate the importance of two opposing impacts. First, the intent of the policy is to increase instream flows by reducing the high level of diversions which bypass the critical river reach. We find that under the lowest quintile flow conditions (the 20% of years with the lowest flows), the savings from reduced diversions contribute to an increase in average river flows of 19%. An unintended consequence, however, is that aquifer recharge from such diversions is reduced, with a corresponding reduction in groundwater flows to the critical reach. This latter impact could be particularly detrimental in the case of sequential drought years, as groundwater return flows decline just when instream flow levels are already low. Under lowest quintile flows, the effect of reduced flow from groundwater is about 4% of river flows. The net impact of the policy is thus to increase river flows by an average of 15% under lowest quintile flow conditions.

Under lowest decile flow conditions the absolute net increase to flows is only one third the level estimated under the lowest quintile conditions. Under such extreme conditions the policy is thus much less effective in enhancing instream flows. This result arises because of the extreme nature of the lowest decile conditions: there is little diversion to begin with under these very low river flows.

The economic impact of the policy is to decrease farm net revenues for irrigators near the critical reach, but to increase net revenues for upstream irrigators as a result of increased deliveries. Under lowest quintile flow conditions, the net revenue decreases average $700,000 per year, while net revenue increases average $400,000 per year. The policy imposes net economic costs because it requires that shortfalls in irrigation deliveries are not uniform, but rather are concentrated in a single region. Downstream water users in New Mexico, Texas, and Mexico are not impacted.

These results suggest a mixed picture for achieving silvery minnow habitat protection through purely cooperative efforts. Essential players in such efforts include Middle Rio Grande Conservancy District (MRGCD) irrigators and the U.S. Fish and Wildlife Service (FWS) representing endangered species and habitat interests. Downstream water users, because they would not receive significant benefits or costs under the policy, are not considered. Following Le

Table 2. Costs and benefits of increasing instream flow at San Marcial under a policy of concentrating Rio Grande Compact required reductions in MRGCD water use to diversions near San Marcial.

	Initial estimated annual flow at San Marcial	Increase in annual streamflow at San Marcial	Water savings from reduced diversions	Water cost from reduced groundwater return flow	Net revenue decrease near Socorro	Net revenue increase above Socorro
	(kaf)	(kaf)	(kaf)	(kaf)	($ million)	($ million)
average	575.4	9.6	14.6	5.0	0.46	0.28
10%	83.8	6.9	8.4	1.5	0.14	0.09
20%	131.4	19.4	25.3	5.9	0.70	0.40
50%	266.7	16.7	22.7	6.0	0.74	0.46

Table 3. Costs and benefits of a tri-party water market including EBID, El Paso, and EPCWID #1 water users.

	Initial estimated annual flow at El Paso	Increase in annual streamflow at El Paso	Benefit increase for City of El Paso	Net revenue increase for EPCWID #1	Decrease in groundwater pumping by El Paso	Net revenue decrease for EBID
	(kaf)	(kaf)	(million $)	(million $)	(kaf)	(million $)
average	251.7	15.9	1.59	0.54	6.8	-1.60
10%	89.0	57.9	8.19	3.11	28.3	-8.04
20%	138.7	37.2	4.98	1.76	19.7	-6.05
50%	187.5	19.6	2.54	0.86	10.6	-3.19

Marquand's (1977) suggestion that possibilities for integrated resource development enhance cooperation suggests that a cooperative policy also include nearby Albuquerque municipal and industrial water interests. Such an integrated approach is in fact already the reality, with Albuquerque having played a key role in negotiations over water supply availability for to supplement instream flows for endangered species protection (U.S. Bureau of Reclamation, 2000). Looking to the future, adding conjunctive use management through Albuquerque's extensive groundwater pumping capabilities coupled with its planned surface diversions might be considered.

A significant obstacle to cooperative approaches is the differing and uncertain nature of water rights and control (and obligations) exercised by MRGCD, the FWS (under the U.S. endangered species act), and Albuquerque water users. For example, from the perspective of MRGCD there is "no clearly defined process or adequate forum" for addressing endangered species protection in the basin. Further, while the level of negative impacts under the proposed policy ($700,000 annually under lowest quintile conditions to irrigators near the critical reach) is modest, there is no clear method of compensation which might create conditions under which these irrigatos might support such a policy. One such opportunity might be the development of dry year options (e.g. Michelsen, 1993) to compensate irrigators foregoing water deliveries and use under low flow conditions. Finally, Ostrom's requirement that resource conditions be measurable and predictable tempers optimism, because neither the amount of foregone water use needed to prevent dewatering of the critical reach, nor the level of instream flow required to sustain silvery minnow populations is generally agreed upon (O'Brien, 1999).

Instream Flow and Habitat Restoration below Elephant Butte Reservoir

As municipal demands increase and groundwater depletions become increasingly acute, water transfers from existing agricultural users become nearly inevitable. Below Elephant Butte Reservoir, major agricultural users include New Mexico's Elephant Butte Irrigation District (EBID), El Paso County Water Improvement District #1 (EPCWID) near El Paso, and Mexican agricultural users near Ciudad Juarez. Existing policies focus on water transfers facilitated by efficiency improvements in irrigation management, and conversion of agricultural land nearby growing municipal demands. For example, the El Paso - Las Cruces Regional Sustainable Water Project reportedly projects agricultural land conversion of up to 33,000 acres of currently irrigated land. A similar transfer from Mexican surface irrigated agriculture to municipal use is anticipated for addressing Ciudad Juarez water demand (Paso del Norte Water Task Force, 2001). These transfers of water from irrigated agriculture would occur in a context in which agricultural acreage served by Rio Grande surface water has remained roughly constant over the past 20 years within New Mexico, Texas, and Mexico (Paso del Norte Water Task Force, 2001). Population in the corresponding region, currently estimated at 2.1 million, is projected to grow to almost 4 million be 2020 (Paso del Norte Water Task Force, 2001).

While such transfers begin to address current nonsustainable groundwater use, they are limited in their capacity, by themselves, to address emerging demands to restore instream flows. Further, such transfers do not consider the potential economic benefits from focusing water reallocations on the least valued water uses in the region. Moreover, command and control approaches for reallocation may have difficult responding to unanticipated changes in demand over time. Given the uncertainties in projecting future population, it is unlikely that current projections of regional water demand will in fact match the future reality (Peach, 2000).

Following these ideas suggests a policy of market based transfers which might include reallocations from upstream to downstream users. Water transfers from upstream users would result in higher annual instream flows which, together with a year-round use for municipal purposes could be a critical component in restoring perennial instream flows, at least upstream of El Paso/Ciudad Juarez. Utilizing market based transfers potentially maximizes economic benefits of water use through reallocation from the lowest to highest valued uses. The specific policy we consider allows market based water transfers within the Rio Grande Project, a U.S. Bureau of Reclamation project serving water users in EBID (New Mexico) and EPCWID and the City of El Paso (Texas). The policy is consistent with the Rio Grande Compact and the U.S.-Mexico Water Treaty, but faces obstacles because of the potential for interstate water transfers (though occurring within a single federal irrigation project).

Table 3 shows the impact on flows and economic benefits of such a policy. Focusing first on lowest quintile flow levels, the policy increases average annual flows near El Paso by about 27%, while allowing the City of El Paso to reduce groundwater pumping by almost 20 kaf per year. The policy would have less impact during more typical conditions. The average impact on flows near El Paso, averaged across all years, is only a 6% increase, while groundwater pumping is reduced by about 7 kaf per year. Net economic impacts are generally small, with the increased benefits to consumptive water users (City of El Paso and EPCWID) only slightly greater than the foregone benefits in EBID. For example, during lowest quintile flows, El Paso region water users enjoy an average annual increase in benefits of about $7 million, while EBID irrigators suffer reduced net revenues of about $6 million. Extending water transfers across the state line thus provides little net economic benefit, but does provide substantial increases in instream flows.

Cooperative approaches to implementing such a policy would seem favorable at least in the long run. First, by definition market based approaches increase benefits for market participants. Most importantly, reductions in farm net income to EBID irrigators would be more than compensated by payments to willing sellers from municipal water users, the buyers. In addition, following Ostrom (1991), water rights held by the major parties are in general well-quantified, and derive from a single U.S. federal project, the Rio Grande Project. Further, EBID and El Paso each make extensive use of complementary groundwater resources. While market based transfers below Elephant Butte Reservoir are Pareto improving and would involve users with similar levels of water resources control, the necessity of transferring water across U.S. state lines is a significant barrier to cooperation. Indeed, El Paso spent much of the 1980s in a futile attempt to develop groundwater resources in located in New Mexico for export to Texas water users (Earl and Czerniak, 1996).

The obvious extension of a triparty market between U.S. water users would be to include Ciudad Juarez area municipal and agricultural water users. While such an approach might offer demonstrable further net economic and sustainability benefits (impacts on instream flows are less clear), the objections to implementing cross-border water transfers makes such an approach impractical at this time. More promising would be an approach to forego a binational market in favor of developing independent markets within each nation. This more limited policy innovation would likely offer similar economic, instream flow, and sustainability benefits while being more acceptable to the range of Rio Grande water users.

6. Conclusions

Population growth and increasing water demands will result in continued pressure to secure new water supplies, particularly for El Paso and Ciudad Juarez. Increasing the urgency of these efforts is the imminent depletion of the shared Hueco Bolson, the aquifer providing the sole current water supply for Ciudad Juarez. The only renewable source of new supplies is surface water from the Rio Grande. While the demand growth in El Paso/Juarez could provide an important opportunity to provide upstream and downstream instream flow benefits, there are equally important threats. Binational cooperative approaches to providing, through a rejuvenated river channel, surface water of adequate quality to both the El Paso and Ciudad Juarez offer a low cost method of increasing instream flows. These might be pursued in conjunction with cooperative solutions to meet municipal water demands, as suggested by the 1999 agreement between Junta Municapal de Ague y Saneamiento de Ciudad Juarez (JMAS) and El Paso Water Utilities (EPWU) to "increase communication, cooperation, and coordination of joint actions on transboundary water projects of common interest" (Paso del Norte Water Task Force, 2001). Approaches which capture upstream water for downstream delivery via pipeline or aqueduct severely increase the cost and limit the possibilities for river restoration below Elephant Butte Reservoir, and may constrain timing requirements of future Mexican water demands. In depth exploration of the alternatives for meeting future binational municipal and environmental demands is an area ripe for continued inquiry.

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PART IV

AIR POLLUTION, TRANSPORTATION, ENERGY, HAZARDOUS MATERIALS

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Solving Transboundary Air Quality Problems in the Paso del Norte Region*

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INTRODUCTION

Air quality is a critical environmental problem in the Paso del Norte region. Improving air quality involves identifying the primary sources of emissions and characterizing pollutants and their effects on the health of the environment and the human population. Likewise it is necessary to better understand the region's socioeconomic and historic conditions, with the aim of designing environmental policy and strategies through which attitudes and activities can be modified with the support of the diverse economic, social, and governmental sectors. Efforts to improve the environmental quality of the Paso del Norte region have binational connotations, historically characterized by the social and economic interdependence between both nations. Among Paso del Norteans, air quality is the environmental issue of greatest concern. In fact, the region's development has led to the deterioration of air quality during the past 20 years. El Paso exceeds the U.S. National Ambient Air Quality Standards (U.S. NAAQS) for ozone, particulate matter, and carbon monoxide; portions of southern Doña Ana County exceed the NAAQS for ozone and PM10; Ciudad Juarez does not meet the air quality Mexican Official Norms (NOM). Long-term exposure to these air pollutants threatens even healthy individuals.

To protect public health for all Paso del Norte residents, it is important to design strategies and undertake actions aimed at pollution prevention and control within the air basin, directing resources and efforts towards a basin-wide approach, while respecting jurisdictions and sovereignty within a framework of binational cooperation.

El Paso, Ciudad Juárez, and Doña Aña County must implement air pollution control strategies to attain air quality standards. Unilateral efforts, however, may not be sufficient to improve air quality. Binational, tri-state cooperation is a necessary ingredient for solving these critical air quality problems. The JAC has developed a Strategic Plan to focus binational efforts on those priority areas that have the greatest potential for improving air quality for the Paso del Norte community.

Author acknowledges the Joint Advisory Committee for Air Quality Improvement of the Ciudad Juarez, Chihuahua/El Paso, Texas/Dona Ana County, New Mexico Air Basin and the Paso del Norte Air Quality Task Force for their efforts and achievements described in this paper and for the tangible results in lowering contaminants within the international air basin (the Paso del Norte region). Author also recognizes and gives credit to the work, papers, and materials produced by the Strategic Plan Technical Commission of the JAC.

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** Project Director for the Environmental Defense

L. Fernandez and R.T. Carson (eds.), Both Sides of the Border, 255–280.

DESCRIPTION OF THE ISSUE AND THE REGION

Due to its intertwined sharing of resources, its impressive urbanism, demography, manufacturing and entrepreneurial dynamics, neighboring Ciudad Juarez, El Paso, and Dona Ana have a relevant and significant role in the national economy, which makes them, along with Tijuana/San Diego, ones of the U.S.-Mexico's most important border communities. However, the dynamic nature of these communities brings not only social and economic benefits, but also environmental problems (particularly concerning air quality) related to urban development and the establishment of infrastructure and related services.

Population growth of the last four decades, as well as the proliferation of countless industrial, commercial and service activities, has caused a degradation of regional air quality in the Paso del Norte. The poor maintenance of public transportation, inadequate planning in the implementation of this service as well as the rapid increase in the vehicular fleet due to both the purchase of imported used cars that generally are in bad mechanical and safety conditions are causing additional problems. While all three levels of government have made attempts to ameliorate the problem, jurisdictional and sovereignty issues have been an obstacle for a coordinated management program. Moreover, to effectively deal with the air quality problem is complicated by a number of factors. It is clear that the region has Mexican and U.S. authorities from all three government branches, with different responsibilities and jurisdiction: structures, urban conglomerations at different levels of development, the diversity of industrial and commercial activities, and vehicular fleet older than the national average and with different management technologies.

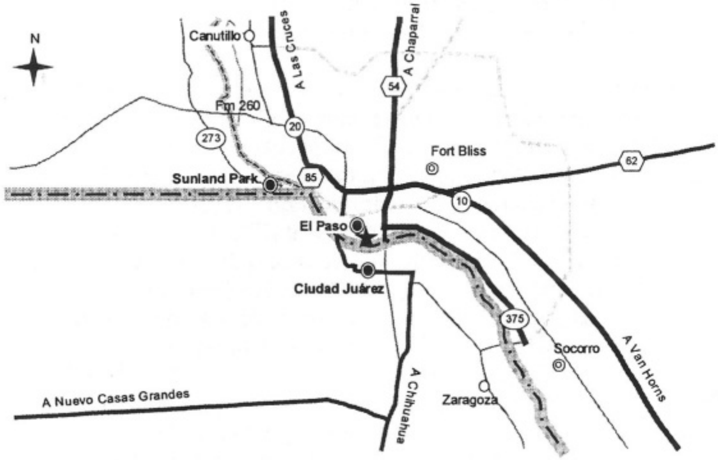
The Paso del Norte region is rich in historical significance for both the United States and Mexico. The community is located between the Sierras de Juarez in Mexico and the Franklin Mountains of the United States, where the Rio Grande/Rio Bravo flows southeastward forming a natural boundary between the United States and Mexico. These geographic facts led to the establishment of Paso del Norte as one of the first missions in the region in the 1600s. In 1659, the Nuestra Señora de Guadalupe mission was founded in what is now known as Ciudad Juarez. The mission was so named because its location represented the most adequate crossing point in the river, towards the north. The area's growth was slow, and it started developing as a resting-place for travelers to and from Central Mexico and northern New Mexico.

Social – Economic Features

After the U.S.-Mexico War (1847), in which Texas and New Mexico became part of the United States, the region became an international border with shared natural resources and exchange of everything from customs, employment, goods and services to pollution. El Paso and Ciudad Juárez also became international border cities. This blend of political and geographic boundaries produced an economically viable and dynamic international community. In fact, Paso del Norte is the largest international metroplex in the world (El Paso MPO, 1998).

The Paso del Norte region is part of the U.S.-Mexico border. The region includes the County of El Paso, Texas, the area of New Mexico south of the 32 degrees 00 minutes latitude north and east of the 106 degrees 40 minutes longitude west, and the area of Chihuahua north of the 31 degrees 20 minutes latitude north to the 106 degrees longitude west. Ciudad Juarez, El Paso, and Sunland Park share a common air basin in which air pollutants, facilitated by winds, move freely across the border. Therefore, it is extremely important to consider the relationship between the three cities.

Figure 1. Ciudad Juarez-El Paso-Sunland Park



The history of the Paso del Norte region has resulted in the fusion of innumerable cultural, social, economic, educational, and environmental factors. Culturally, languages and traditions are shared as the majority of the population is of Latino descent. Many people have families on both sides of the border, which in general has facilitated the transfer of knowledge and technologies, as well as the academic and professional training of some social groups. As can be expected with such close cultural and economic ties, Spanish and English are spoken on both sides of the border.

The economies of the communities are intricately interwoven through commercial, industrial, financial, and service activities and are interdependent. There are considerable differences generated primarily by the distribution of income and the consumption capacity of various social groups in the region. By U.S. standards, El Paso and southern Doña Ana Counties are considered relatively poor with per capita incomes at 59% of the U.S. per capita income (El Paso MPO, 1998). According to the Texas Department of Human Services, 27% of the population of El Paso County has income below the poverty level. The unemployment rate for El Paso County has "consistently exceeded 10% since 1990 and is estimated to be 11.1 percent for 1997" (El Paso MPO, 1998), which is well above the U.S. national average of approximately 4%. In Ciudad Juárez, 63% of the population earns less than the poverty level defined as three times the minimum wage (Suarez and Chavez, 1996). The unemployment rate for Ciudad Juarez as of February 1999 is estimated to be 0.9%, well below the State of Chihuahua's 4.18%, as of December 1996, and the National rate of 3.5%, as of March 1998 (INEGI, 1998).

A major component of regional trade is the *maquiladora* sector. The *maquiladora* sector is a series of plants set up as "off-shore" assembly plants under Mexican law, and duty-free assembly and cost centers under U.S. law. Companies from the United States, Europe, and Asia operate the facilities directly or in conjunction with Mexican investors, to reduce product assembly labor costs. Given specific tariff advantages by the U.S. Treasury, the *maquiladora* sector has thrived on inexpensive and plentiful labor from Mexico and easy physical and cheap tariff access to the U.S. market. Hundreds of plants that employ thousands of workers in Mexico have accelerated the economic growth of the region and its urbanization. This growth and urbanization have led to environmental problems that, like the economic benefits, both communities must share.

The growth of the *maquiladora* sector and the population of Juárez follow a positive feedback loop. As more companies open facilities in Juarez, more workers arrive from other regions in Mexico seeking employment. The population of Ciudad Juárez is estimated to reach 2 million in 2010 (SEMARNAP, 1998). In El Paso and Doña Ana Counties, U.S. and multinational corporations are locating production facilities of their operations to take advantage of expanding trade under the North American Free Trade Agreement (NAFTA) and convenient access to multi-modal transportation hubs and enterprise zones located in both countries. The population of Doña Ana County is expected to double from 1990 to 2015 (from 135,000 people to 322,000) with growth occurring mostly in the southern end of the county as the area around the Santa Teresa Port of Entry is developed (El Paso MPO, 1998). El Paso's population is estimated to increase to 980,000 by 2020 (El Paso MPO, 1998).

This cycle occurs at such a rate that border infrastructure is not adequate to keep pace with the growth in demand for services. For instance, the growth in population leads to rapid growth in housing needs, which are met by expanding the existing periphery of the Paso del Norte region for new housing developments. Roads to these new settlements are frequently unpaved. Roughly half of all streets in Juárez are unpaved (IMIP, 1999). Particulate matter entrained into the air by traffic traversing unpaved roads becomes a problem for local residents. In El Paso and Doña Ana Counties low-density development causes long travel times and travel distances between land uses. The result is an increase in VMT and associated difficulty in meeting air quality standards (El Paso MPO, 1998).

Local Topography and Climatic Conditions

Climate and topography are an important factor in the formation and transport of air pollution. The local topography in the region falls into the category of complex terrain as a result of moderately sized mountain ranges that lie north, south, and west of the central Juárez urban area. Local elevations range from 1,150 meters at the Rio Grande River to 1,850 meters at Ranger Peak, located atop the Franklin Mountains. The ridge of the Franklin Mountains runs north-south and divides the urban areas of west and north central/northeast El Paso. The downtown El Paso area lies just beyond the southern extent of the Franklins. Figure 1 shows the major geographical features of the air basin.

The Rio Grande flows southward out of central New Mexico through the Mesilla Valley on the west side of the Franklin Mountains, At the southern extent of this valley, a large igneous intrusion, Sierra de Cristo Rey, lies directly in the path of the river's southward course. The river bends around Cristo Rey, cuts through the pass between the Franklin and Sierra de Juárez Mountain Ranges, courses in a generally southeasterly direction between the downtown districts of El Paso and Ciudad Juárez and finally flows into a broad valley to the southeast.

To the southwest of Ciudad Juárez lie the Sierra de Juárez Mountains, rising to 1,650 meters above the valley floor. To the south of Ciudad Juárez lies the Chihuahua Plateau characterized by relatively flat terrain, gradually increasing in altitude above the valley floor as one moves toward the south. To the northeast of the downtown El Paso region lies the extreme southern portion of the Tularosa Basin, bordered on the east by the Sacramento Mountains and on the west by the northern reaches of the Franklin Mountains. Much of the recent urban growth in El Paso is occurring in northeast and northwest sections at the foot of the Franklins (Einfeld and Church, 1995).

The other name for El Paso is the "Sun City" in reference to the sun's appearance over the area almost 364 of 365 days of the year. The Paso del Norte region enjoys the broad extent of seasonal conditions. Snow falls almost annually, but quickly melts due to the generally balmy conditions which prevail during the winter. Spring quickly fades into summer as temperatures usually reach the mid-80sto mid-90s between April and May. From June to September daily high temperatures can be expected to remain in the mid-90s and can hover between 100-104° F for several consecutive days. During 1996, we experienced the hottest summer on record, which included the number of continuos days with temperatures of at least 100° F, the highest daily average high temperatures, the highest average low temperatures, the hottest day on record when temperature reached 114° F. Given this is also a high desert region, the low for most nights will drop to the mid-60s. Moreover, 30-40° F diurnal temperature swings are not uncommon in the region. Relative humidity in the Paso del Norte ranges between 10-25% the majority of the year.

Thermal Inversions

Normally, air temperature decreases with altitude. The inversion of this process is called "thermal inversion." Information gathered in the El Paso area indicates the thermal inversions in the Paso del Norte region occur in the fall and winter, starting in September when the nights become longer. However, they are more frequent in November, December, and January when nights are longer and days are shorter. In December, for example, the nights are approximately 14 hours, while the days are 10 hours (Texas Air Control Board, 1991).

Additionally, during this time of the year, the desert presents a bit of humidity, favoring strong cooling when there are clear skies. The air close to the ground is cooled more quickly than the air in high atmospheric layers, which causes a nocturnal thermal inversion that traps the pollutants emitted in the basin. These inversions tend to be shallow, thus reducing the volume available for the vertical mixing and dispersion. This causes high concentrations of pollutants near the surface. During the morning, strong local heating begins to break the inversion and by the afternoon, the usually unstable atmosphere makes it favorable for the pollutants to dissolve in the high atmosphere.

Height of Mixing Layer

The height of the mixing layer is the region of the atmosphere where pollutants are dispersed. The importance of the height (which goes from ground surface to the point where it either becomes stable or encounters the first thermic inversion) varies with the atmospheric stability, depending on the temperature of the air and wind speed.

In 1997, the U.S. EPA sponsored a study for the gathering of meteorological data in El Paso-Ciudad Juarez-Sunland Park. The study was a continuation of the "Summer Ozone Study" initiated in the summer of 1996, and its objective was achieving a greater understanding of the physical and chemical processes that affect the formation of ozone in the region.

As part of this effort, estimates were made of the heights of the mixing layers in the Chamizal National Park in El Paso during 14 days in August and September in 1997, using a combination of virtual (obtained by acoustic radar RASS), temperature at the surface and a wind profiler. These meteorological parameters were measured near downtown El Paso, which has an altitude of 1,146 meters above sea level. On 7 of the days measured, the concentrations of ozone were above 100 ppb. The rest of the days were chosen because they either preceded or followed high ozone days. Figures 2 and 3 show the height of the mixing layer for three days in both August and September.

Based on the information, it was found that in general: 1) the lowest limiting layer at night is found below 400 to 500 meters before 8 o'clock in the morning (mountain time); b) from 8 o'clock and on, the altitude increases, presumably due to the (daily convective mixing); c) the maximum height of mixing layer varied between 2,000 and 4,000 meters and were registered between 5 and 6 o'clock; d) after this hour the height of the mixing layer experiences an abrupt fall, decreasing to values below 500 meters and remains there at night and until the following morning.

Figure 2. Height of mixing layers at the Chamizal (August 26, 27, and 28 of 1997).

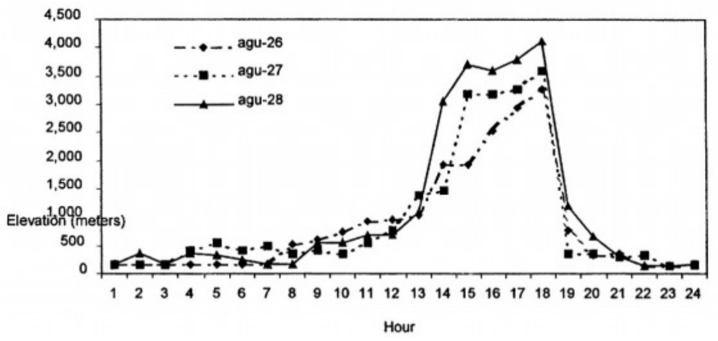
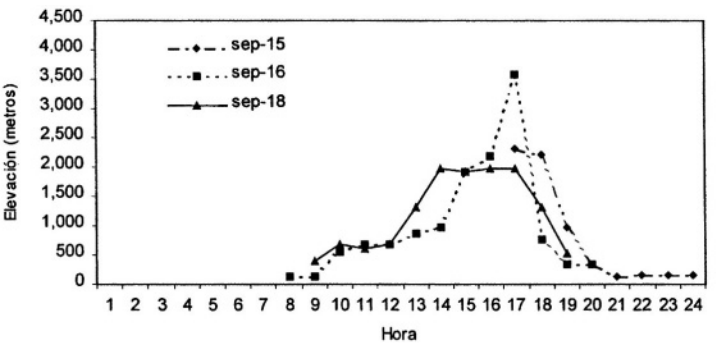


Figure 3. Height of mixing layers at the Chamizal (September 15,16, and 18 of 1997).

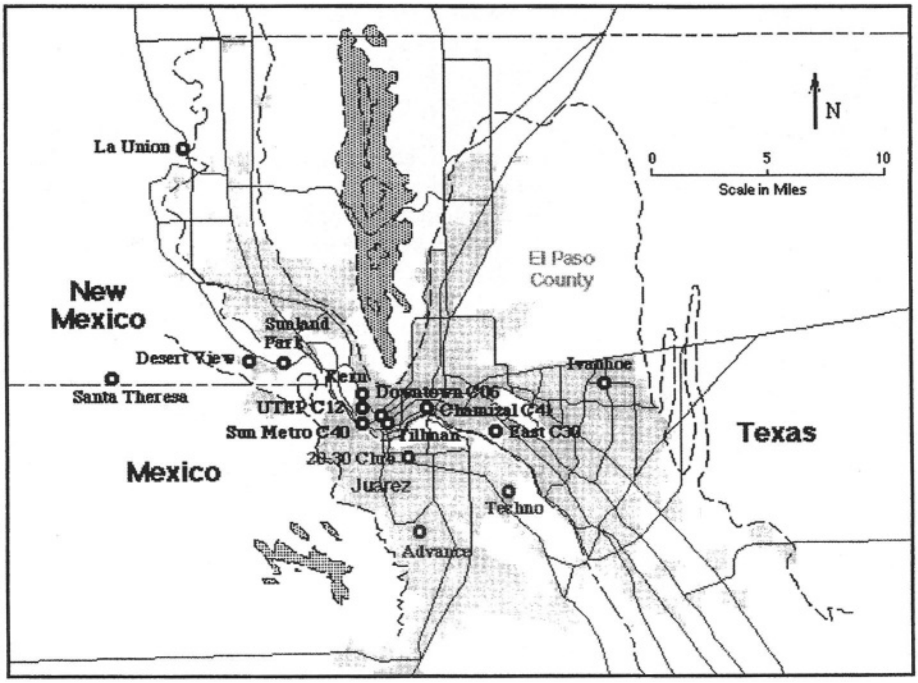


These observations indicate that during the night and sunrise, the pollutants are confined to a layer that is relatively reduced, propelling an increase in their concentrations. After midday, the mixing volume increases significantly allowing the pollutants to be diluted. As will be shown later, this behavior becomes noteworthy in the analysis of the hourly evolution of carbon monoxide measured by the monitoring system.

Air Quality Summaries

Mexico and the United States have established health-based air quality standards. When air quality concentrations exceed these standard levels, both governments mandate that areas take action through control programs to improve air quality. Table 1 shows U.S. and Mexican air quality standards. In some cases, the standards differ between the two countries. Most notably the recently adopted 8-hour O_3 and $PM_{2.5}$ (particulate matter less than 2.5 microns in diameter) standards do not exist currently in Mexico. Air quality monitoring networks have been deployed throughout the air basin to measure population exposure to these pollutants. There are 9 monitoring sites operated by the Texas Natural Resource Conservation Commission (TNRCC) in El Paso, 11 stations in Doña Ana County operated by New Mexico Environment Department (NMED), and 6 monitoring sites in El Paso by El Paso City County Health and Environmental District (EPCCHED). The Ciudad Juárez General Directorate of Ecology and Public Safety (DGEPC) obtains daily air quality data from equipment at five Juárez air quality monitoring sites. The EPCCHED provides maintenance, quality control, and technical support for these stations.

Map 1
Air Monitoring Sites in the El Paso-Juarez-Las Cruces Area



The United States and Mexico have established air quality monitoring networks for the Paso del Norte air basin to measure ambient concentrations of PM, O_3 and its precursors (VOC and NOx), CO, SO_2, lead, and air toxics. Map 1 above identifies most of the ambient air quality monitoring sites throughout the air basin.

Because new monitors are required to measure $PM_{2.5}$ under the new U.S. fine particle standard, the TNRCC and NMED are in the process of establishing a new $PM_{2.5}$ monitoring network for El Paso and Dofia Ana Counties. Once the networks are completely deployed and three years of data are collected, the EPA will make nonattainment designations during the 2003-2005 timeframe. The EPA will make nonattainment designations for the new 8-hour O_3 standard in 2000 based upon three years of air quality data for 1997-1999. EPA and SEMARNAP are working on a proposal to deploy $PM_{2.5}$ monitors in Juarez. El Paso County will remain in nonattainment with the 1-hour O_3 standard until the area can attain. After 2000, El Paso may also be in nonattainment of the 8-hour ozone standard. It is expected that the 1-hour O_3 standard will be met and therefore revoked for Sunland Park. Because these two new standards are in the process of implementation, air quality exceedances are not shown here. However, when the JAC Strategic Plan is reviewed and revised, the two new standards will be incorporated.

Table 1. Comparison of Mexican and U.S. health-based ambient air quality standards.

Pollutant	Mexico		U.S.	
	Units	Average	Units	Average
Ozone (O_3)	0.11 ppm not established	1 hour 8 hour	0.12 ppm 0.08 ppm	1 hour* 8 hour
Sulfur dioxide (SO_2)	0.13 ppm 0.03 ppm	24 hour annual arithmetic mean	0.14 ppm 0.03 ppm	24 hour annual arithmetic mean
Nitrogen dioxide (NO_2)	0.21 ppm	1 hour	0.25 ppm 0.053 ppm	1 hour annual arithmetic mean
Carbon monoxide (CO)	11 ppm	8 hour	9 ppm 35 ppm	8 hour 1 hour
Total suspended particulates (TSP)	260 $\mu g/m^3$ 75 $\mu g/m^3$	24 hour annual arithmetic mean	not applicable not applicable	24 hour annual arithmetic mean
PM_{10}	150 $\mu g/m^3$ 50 $\mu g/m^3$	24 hour annual arithmetic mean	150 $\mu g/m^3$ 50 $\mu g/m^3$	24 hour annual arithmetic mean
$PM_{2.5}$	not established not established	24 hour annual arithmetic mean	65 $\mu g/m^3$ 15 $\mu g/m^3$	24 hour annual arithmetic mean
Lead (Pb)	1.5 $\mu g/m^3$	3 month arithmetic mean	1.5 $\mu g/m^3$	3 month arithmetic mean

- **The 1-hour ozone standard will be revoked under the U.S. NAAQS program once areas have reached attainment. The new 8-hour ozone standard will then take effect.**

Air Quality in El Paso County

El Paso County, or portions of it, does not meet the NAAQS for three of the U.S. Environmental Protection Agency's (EPA) criteria air pollutants. Under the U.S. Clean Air Act (CAA), an area not meeting the standard for a criteria air pollutant is designated "nonattainment," and then classified by severity. El Paso County is classified as a "serious" nonattainment area for the one-hour ozone standard. A small portion of El Paso, near the border in the downtown business sector, has not met the standard for carbon monoxide. The City of El Paso does not meet the standard for inhalable particulate matter, a mixture of solid particles and liquid droplets with an aerodynamic diameter of 10 micrometers (µm), known as PM_{10}. Table 2 presents recent air quality monitoring results for El Paso County based upon both TNRCC and

EPCCHED monitors showing the number of annual violations of selected air quality standards. Incidences where the concentration "exceeded" the standard, are referred to as "exceedances" under the Act. "Violations" are those exceedances that once reviewed through EPA's quality assurance procedures and policy guidelines are deemed in violation of the standard.

Table 2. Number of annual exceedances of selected air pollutant standards for El Paso County, TX, 1989-2000.

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CO	6	7	3	3	2	2	0	1	1	1	0	1
PM10	7	4	1	2	0	2	0	1	1	0	0	1
O3	7	4	3	5	4	5	3	1	1	2	1	1

Source: U.S. EPA AIRS database and the El Paso City County Environmental District.

Air Quality in Doña Ana County

A portion of Doña Ana County, containing the small community of Sunland Park, is designated nonattainment for ozone, and is classified as marginal. Anthony, NM, is classified as a moderate PM_{10} nonattainment area. Below is a table of recent ozone and PM_{10} data for the Sunland Park and Anthony, NM, nonattainment areas.

Table 3. Number of annual exceedances of selected air pollutant standards for Doña Ana County, NM, 1995-1998.

Pollutant Year	1995	1996	1997	1998[a]
Ozone	3	1	0	2
PM_{10}[b]	8	79	39	45

Source: U.S. EPA AIRS database.
[a] Through 3rd quarter 1998.
[b] PM_{10} exceedances are all a result of high wind events.

Air Quality in Ciudad Juárez

Ciudad Juárez does not meet Mexican health-based air quality standards for O_3, PM_{10}, and CO. Most analysis of air quality monitoring information in Mexico is done in reference to the Indice Metropolitano de la Calidad del Aire, or IMECA. This technique uses the Mexican standard as a base of 100, where the daily maximum value is measured as a percentage of the national standard. Additionally, overall air quality is rated by measuring the percentage of days in a year that air pollution is at or above the standard. Table 4 provides the number of days during which pollution in Juárez was at or above the Mexican standard. Although the actual standards are not the same, they are available for general comparisons.

Table 4. Number of Days Per Year Above Standard for Selected Air Pollutants for Ciudad Juárez, Chihuahua.

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CO	5	1	1	0	1	12	24	19	14	2
PM10	15	14	13	20	7	14	11	7	9	15
O3	8	11	1	10	7	14	7	5	1	8

Source: Dirección General de Ecología y Protección Civil.

AIR QUALITY MANAGEMENT ACTIVITIES IN THE PASO DEL NORTE AIR BASIN

Because of the severity of the air quality problem in the Paso del Norte area and under the authority of their respective country's environmental legislation, the federal governments of both the U.S. and Mexico have mandated that air quality control programs be implemented to attain health-based air quality standards. Through the U.S. Federal Clean Air Act, the state environmental authorities of Texas (Texas Natural Resource Conservation Commission, TNRCC) and New Mexico (New Mexico Environment Department, NMED) are required to submit to EPA State Implementation Plans outlining air pollution control programs for nonattainment areas. The Mexican Federal Secretariat for Environment, Natural Resources and Fisheries (SEMARNAP) has worked with the State of Chihuahua and the municipal government of Ciudad Juárez to develop and implement the "Air Quality Management Program for the Improvement of Air Quality in Cd. Juárez 1998-2002" (SEMARNAP, 1998).

Air quality planning and assessment are the first steps in the air quality management process. Monitoring, characterizing air quality, and developing and maintaining an emissions inventory, in conjunction with mathematical modeling of the air basin, are indispensable tools for the design and implementation of strategies that will achieve air quality standards established by both nations.

An emissions inventory allows for an analysis of major emissions contributions and makes it possible to determine the source categories for emissions control. Accurate emissions inventories (EI) in conjunction with air quality modeling are the tools employed to develop appropriate control strategies for attainment of air quality standards. Under the U.S. Clean Air Act, nonattainment areas must develop emissions inventories, conduct air quality modeling, and develop control strategies to achieve air quality standards. These analyses are submitted to EPA in the State Implementation Plan or SIP. For Mexico, such tools constitute the methodological foundation of the Air Quality Programs relying on Environmental Operating Permits and Statements of Operation (for the industrial sector), Mexican Official Norms, emissions factors, and mass balance modeling.

El Paso and Doña Ana County State Implementation Plans (SIPs)

Both the TNRCC and NMED are required to submit SIPs to EPA outlining the states' commitments under the U.S. Clean Air Act (CAA). SIPs demonstrate how and by when the states intend to attain the NAAQS for those areas in nonattainment. If areas do not meet their attainment deadlines, they are "bumped up" to the next highest nonattainment classification, which in turn requires that more stringent control measures be implemented in the nonattainment area.

El Paso has submitted SIPs for O_3 (TNRCC, 1994), CO (TNRCC, 1995), and PM_{10} (TNRCC, 1991). Control requirements apply to new and existing point and area sources and mobile sources of ozone precursor emissions of VOC and NOx, and of PM and CO. Point and area source controls for O_3 precursors include the following:

1) Fugitive emissions controls for refineries and bulk plants;
2) Bulk gasoline terminal VOC controls;
3) Industrial wastewater VOC controls;
4) Low NOx burners for electric power plants;
5) Stage I and II gasoline vapor recovery;
6) Consumer products program;
7) Area source VOC controls applicable to dry cleaners, auto refinishing, and architectural coatings.

A vehicle inspection/maintenance (I/M) program, low summertime Reid Vapor Pressure (RVP) limits, and measures to reduce vehicle miles traveled (VMT) have also been implemented in El Paso to reduce emissions of VOC and NOx from vehicles.

The El Paso PM SIP outlines mass emission rates and opacity limits for eight sources classified as major sources emitting greater than 25 tons per year. Area source control measures include the following:

1) Roadway paving and more intensive street sweeping;
2) Dust controls at construction sites;
3) Restrictions on fireplace burning during stagnation periods;
4) Paving of industrial and commercial roadways;
5) Paving of parking areas with spaces for more than 5 vehicles;
6) Trucks carrying dusty material must be tarped;
7) Trash burning prohibition; and
8) Opacity and particle mass emissions limits for vehicles as part of the vehicle I/M program.

Finally, the El Paso CO SIP describes a number of measures directed toward reducing CO concentrations during the winter CO season including:

1) Oxygenated fuels program;
2) Annual vehicle I/M program;
3) Woodburning controls; and
4) Measures to reduce VMT.

Because Sunland Park is a marginal nonattainment area, control requirements as laid out in the CAA are less stringent than for a serious area such as El Paso. Thus point sources are not required to apply Best Available Control Technology (BACT). However, new sources or modifications to existing sources must offset their emissions by a 1.1-to-1 ratio such that a net air quality benefit will occur. Since unpaved roads and windblown dust from unvegetated and sparsely vegetated areas and rangelands predominantly contribute to the PM problem, the Anthony PM SIP requires the following area controls:

1) Paving of roads when economically feasible;
2) Subdivision road paving;
3) Dust controls at construction sites;
4) Covering of haul trucks;
5) Permitting for open burning;
6) Prohibition on trash burning in Dona Ana County; and
7) Minimization of overgrazing on leased land.

Sunland Park was designated as a marginal ozone nonattainment area in 1995 and thus had until 1998 to come into attainment of the ozone standard. NMED submitted its revision to the New Mexico Ozone SIP for Sunland Park (NMED, 1997). Based upon a comparison of emissions between El Paso and Sunland Park, NMED has requested a waiver under § 179(B). A decision by EPA on the waiver is still under review.

Ciudad Juárez Air Quality Management Program 1998-2002

The Air Quality Management Program for Ciudad Juárez for 1998-2002 represents a joint effort undertaken by the academic, economic, social, and governmental sectors to protect the health of the residents of Ciudad Juarez and the Paso del Norte region.

The proposed general goals of the program are to gradually achieve the reduction of emissions of hydrocarbons by 27%, nitrogen oxides by 24%, carbon monoxide by 26%, and particulates by 44% during the period between 1998-2002. The program proposes 40 specific actions that will allow in the medium term, reaching the air quality standards established by the Mexican Official Norms (NOM) whose benefit will be reflected throughout the air basin. The program's success is contingent upon the degree of involvement of people that live and work in the Paso del Norte region and the cooperation of authorities in the application of the necessary measures.

The document consists of two parts. The first presents a diagnosis of the actual air quality situation and a review of the most relevant efforts conducted to date for pollution control. The second part describes the Ciudad Juárez's emissions Inventory and includes a conceptual analysis of the interaction and interdependence between the policies of other sectors and the environment and a vision of air quality management in the binational air basin.

La Paz Agreement and Border XXI Program

The Agreement between the United Mexican States and the United States of America on the Cooperation for the Protection and Improvement of the Environment in the Border Area, commonly referred to as the La Paz Agreement, was signed by President Miguel de la Madrid and President Ronald Reagan in La Paz, Baja California in 1983. (The entire La Paz Agreement is contained in Appendix D.) This agreement is the vehicle through which the two countries work cooperatively to address environmental issues along the 2000-mile U.S.-Mexico border. The border zone is defined in the agreement as 100 kilometers to the north and south of the border.

During 1996 through the year 2000, a binational framework, the Border XXI, took place implemented under the "La Paz Agreement." The U.S. EPA and Mexican Ministry of Environment, Natural Resources (SEMARNAT) were the lead agencies in charge of the program. Border XXI was organized into nine binational workgroups that address the following issues: water, air, natural resources, pollution prevention, hazardous and solid waste, cooperative enforcement, environmental health, environmental information resources, and contingency planning and emergency response. Each work group is comprised of two Federal co-chairs[1], one from Mexico and the other from the United States. The workgroups have the active participation of state and local government officials, NGO's, industry, academia, and other interested individuals from both the United States and Mexico. These workgroups served as a forum through which the two countries met to develop cooperatively five-year objectives and annual work plans and to discuss progress and issues associated with the implementation of projects to address environmental issues along the border.

The Air Workgroup (AWG) is in charge to resolve air quality problems in the Paso del Norte air basin, as well as other sister cities along the border. Finalized in 1989, the AWG derives its authority from Annex V of the La Paz Agreement, which addresses urban and regional air quality in the border. Annex V provides the framework for a series of joint U.S.-Mexico air pollution studies designed to more fully understand pollution sources and their impacts on either side of the border. The fundamental intent of Annex V is the implementation of binational control strategies to solve the air quality problem in border sister cities. The group meets biannually to discuss progress on border emission inventory development, air quality monitoring issues, air quality modeling, binational control strategies, information and technology transfer, and technical training among other topics. Meetings are open to the public and all interested individuals are encouraged to participate. Summaries of AWG meetings as well as U.S.-Mexico border air quality information can be found through the Centro de Informatión Sobre Contaminación del Aire (CICA) homepage (URL: www.epa.gov/ttn/catc/cica).

Establishment of the Joint Advisory Committee for Improvement of Air Quality in the Paso del Norte Air Basin

In Spring 1993, the Paso del Norte Air Quality Task Force was formed under the auspices of the Texas Air Control Board (TACB) as a means for citizens to take an active role in air quality improvement in the air basin. The Task Force, with the support of the Environmental Defense, made the implementation of an "International Air Quality Management District (IAQMD)" their first priority. The idea was modeled after the South Coast Air Quality

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[1] The Environmental Health Workgroup has additional co-chairs from the U.S. Department of Health and Human Services and the Mexican Ministry of Health.

Management District in the Los Angeles, California area. The Task Force believed that Paso del Norte air quality needed to be managed both binationally and at the local level to achieve significant air quality improvements.

The Environmental Defense drafted a proposed Annex VI to the La Paz Agreement in summer 1993 outlining the concept of an IAQMD. As mentioned previously, the La Paz Agreement is the official mechanism through which the United States and Mexico work cooperatively to address environmental issues in the border region. The IAQMD would encourage cooperation in monitoring networks, compliance activities, economic incentive programs, public outreach, and technology transfer. Under the draft language, international air pollution emissions trading were a possibility.

At the La Paz National Coordinator's meeting in El Paso in March 1996 and after almost two years of discussions and negotiations, the United States and Mexico agreed in principle on the wording for an agreement as Appendix 1 to Annex V of the La Paz Agreement. The two countries formally signed Appendix 1 in Mexico City on May 7, 1996 creating a Joint Advisory Committee (JAC) for Air Quality Improvement in the Ciudad Juárez, Chihuahua/El Paso, TX/Doña Ana County, NM Air Basin. Although not an IAQMD as originally envisioned by the Task Force, the JAC serves an oversight role in Paso del Norte air quality management.

The JAC consists of 20 members, 10 from each country. For the U.S. contingent, there is a federal government co-chair from EPA and members of the State of Texas, State of New Mexico, El Paso County, and Doña Ana County governments and five nongovernmental representatives from the local area including at least one representative from business and an NGO. The Mexican delegation is composed of a federal government co-chair from Instituto Nacional de Ecología (INE-SEMARNAT) and members of the State of Chihuahua, Ciudad Juárez government, Ministry of Health, the Procuraduría Federal de Protección del Ambiente (PROFEPA), and local NGOs.

As indicated in the mission statement, the JAC is charged with recommending to the La Paz Air Work Group those actions that can bring about air quality improvements in the Paso del Norte air basin. The emphasis has been given to those strategies that are cost-effective and easily implemented so that air quality benefits can be realized relatively quickly.

The JAC has been meeting quarterly since the fall of 1996 to discuss progress on air quality planning and management projects throughout the air basin. The group's meetings are open to the public and local participation is encouraged. To get the group started, the Environmental Defense sponsored a symposium in June of 1996 on the functions and scope of the JAC. There was broad participation from the community with approximately 100 individuals in attendance. The JAC also finalized its bylaws in fall of 1997.

The JAC receives staff support from designated administrative liaisons from the United States and Mexico. The TNRCC El Paso field office serves as the U.S. administrative liaison while a Ciudad Juárez private sector consultant currently serves as the Mexican administrative liaison. These individuals coordinate JAC meeting agendas, develop and distribute minutes from the meetings, and organize other activities or projects of the JAC as described in the bylaws.

The JAC has made a number of recommendations to the La Paz Air Work Group on several topics. A sample of the recommendations include:

- Support a designated commuter lane to ease bridge queuing in order to reduce air emissions from idling vehicles.
- Introduce oxygenated fuel in Juarez.

- The State of Chihuahua is required to reestablish the legal requirement that vehicles in Juarez pass an emissions inspection prior to registration.
- Produce a notebook for a comprehensive guidelines, design, and framework for the requirement of the construction industry to use bricks produced by an environmentally friendly brick kiln.
- Produce guidelines for implementing international supplemental environmental projects (ISEP) in support of transboundary investments under each countries' laws and regulations.
- Promote the use of economic incentives for emissions trading (ERC) and offset of emissions under an international scenario.
- Promote to Mexico's Ministry for Economic (Commerce) and Treasury (Finance) for implementing requirements set up in the customs and importation regulations when importing vehicles for the border region.
- Support the solid waste program for Ciudad Juarez that includes a used tire thresher.
- Create a comprehensive strategic plan for the Paso del Norte region with a holistic approach with a set of measures that are cost effective but have a basin-wide impact.

Overview of the JAC Strategic Plan Development Process

The JAC Strategic Plan outlines priority actions to address the ozone, particulate matter, and carbon monoxide air quality problems in the Paso del Norte air basin given the frequency of exceedences of standards for these pollutants. NO_2 is addressed in the strategic plan as an O_3 precursor rather than as a criteria air pollutant. Additionally, strategies to achieve reductions in CO_2 emissions to curb global climate change are contemplated as an additional benefit as countries move forward in signing and ratifying the Global Climate Change Accord. This may in turn bring this issue to the attention of JAC activities.

In December 1997, a JAC Strategic Plan Technical Commission (SPTC) was established to develop the group's strategic plan. The SPTC began first by planning and executing a Strategic Plan Symposium held in February 1998 at which the JAC mission, goals, objectives, and guiding principles were developed and agreed to through a consensus-based process. The Symposium gathered JAC members, the SPTC, and interested members of the public and invited technical experts for a one-day session to discuss the Paso del Norte air quality problem, emission sources, and potential projects to address the air quality situation. Issue papers were prepared for the symposium outlining various air quality planning and management topics and proposing potential projects to address key issues.

Over 100 projects were identified as potential candidates for the JAC's first strategic plan. Symposium participants agreed that a prioritization process should be developed and applied to narrow the scope of projects. The group also agreed that projects should be evaluated based on cost-effectiveness, significance of impact, and feasibility. In subsequent meetings, the SPTC developed a matrix of candidate projects and asked SPTC members, the JAC, and other interested individuals to rank each of the projects as high, medium, or low priority for each of the three ranking parameters mentioned above. Responses were collected and evaluated resulting in a final list of 26 priority projects. Project summaries, action plans, and timelines were prepared by the SPTC for each of the 26 priority projects. Finally, a set of indicators by which to measure progress towards the JAC's goals and objectives were agreed upon by the SPTC.

The remainder of this document describes: 1) the JAC mission, goals, objectives, and guiding principles followed in developing the strategic plan; 2) indicators by which to measure progress in achieving JAC mission, goals, and objectives; 3) the methods and approaches used to address the Paso del Norte air quality situation; 4) the identification and prioritization of projects resulting in a consensus-based list of actions addressing areas of highest priority; and 5) action plan and timeline for each priority project.

JAC Mission, Goals, and Objectives[2]

The JAC's **Mission** is to:

> *Develop, promote, and recommend to the La Paz Agreement Air Work Group air quality planning and management strategies to ensure a reduction in air pollution concentrations for public health and welfare of residents of the Paso del Norte air basin, recognizing the importance of the participation of local communities in carrying out this mission.*

A set of **Basin-wide Goals** is defined to carry out the JAC mission as follows:

- Achieve ambient air quality standards on both sides of the border.
- Continue to characterize the air quality situation and its sources and resulting health effects in Paso del Norte air basin including:
    - Monitor ambient air pollutant concentrations in the air basin.
    - Develop and maintain a valid emissions inventory for the air basin, updated and disaggregated as possible.
    - Conduct basin-wide air quality modeling to identify appropriate control strategies for attainment of ambient air quality standards.
    - Develop health parameters and monitor health status of residents to track incidence of adverse health effects in Paso del Norte population as a result of air pollutant exposure. Develop health parameters and monitor health status of residents to track incidence of adverse health effects in Paso del Norte population as a result of air pollutant exposure.
- Establish instruments to promote and achieve voluntary compliance and emission reductions.
- Promote partnerships between and among industry and regulatory authorities on both sides of the border to pursue economic incentives according to each country's laws.

A series of **Objectives** is outlined to achieve the JAC's goals:

- Realize basin-wide emission reductions.
- Implement air quality management programs according to State Implementation Plans (SIPs) for El Paso and Doña Ana County.
- Implement the Air Quality Program for Ciudad Juarez.
- Recommend measures to deal with elements not covered in SIPs or Ciudad Juárez Air Quality Improvement Plan.

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[2]The JAC mission, goals, and objectives were agreed to in February 1998. As the group evolves, these may be revisited and revised as necessary to accommodate potentially changing roles and functions of the JAC.

Measures of Progress

Appropriate indicators must be identified and employed in order to measure progress towards achieving the JAC's goals and objectives. The JAC will measure progress in these areas by analyzing ambient air quality monitoring data to assess progress towards attainment of standards, quantify emission reductions, evaluate health data from a basin-wide epidemiological surveillance program, and finally assess participation in JAC programs. These progress measures will be evaluated annually.

Principles Followed in the Development of the JAC Strategic Plan

In addition to the JAC basin-wide goals and objectives, the SPTC agreed to a set of principles to follow while developing the strategic plan. These principles have guided the strategic plan development process and have served as the reference framework by which the group identified and prioritized projects and outlined project action plans. These principles also will guide the future activities of the JAC.

One Air Basin

Because air pollution knows no political boundaries, we need to acknowledge that we are one air basin and that pollution travels across state lines as well as the international border. We will not attribute blame to any one jurisdiction.

Binational, Tri-state Cooperation

Because of the international and state borders that lie within the air basin, binational, tri-state cooperation is a critical element to solving the area's air quality problems. We will cooperate fully with one another in the implementation of this strategic plan and in other JAC activities.

Coordination and Leveraging of Resources

Because of limited staff and financial resources on both sides of the border, effective coordination of air quality planning and management activities in the Paso del Norte Air Basin will preclude duplication of effort and allow for the leveraging of resources. Through its strategic plan, the JAC has attempted to integrate and coordinate its air quality priorities with the ongoing activities of agencies and organizations throughout the air basin.

Reflect Community's Input

The opinions and recommendations of the Paso del Norte community are an important and necessary input to improving air quality in the region. It is with full community participation that the JAC can develop strategies acceptable to the public and with the greatest probability for success.

Information Sharing

Sharing of information is critical for all agencies and organizations involved in Paso del Norte air quality planning and management to coordinate effectively. Dissemination of information to the public is also necessary for Paso del Norte residents to understand the causes of air pollution in the air basin.

Reach Consensus

Development of the strategic plan reflects a consensus-based process. SPTC members have worked together and agreed to the process and the anticipated results of the strategic plan priorities.

Cost-effectiveness

Achieving emission reductions and improving air quality at least cost is an important principle. Cost-effective control strategies most likely will have a higher probability of success given limited resources in the area.

Significance of Impact

It is important to focus efforts towards those areas and projects that when implemented would have a significant impact on air quality.

Feasibility

Feasibility from technological, regulatory, and financial perspectives is an important consideration in determining what air quality projects can be effectively implemented in the Paso del Norte air basin.

Methods and Approaches for Achieving JAC Goals and Objectives

The JAC undertook the development of a strategic plan to identify and prioritize those opportunities for cooperation between the public and private sectors and across political jurisdictions to resolve Paso del Norte air quality problems. In the initial stages of developing the strategic plan, the JAC SPTC created a framework within which to address air quality problems in the air shed. Projects were identified for each emission source type (i.e., mobile, point, and area) according to each topic area.

At the Strategic Plan Symposium held February 18, 1998, JAC members and residents of Paso del Norte discussed air quality issues and identified priorities according to the matrix. Issue papers were drafted to guide discussion at the symposium. To the extent possible, the issue papers were comprehensive in nature and included the following information: description of issue, lists of current and planned projects in the area, lists of available information and resources, and recommendations for JAC activities.

Next, we will give a brief description of key categories of the matrix which were addressed at the symposium and which serve as the basis for this strategic plan.

Air Quality Planning

A comprehensive understanding of Paso del Norte air quality problems is the first step in determining how to improve it. Emissions inventories contain information on air pollutant sources, the magnitude of emissions and their location. Air quality monitoring networks measure ambient concentrations of key air pollutants providing data on temporal and spatial characteristics of pollutant formation and transport throughout the air basin. Air quality modeling and control strategy design allow air quality planners to determine the best strategies for reducing emissions and improving air quality. Symposium participants identified gaps in planning activities, which are necessary to adequately characterize air quality in the air basin.

Air Quality Management

Air quality management tools can be thought of as mechanisms by which we can achieve emission reductions from all types of sources within the Paso del Norte air basin. Symposium participants were asked to identify projects in the areas of: 1) public and industry outreach; 2) legislation/regulation; and 3) economic incentives. Public and industry outreach campaigns can be used to educate individuals and businesses about air pollution and encourage voluntary, cost-effective reductions. Legislation and regulation is typically used to mandate that sources control their emissions. Laws, rules, and regulations are in place at the federal, state, and local levels in both Mexico and the United States to control air pollutants. However, due to the binational character of the air basin, the current set of regulations may not be adequate to achieve emission reductions needed to attain standards. Therefore, extension or slight modification of existing rules and regulations or addition of wholly new regulations may be warranted to cover previously unregulated sources. Because traditional "command and control" approaches have been found to be cost ineffective, the implementation of economic incentives may be appropriate to achieve emission reductions at lower cost.

Health

Given the unique nature of emission sources in the air shed, the ambient pollutant mix in the Paso del Norte air basin may not be typical of other U.S. or Mexican cities. It therefore may be important to understand the linkages between air pollution and health effects specific to the Paso del Norte community. Symposium participants were asked to identify potential projects to assess the health risk of air pollution to citizens of the Paso del Norte air basin and to reduce exposure to air pollution through health education programs.

Applied Research and Special Studies

For this topic area, symposium participants were asked to identify areas of applied research or special studies that might be needed to better understand the nature of the air quality problem in the air basin. Among the studies recommended to be undertaken were the following: characterization of regional PM in both the coarse and fine fraction, photochemical modeling, receptor modeling, enhancement of the mobile source emissions inventory and mobile source emissions factors for regional vehicles, development of emissions factors for batch-type brickmaking operations, development of VOC emissions factors for industrial operations, and coordinated research projects to better determine the contributions to regional air quality degradation from each of the jurisdictions represented on the JAC.

Finance

Finance is the key component to implementation of any air quality management project. While one possible source of funding air quality improvement projects could be fines or penalties, the most important contribution will come from the private sector. NGOs, industry, and private industry must contribute, whether for the benefit of an individual facility or the community in general. The public sector is also responsible for funding projects whether for paving roads or furthering research in air quality. We live in a community where all citizens, regardless of affiliation, can contribute by acting responsibly for the benefit of themselves and their neighbors.

Project Identification and Prioritization

As stated previously, a technical commission comprised of both Mexican and U.S. JAC members and interested persons formed in December, 1997, to develop a Strategic Plan to guide and accomplish the binational committee's objectives as stated in Appendix I to Annex V of the La Paz Agreement. In February, 1998, the JAC Strategic Plan Technical Commission (STPC) held its first public meeting, the JAC Strategic Plan Symposium, to map out a direction and set the foundation for what would become a product of binational cooperation with far-reaching benefits for the Paso del Norte community.

Most fledgling organizations discuss a variety of activities to guide their actions; among those is the development of priorities. Through a series of binational meetings, the SPTC forged ahead by drafting lists of the following: sources and activities which generate air pollution in the Paso del Norte air shed; health-based actions that could be undertaken to determine air pollution-related health effects among residents of this region; economic incentives and regulations to guide industry in developing pollution prevention and clean technologies projects, reduce air pollution, and perhaps improve the bottom line for those willing to invest; outreach activities to promote citizen participation and inform industry of the benefits of investing in pollution prevention and clean technologies; and special studies to identify and characterize ambient air pollution or improve data found in the emissions inventories for each of the three political jurisdictions within the air shed among others.

As the list of projects, activities, and recommendations grew it was evident that categorization of projects and a grading scale were needed to narrow the projects to a more manageable number. A matrix was developed identifying over 100 individual projects or sources of air pollution such as mobile, point, area sources; special studies; health, legislation; regulation, etc. Each project on the matrix was graded according to the following criteria: cost effectiveness (CE), feasibility (F), significance of impact (SI), and overall (Over) priority. Each criterion was rated as having a high, medium, or low priority.

Matrices were distributed to individuals within the Paso del Norte community representing government, industry, academia, and NGO sectors in both the United States and Mexico. Twenty-six matrices were completed. Respondents were asked to use an intuitive approach to rank projects in the matrix indicating whether the project had a high, medium, or low priority under each grading criterion. Respondents may be expert in one or more areas, but perhaps not in all areas. When filling out the matrix, respondents are assumed to rely on their knowledge of the Paso del Norte air quality problem derived from personal interest or professional involvement and from information provided at the Symposium.

In order to establish a "first cut" list of projects, the "overall priority" category was selected. The high, medium, and low response was tallied within the "overall priority" category. If the tabulated results indicated there were more high's than medium's or low's under the "overall priority" for the project, then that project would be selected. Continuing this tabulation method for all 100+ projects resulted in 44 projects with a majority of high results under the overall priority criteria.

Next, the 44 projects which survived the "overall priority" cut were screened using the "feasibility" and "significance of impact" criteria. Similar tabulations were conducted, and this time only those projects where a majority of high's existed under both the "feasibility" and "significance of impact" criteria for each individual variable was selected. This final cut led to the 26 projects described in this strategic plan. Next is a list of those projects considered to be of highest priority by the SPTC.

Figure **4. JAC Priority Projects.**

Mobile Sources:

1) Enforce vehicle importation regulations.

2) Strengthen Vehicle I / M Programs.

3) Promote Dedicated Commuter Lanes (D.C.L.) to expedite crossing at international bridges.

4) Require the distribution of seasonally appropriate gasoline such as the same low-RVP gasoline during summer and oxygenated gasoline during the winter.

5a) Improve and promote the transit system.

5b) Improve vehicle traffic flow.

Industrial / Commercial / Service Sector -- Area / Point Sources:

6) Recommend to the industrial, commercial, and service sectors, as well as government, the implementation of voluntary programs, beyond compliance with rules and regulations, for the reduction of total combustion emissions, suspended particles and VOCs.

7) Regulate the use of fuels and promote cleaner technologies in the fabrication of brick.

8) Strengthen reforestation programs.

Health

9) Conduct epidemiological studies to assess the health impacts from current exposures to air pollutants in general.

10) Develop health education programs to achieve changes in personal habits regarding care of the environment, with special emphasis on air quality.

11) Institute an Epidemiological Surveillance Program Associated with Air Pollution.

Air Quality Planning

12) Procure resources to expand and update a basin-wide emissions inventory (EI)

13) Update and improve a basin-wide VOC emissions inventory (EI).

Outreach:

14) Identify and promote Pollution Prevention / Reduction incentive programs that can be used in conjunction with public and industry outreach efforts to achieve voluntary compliance and emissions reductions.

Legislation/Regulation

15) Contribute to updating of the State of Chihuahua Ecological Law to coincide with reforms of the General Law of Ecological Equilibrium and Environmental Protection (LGEEPA).

16) Contribute to update the Regulations for Cd. Juarez regarding Ecology and Environment for the municipality of Cd. Juarez

17) Promote reforms to regulations specifically for air pollution prevention and control.

18) Recommend reforms and standards regarding volatile organic compounds (VOCs) emissions.

Economic Incentives

19) Promote the Voluntary Environmental Audit Program; Follow-up on the resulting agreements and certify "clean industries."

20) Promote economic mechanisms of a fiscal, financial & market-based character (e.g. low interest rate loans, Basin-wide Emissions Reduction Credits Trading, etc.) to provide incentives for the prevention and control of air pollution in each country according to its rules and regulations.

21) Establish guidelines to promote and implement a basin-wide Clean Air Investment Fund.

Applied Research and Special Studies

22) Promote research projects to characterize the nature of particulate matter (PM) in the $PM_{2.5}$ and PM_{10} fractions within the airshed. Determine its ambient concentrations; size and mass distribution; spatial and temporal distribution; and chemical composition (organic and inorganic).

23) Develop studies for the determination of VOC emissions factors.

24) Coordinate monitoring and research activities within the airshed. Establish a regional clearing house.

25) Undertake a study of the socio-economic and cultural factors which may determine compliance and non-compliance with air quality rules and regulations.

Emerging Lessons

Due to the success of the Paso del Norte Air Quality Task Force and the Joint Advisory Committee for Air Quality Improvement, other community-led efforts have started within the U.S.-Mexico border region to protect and conserve shared resources, such as water in the Paso del Norte region. A top-down strategy would require a formal agreement between the governments of Mexico and the United States, as well as state governments, to set up mechanisms for water planning in the region. An alternative will be a bottom-up strategy under which communities and local water agencies would lay the foundation for regional coordination. A model using this strategy already exists as of 1990s initiated by the Environmental Defense, which includes citizens and experts from both countries and submits proposals for action to national, state, and local authorities. On April 1999, the Commissioners of IBWC and CILA convened the first meeting of the Paso del Norte Water Task Force, which constituted itself as a nongovernmental forum for the purpose of conducting joint studies, organizing outreach activities, and preparing policy recommendations. Task Force unites water managers, water users, experts, and citizens working cooperatively to promote a tri-state, binational perspective on water issues that impact the future prosperity and long-term sustainability of the region.

Similarly, as of December 2000, a meeting was convened by public health and medical organizations, institutions, and agencies in order to discuss the creation of a bi-national group dealing with environmental health and the Paso del Norte Environmental Health Coalition (PDNEHC) was formed. We at the Paso del Norte envision a border region whose citizens' health is not adversely affected by environmental exposure. The PDNEHC will function as a model of binational cooperation with the following guiding principles:

1) Establish collaborative efforts between institutions, organizations, and communities.
2) Develop lines of communication for sharing information, resources, and ideas.
3) Promote community involvement.
4) Promote complementary activities between basic and clinical sciences.
5) Facilitate professional development through educational programs.

The Paso del Norte community has been recognized as a pro-active, pro-positive community which undertakes innovative approaches to manage and preserve precious resources and fragile ecosystem learning from the framework set up by the air quality task force. Such a model has been replicated in other communities such as the Tijuana-Rosarito-San Diego Binational Air Quality Alliance that started in late 1999 and is on the verge of setting up priorities, tasks, and projects that will bring them to the next level of partnership and formal recognition through an official declaration by its corresponding authorities.

Other effort of binational cooperation that includes broad – local – stakeholders is the Paso del Norte Clean Cities Coalition, which was created in November of 1995, with the purpose of promoting alternative fuels and is the leading organization in charge of the Ozone Action Day. The Paso del Norte Clean Cities Coalition was the first international Clean Cities Coalition under the auspices of the Department of Energy, and it has been replicated in other border communities and is even being considered as a model in Santiago de Chile in South America.

As of 2000, the NAFTA created institutions on the U.S.-Mexico border: BECC and NADBANK have received authorization from their boards of commissioners and governors to expand their mandates into providing opportunities for communities to develop more extensive environmental infrastructure benefiting the citizens of the border region by including projects related to air quality. The Paso del Norte Air Quality Task Force and the JAC's strategic plan and measures for improving the air quality were used as testimony of how the BECC and NADBANK institutions could embark upon other projects beyond the water and solid waste mandate.

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Border Congestion, Air Quality, and Commerce

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The U.S.-Mexican border region, typically defined as a 100-km band (approximately 62.5 miles) on each side of the nearly 2,000-mile international boundary, includes 10 U.S. and Mexican states[1] and a combined population of over 9 million people, a number expected to double by 2010. International (cross-border) transportation is critical to the support of this regional economy and to the economic growth of both nations. Traffic congestion and delays at the border crossings have increased in many locations due in part to increasing binational trade and manufacturing, the implementation of the North American Free Trade Agreement (NAFTA), and the associated regional population growth.

There have been two important negative consequences associated with the increase in traffic and congestion. First, vehicles idling in long queues emit harmful pollutants into the air, decreasing air quality, which is already below acceptable standards in some locations[2]. Second, at many larger crossings, substantial delays in the passage of commercial vehicles have been documented. Clearly, such delays have an economic cost associated with them. While it is an important goal to increase international trade and tourism, it is equally important that progress be in consideration of the local and regional environment and the need to successfully engage in commerce.

The operations along the southern border between the United States and Mexico are very different from the operations along the northern border with Canada for two reasons. First, the cultural differences between the United States and Mexico are greater than the differences between Canada and the united States. Second, while English is the predominant language in both the United States and Canada, Spanish is the official language of Mexico.

On the U.S.-Mexico border there is also a constant tension resulting from concerns about the flow of illegal drugs and immigrants. Inevitably this affects the policies of customs and immigration officials, and coincidently the systems for processing people and goods across the border.

The processing of passenger vehicles entering the United States is straightforward. The vehicle will proceed in a queue until it reaches a primary inspection booth. At the booth the vehicle waits until it is waved forward, either by an inspector or by a signal light. The inspector will at least question the vehicle occupants with regard to country of residence and citizenship and whether or not items were purchased in Mexico. He may also use a mirror to look under the vehicle. If the primary inspector determines a more thorough inspection is warranted, the vehicle

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[1] The U.S. states are California, Arizona, New Mexico, and Texas. The Mexican states are Baja California, Sonora, Chihuahua, Coahuila, Neuvo Leon, and Tamaulipas.

[2] The Clean Air Act: New EPA Air Quality Standards – Implications for Texas, Published by the Texas Legislative Council, Austin, Texas, October 1998 *and* EPA Green Book: Nonattainment areas for Criteria Pollutants, July 2000.

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is sent to a secondary inspection area. Inspectors are trained to look for visible signs of stress from the vehicle occupants. They are also very aware of the profiles of people recently caught illegally transporting drugs across the border.

Commercial vehicles also have to pass through a primary and secondary inspection processes, normally in an area separate from the passenger vehicle area. Additionally, they must have the appropriate paperwork on the goods they are transporting.

It is clear that the behavior of the individual inspectors has a great influence on how long a primary inspection will take. The longer an inspector decides to hold a vehicle in primary, the more entrenched congestion becomes.

The concern about the transport of illegal drugs and immigrants is important and drives many policies and procedures at the border. To a certain degree, these policies and procedures themselves contribute to the congestion problems in evidence at many crossings. The objective of moving people and goods across the border quickly and efficiently does not easily correlate with the objective of eliminating the transport of illegal drugs, goods, and immigrants. The key policy issue is whether we can maintain the integrity and effectiveness of Customs, Immigration, and drug interdiction programs, while at the same time significantly reducing congestion. Therefore, the major goal of this study is to provide potential solutions to the congestion problem without compromising encompassing national goals.

Study Purpose

There is a number of possible explanations for border congestion. While some previous studies have postulated differing causes of border congestion, there is still no consensus about the elements most influential in making congestion endemic. This underscores the fact that the border is not homogeneous with respect to geography, climate, and economic conditions.

This study is designed to examine explanations for border congestion, to elucidate the relationship between various factors that contribute to border congestion and delays, and to propose opportunities for alleviating that congestion and the resulting impacts on air quality and commerce.

Generalized Approach

The basic approach of this study is to examine congestion problems in both a qualitative and a quantitative way. This entailed both reviewing prior studies and performing new field work. It also placed a heavy emphasis on getting input from people familiar with the border and its problems, generally referred to as the stakeholders.

The major goal of the study was to achieve a consensus among the stakeholders with regard to the causes of congestion and the most viable opportunities for alleviating it. To develop the consensus, five steps were taken. First, the amount of congestion attributable to primary causes, as well as the impact that traffic congestion had on air quality, was confirmed and quantified.

Second, information was gathered from stakeholders about their border transportation experiences and operations, perceptions of border congestion problems, and ideas regarding changes that might be introduced at border crossings to reduce congestion. This information was gathered either by direct interview or through group participation in workshops. Four similar workshops were held in local border communities in Texas (2), Arizona, and California.

Third, after data were collected or assembled from other sources, potential improvement strategies were then quantified to measure their effect on border congestion and air quality.

Fourth, a Workshop was held in San Antonio, Texas, from April 27 through April 29, 1999. This workshop brought together interested public and private sector stakeholders from all along the U.S.-Mexican border. This workshop was organized according to a method that enabled the stakeholders to identify and prioritize the most critical congestion-related problems and corresponding workable and acceptable actions to alleviate those problems.

Finally, the results of the workshop input were summarized and the analyses completed.

Steering Committee Guidance

This study was undertaken with the guidance of a Steering Committee[3] comprised of state, federal, private, and environmental representatives. The main functions of the steering committee were to:

- Provide policy, technical, and political guidance.
- Provide guidance on the structure and implementation of the stakeholder workshops.
- Review the technical analyses.
- Review and discuss the tentative conclusions that were generated in the workshops.
- Complete the final report.

Study Ports of Entry

Four Port of Entry (POE) systems on the U.S.-Mexican border were selected for evaluation and analysis. These locations were:

- Laredo, Texas–Nuevo Laredo, Tamaulipas
- El Paso, Texas–Ciudad Juárez, Chihuahua
- Nogales, Arizona–Nogales, Sonora
- San Ysidro/Otay Mesa, California–Tijuana, Baja California

These locations generally represent the busiest crossings along the U.S.-Mexican border. Further, most congestion-related problems along the border are present at one or more of these POEs. By defining conditions leading to congestion and related air quality issues at these crossings, it was assumed that problems at other crossings could be similarly defined. These four locations were selected in order to comprehensively characterize and analyze the congestion problems and form a solid basis for reaching agreement on solutions to problems along the entire border. All field work was completed between January and March 1999.

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[3] The Steering Committee was comprised of representatives from the States of Arizona, California, New Mexico, and Texas, U.S. EPA, the National Ecological Institute of Mexico, U.S. Department of Transportation, Environmental Defense Fund, U.S. Customs Agency, Immigration and Naturalization Service, the Western Highway Institute, and the Western Governors' Association.

Prior Studies

This study relies upon data collected in previous studies of the four study locations, including the *U.S. Mexico Binational Border Transportation Planning and Programming Study*[4] completed in April 1998 and the study on the *Effect of the North American Free Trade Agreement on the Texas Highway System*[5]. The data from the previous studies were compiled for comparison with recently collected data at the ports of entry. Traffic counts of commercial vehicle arrival and processing rates for the four major commercial ports were derived from the Binational Study. The four locations under analysis were: Ysleta-Zaragoza in El Paso–Juarez, Laredo II in Laredo–Nuevo Laredo, Nogales III-Nogales in Nogales–Nogales, and Otay Mesa-Mesa de Otay in San Diego-Tijuana.

Existing Conditions

In order to determine how improvements to traffic congestion could reduce delays and improve air quality at the four study locations, it was first necessary to determine existing conditions. This was done in two steps: quantitative data collection and qualitative information gathering.

Traffic congestion was quantitatively measured through a study of vehicle arrival and departure rates, both northbound and southbound. Ambient air quality data from area metropolitan planning organizations and/or state air quality divisions were examined to provide a reference point for the intensity of problems along the border.

Border stakeholders were invited to attend meetings to discuss border congestion and air quality concerns, problems, causes, solutions, and benefits. Information gathered from the workshops was supplemented by interviews with key stakeholders identified by the Steering Committee. The interviews and workshop input were intended to cover at least six important groups operating within the border region in both countries: customs and immigration, local politicians, local trucking companies, local businesses (Chambers of Commerce), local transportation officials, and local or regional air quality officials. This input provided insight into local aspects of individual POE operation, local issues, problems, improvement ideas, and proposals.

Primary Data Collection

Passenger vehicle arrival and departure rates were evaluated at crossings that experience significant congestion and associated delay and potentially reducible (avoidable) vehicle emissions. Data was collected at the following ports of entry:

- Laredo I and Laredo II in Laredo–Nuevo Laredo
- Bridge of the Americas and Ysleta–Zaragosa in El Paso–Juarez
- Nogales I–Di Concini in Nogales–Nogales
- San Ysidro-Puerta México and Otay Mesa-Mesa de Otay in San Diego–Tijuana

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[4] Binational Border Transportation Planning and Programming Study, prepared by La Empresa and Barton Aschman, May 8, 1997.

[5] Effect of the North American Free Trade Agreement on the Texas Highway System, prepared by Louis Berger & Associates in conjunction with Dye Management Group, December 1998.

Traffic counts were all conducted on Fridays. Friday was selected because traffic conditions reach their peak volume then according to the Binational Transportation Planning and Programming Study, where Friday was generally described as the busiest weekday.

Prior to completing each count, site reconnaissance of the ports of entry was conducted. This included the identification of access routes, border crossing layout, and location and operation of toll facilities. Operations of the various ports of entry were observed during field visits to the actual ports and discussed with inspectors prior to data collection. This groundwork allowed the data collection personnel to have an understanding of the operation of each POE and to select the best physical locations from which to collect data.

Surveys of commercial vehicle processing rates were conducted at Colombia near Laredo-Nuevo Laredo, and Nogales III-Mariposa in Nogales-Nogales. Observations were made at other commercial vehicle processing locations including Laredo II-Nuevo Laredo in Laredo-Nuevo Laredo, Ysleta-Zaragoza and Bridge of the Americas in El Paso-Juárez, Santa Teresa-San Jeronimo near El Paso-Juárez, and Otay Mesa-Mesa De Otay in San Diego-Tijuana.

Analysis of Candidate Improvements

The impacts and benefits of candidate actions and improvements were analyzed using data collected for this and prior studies. The vehicle exhaust emissions estimation model MOBILE-Juarez was used to estimate emissions for carbon monoxide, nitrogen oxides, and volatile organic compounds associated with avoidable or correctable congestion-related delay in existing conditions as well as under improved operations. MOBILE-Juarez is applicable to both Mexico and U.S. registered vehicles. The study used an improved version of the EPA's PART5 model to produce particulate matter idling emission rates.

The data collected at the border crossings formed the basis for estimating the existing delays. Future potential changes in delays were estimated using variations of a model developed for border station transportation operations as part of the Binational Border Transportation Planning and Programming Study. This model estimated future queues and delays under improved conditions associated with the identified candidate improvement actions.

San Antonio Workshop

The Western Governors' Association conducted a workshop in San Antonio from April 27 through 29, 1999, to review and discuss the border congestion, delays, and air quality, as well as commerce across the border. A broad cross-section of public and private stakeholders were invited from both sides of the border. Among the participants were the mayors of both Ciudad Juarez and El Paso, and other elected officials and representatives of inspection, transportation and environmental agencies, shippers, and trucking and environmental interest groups. Approximately 60 people participated in this workshop.

The goal of the workshop was to reach concurrence on border congestion-related problems and needs and to produce a list of improvement actions supported by the border stakeholders. The workshop successfully reached consensus on problems and needs and their causes, and divided priorities of the problems and needs into high, medium and low priority groups. Consensus was also reached on which opportunities should be considered for further analysis and possible implementation. These consensus problems, needs, and opportunities are described below.

Perceived Deficiencies and Needs

Problems and needs were identified in an initial series of workshops held at each of the four POE locations as well as through interviews and field observations. In some cases, input was provided in the form of suggested improvements rather than problems, needs, or related causes. San Antonio Workshop participants modified some of the problems and their descriptions and also prioritized them into high, medium and low priority categories. The first column of Table 1 lists the problems and needs that were identified by the workshop participants. These are presented in the three priority groups; however, within each group the items are not ordered according to rank.

In addition, for each problem or need, a root cause or causes were identified. This was done to make it easier to identify applicable actions for reduction of the deficiencies and improvement of mobility and air quality conditions.

The problems and needs discussed in Table 1 are those that workshop participants determined directly or indirectly affect border traffic congestion or air quality. Other problems and needs were also discussed during the study, but the workshop participants decided that they did not have a major impact on border congestion.

Suggested and Identified Opportunities

The laws of the United States and Mexico mandate inspection of people and items entering the respective countries. This study recognizes that the inspection process itself has important goals related to legally moving people and goods across the border.

> *Avoidable and correctable delay.* Avoidable or correctable delay is defined as time lost due to waiting to enter an inspection location and waiting through abnormal congestion on a route to or from the border. For example, waiting in a long queue approaching the first inspection booth is considered correctable. Being given an extended inspection is not.
>
> *Opportunities considered in this study.* The opportunities presented in this study are aimed primarily at reducing the avoidable or correctable delay and not at expediting inspections themselves.

Table 1 lists candidate opportunities identified from the workshops or technical analyses. All candidate opportunities shown in Table 1 are aimed at accomplishing one or more of the following objectives by addressing the sources and causes of the problems:

- Reducing congestion and the resulting delay and vehicle exhaust emissions.
- Reducing processing time for vehicles crossing the border.
- Reducing the vehicle exhaust emissions rates and thereby total emissions.

A number of actions have application at most border crossings between the United States and Mexico. Others address problems or needs at individual locations. Some other actions, however, are applicable only for northbound traffic entering the United States, and some only for southbound traffic entering Mexico. It is understood that there may be seasonal variations in port activity that have not been accounted for in this study.

Table 1
PROBLEMS, NEEDS, AND CORRESPONDING POTENTIAL OPPORTUNITIES AND RELATED BENEFITS

Problems	Causes	Potential Opportunities
High Priority		
Many vehicles crossing the border pollute excessively	• Varying fuel and emissions standards • Older vehicles • Poor Maintenance • Limited enforcement	Establish and enforce emissions and fuel standards for all vehicles operating in border areas; ensure exported vehicles meet applicable standards in country of export; work toward common standards.
Unnecessary delay in queues at border station primary inspection booths	• Insufficient staffing to meet demand patterns • Insufficient monitoring to establish staffing needs	Monitor and staff inspection lanes to meet demand
		Use inspection lanes to maximum capacity
	• Too few primary inspection lanes	Add primary passenger vehicle inspection lanes where deficient
		Provide additional commercial vehicle inspection lanes
	• No official goal for total time to process vehicles through primary inspection, including wait time	Establish hourly average maximum queue time (e.g., 20 minutes)
Dead heading (returning empty one way) trucks produce congestion and unnecessary emissions	• Provisions to permit return loads from alternate locations are not yet implemented	Fully implement NAFTA provisions; convene brokers and shippers to increase efficiencies within the local business and inspection environment

Table 1
PROBLEMS, NEEDS, AND CORRESPONDING POTENTIAL OPPORTUNITIES AND RELATED BENEFITS

High Priority

Problems	Causes	Potential Opportunities
No single agency has primacy for coordinating the inspection process	• Multiple agencies and levels of government involved • Variety of primary agency missions that may be in conflict • Multiple inspections • Duplicate inspections	Establish a unified POE entry system under a single authority to coordinate efficient and compliant movement of people and goods across the border. Consider ultimately moving to a binational unified entity.
Border crossing demands peak and exceed crossing capacity, resulting in increased congestion	• Demand spikes during AM and PM commute periods and other popular crossing times	Provide incentives for off-peak crossing
		Provide central transit hub near border stations to encourage park and walk/ride
		Use of high capacity people movers (transit)
		Increased dedicated commuter lanes
	• Commercial vehicle crossings peak due to dispatch platooning and shipping schedules	Develop dispatch schedules to spread traffic throughout the day
		Variable tolls to encourage crossing at off-peak hours

Table 1
PROBLEMS, NEEDS, AND CORRESPONDING POTENTIAL OPPORTUNITIES AND RELATED BENEFITS

Problems	Causes	Potential Opportunities
High Priority		
Border crossing demands peak and exceed crossing capacity, resulting in increased congestion		Encourage use of underutilized crossings (e.g., have continual radio broadcasts of wait times by crossing)
	• There are vehicles crossing the border that might not have to	Establish international trade centers that straddle the border; integrate inspection facilities into the trade center
	• Idling in queue creates excess emissions and air pollution	Create parking areas where vehicles can wait to be called for inspection
	• Free border crossings in the vicinity of tolled crossings create excess traffic at the free crossing	Establish toll structure to minimize congestion
Congestion and delays due to inefficient and/or circuitous access	• All inspections are concentrated at the border	Move some inspections away from the border crossing
	• Commercial traffic congests narrow streets not designed for large vehicles	Provide incentives to use better designed, underutilized, or outlying crossings
	• International truck traffic congests intersections and interchanges along border routes	Make necessary infrastructural improvements at pertinent crossings

Table 1
PROBLEMS, NEEDS, AND CORRESPONDING POTENTIAL OPPORTUNITIES AND RELATED BENEFITS

Problems	Causes	Potential Opportunities
High Priority		
Congestion and delays due to inefficient and/or circuitous access	• Commercial and passenger vehicle movements conflict at combined inspection facility approaches	Separate all major commercial and passenger inspection facility approach roads
	• Existing at-grade railroad crossings cause delay on some routes	Separate grades, reroute or relocate rail lines
Inspection and transportation agencies do not always have the budget to make broad operational and infrastructural changes	• Phenomenal growth over the last decade has strained existing resources and infrastructure	Develop a comprehensive, joint state-federal plan for operational and infrastructural improvements that ensures necessary funding to meet demand
		Involve local communities in planning process
No long range planning for international trade corridors or routes and facilities serving border crossings	• Unified border planning has historically been difficult to coordinate	Establish a binational/trinational planning process for transportation corridors serving international trade and border crossings

Table 1
PROBLEMS, NEEDS, AND CORRESPONDING POTENTIAL OPPORTUNITIES AND RELATED BENEFITS

Problems	Causes	Potential Opportunities
Medium Priority		
Pre-cleared vehicles delayed in primary inspection queue	• Designated commuter lanes (DCL) are not available at all crossings	Ensure there are 1-2 DCL's at major crossings and establish pricing policies to encourage their use
	• Rapid Enforcement Lanes (REL) are not available for trucks at many POE's	Add at least one REL at major commercial crossings and provide incentives for their use
Insufficient physical capacity results in excessive congestion and delays	• Physical site limitations	New passenger vehicle crossings at ports where physical capacity is a limiting factor
		New commercial vehicle crossings at ports where physical capacity is a limiting factor
Unnecessary delays in queues at primary inspection booths	• Some detailed vehicle inspection occurs in the primary lane	Conduct any detailed inspection in the secondary inspection area
	• Some supplemental inspections temporarily block the primary inspection lanes	Conduct any supplemental inspection away from primary lanes
	• Red/green signals do not work requiring manual indication from inspector and hesitation by drivers	Keep signals operational

Table 1
PROBLEMS, NEEDS, AND CORRESPONDING POTENTIAL OPPORTUNITIES AND RELATED BENEFITS

Problems	Causes	Potential Opportunities
Medium Priority		
Differing operating hours at adjacent U.S. and Mexico stations	• Agency management policies	Coordinate operating hours between the United States and Mexico
Inspection and processing inefficiencies	• Automated Customs Entry (ACE) not fully operational	Port managers should develop comprehensive plans to increase inspection and processing efficiency
	• Significant variation in documents extends preparation and inspection times	
	• Absence of pre-filing for most commercial vehicles	
	• Complexity of inspection regulations	
	• Multiple stops and inspection locations for commercial vehicles at some ports	Implement "one-stop" inspection processing

Table 1
PROBLEMS, NEEDS, AND CORRESPONDING POTENTIAL OPPORTUNITIES AND RELATED BENEFITS

Problems	Causes	Potential Opportunities
Medium Priority		
Inspection and processing inefficiencies	• Underutilization of available technology	• ACE implementation • X-ray machines • Laser visas • Palm print readers • License plate readers • Connectivity between brokers, shippers, and regulatory agencies
Not all advances and improvements are implemented border-wide	• Effectiveness of information sharing systems	Communication between state, local, and federal agencies, and private entities such as customs brokers and shippers

Table 1
PROBLEMS, NEEDS, AND CORRESPONDING POTENTIAL OPPORTUNITIES AND RELATED BENEFITS

Problems	Causes	Potential Opportunities
Low Priority		
Operating hours at commercial border stations do not always fit shipping schedules	• Operating hours for the crossing versus business hours for financial institutions, brokers, and shippers can be different	Develop plans that will coordinate better between entities
International railroad operational regulations can add to congestion	• Mexico Agricultural inspection agency (SAGAR) requires exterior of rail cars to be clean before crossing the border. Trains are often delayed for car cleaning.	Negotiate with SAGAR to have the cleaning done at the first rail yard in Mexico
Bridge costs are excessive in certain areas	• Classification as navigable river increases bridge cost to the point where construction of new bridges is prohibitive	Reduce vertical clearance when new and reconstructed bridges are built

Potential Effectiveness of Identified Opportunities

The workshop participants analyzed the proposed opportunities for their potential effect on border traffic congestion and air quality. The air quality analysis described above was conducted for the potential opportunities identified in Table 1. Some candidate actions would produce increased efficiencies but would not produce significant reductions in delays or emissions. A few actions would produce the same improvements as other actions.

Figure 1 shows the daily vehicle volumes for the seven crossings surveyed for this study.[6] The daily volumes ranged from approximately 45,000 vehicles going each way at San Ysidro (near San Diego) to about 5,000 vehicles going each way at Laredo Bridge I (located in downtown Laredo-Nuevo Laredo). The crossings in the San Diego-Tijuana and El Paso-Juarez areas reflect high volumes of commuter traffic between the two border communities.

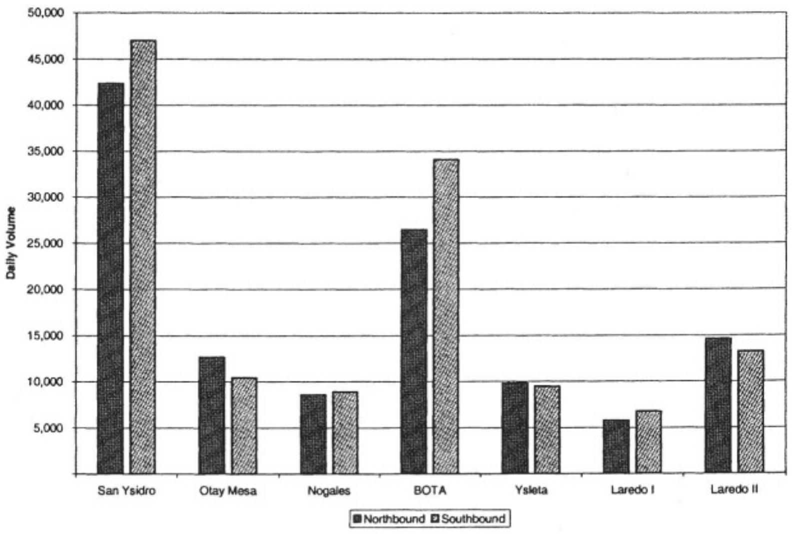

Figure 1. Daily Passenger Vehicle Flows – Surveyed Locations.

Figure 2 shows the estimated avoidable delay for the crossings studied at each of the four ports of entry (POEs). For each of the POEs, estimates of delay were made based on the arrival patterns and processing rates determined from the survey data as follows:

- The time of arrival of vehicles at the back of the queue was noted.
- When the vehicle arrived at the primary inspection booth, the time was checked. The difference between when the vehicle arrived at the queue and when the vehicle reached the inspector was considered the wait time.

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6 Source: United States Customs Service vehicle traffic counts

- From that point, the vehicle was monitored to determine the exact amount of time spent with the primary inspector.
- Individual wait times were then added to determine an average wait time for all vehicles.

Once this data was gathered, it was possible to calculate avoidable delay. This calculation is inherently difficult for two reasons. First, the potential opportunities could not all be considered additive. With the model that was applied it was possible to analyze easily individual strategies for their impact on delay; however, it cannot be assumed that the individual reductions in delay calculated by the model can be added together to get a combined benefit.

Table 2 provides the results of the modeling for selected strategies. Let us look at an example of the non-additive nature of some strategies. Adding inspectors to meet demand patterns will reduce delay by 42,300 vehicle-hours at the ports studied. Establishing an official goal for total time to process vehicles will reduce delay by 35,300 hours. However, because the two strategies are linked, implementing both will result in a delay reduction far smaller than the sum of the individual reductions. The combined benefits depicted in Figure 2 were calculated by the use of an algorithm in the model that weighed each strategy individually.

Table 2
Modeled Reduction in Delay From Selected Strategies

Strategy	Potential Reduction in Delay
Increase the number of inspectors to meet demand patterns	42,300 Veh-hrs
Use inspection lanes to maximum capacity	42,300 Veh-hrs
Add primary inspection lanes in deficient areas	39,000 Veh-hrs
Build park and ride/walk areas	8,700 Veh-hrs
Establish maximum average queue time of 20 minutes	35,300 Veh-hrs
Add dedicated commuter lanes at major crossings	20,700 Veh-hrs
Add Rapid Enforcement Lanes	4,700 Veh-hrs
Add new passenger crossings at selected ports	11,600 Veh-hrs

Second, not all the strategies could be analyzed without making broad assumptions about inspector efficiencies or driver behaviors. For example, broadcasting wait times at various crossings may or may not have a significant effect on the behavior of drivers. Additional research can yield better estimates of the effect many strategies will have on wait times.

For the purposes of making an estimate of the potential impact that reducing wait times could have on air pollutant emissions, it was assumed that most of the high and medium priority opportunities would be implemented. This information was put into the delay model and the results are shown in Figure 2.

Figure 2 also shows that the majority of the avoidable delay occurs in the northbound direction. The exception is Laredo, where there is more southbound avoidable delay. The crossings with the highest volumes of traffic generally have the most avoidable delay.

With the counts for vehicles crossing and average avoidable delay, it is possible to calculate total avoidable delay for all locations. Figure 3 presents the total daily avoidable delay for combined passenger and commercial traffic. The daily avoidable delay for the surveyed crossings totals about 68,000 vehicles per hour of which about 10,000 are commercial vehicles.

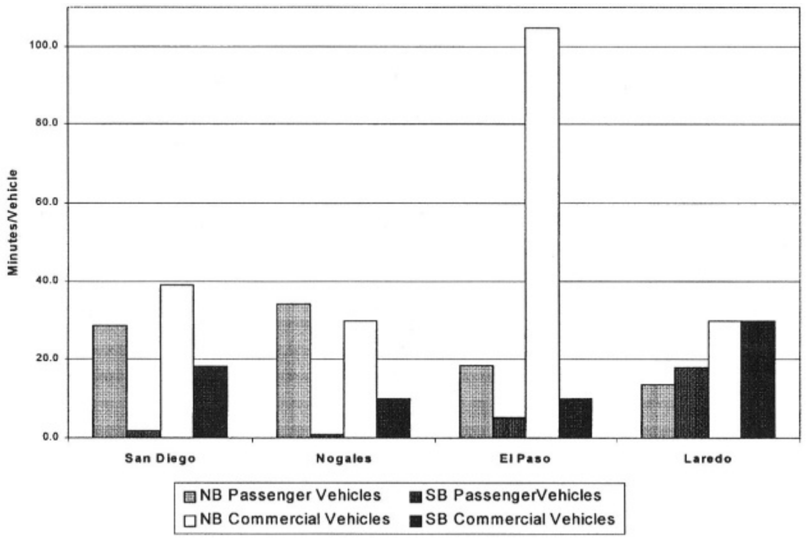

Figure 2. Estimated Average Avoidable Delay in Minutes Per Vehicle.

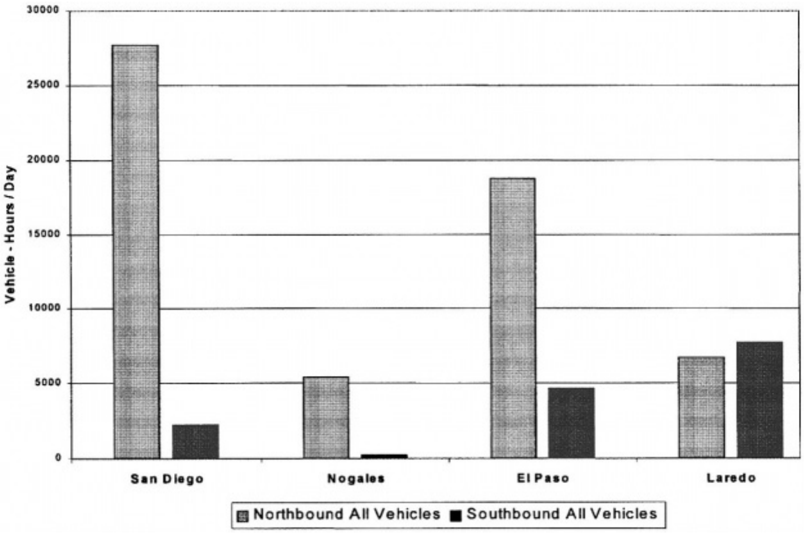

Figure 3. Total Daily Avoidable Delay – Surveyed Locations.

Air Quality

The mobile source emissions estimation model MOBILE 5-Juarez was used to estimate emissions for carbon monoxide (CO), volatile organic compounds (VOC), and nitrogen oxides (NOx). Particulate emissions were estimated using PART5-TX1.

Table 3 shows emissions from vehicles idling in the queue in grams/vehicle hour for CO, VOC, NOx, and PM. It also provides an average number for the entire fleet, which can be used to evaluate air pollutant emission reductions from lowering wait times.

Table 3
Emissions (g/veh-hr)

	VOC	CO	NOx	PM
Light Duty Gasoline Vehicles	99.58	1130.70	12.66	0.043
Light Duty Gasoline Trucks (Class 1)	93.84	1033.30	11.58	0.041
Light Duty Gasoline Trucks (Class 2)	111.80	1233.04	13.14	0.110
Heavy Duty Gasoline Vehicles	54.46	668.30	11.78	0.219
Light Duty Diesel Vehicles	3.20	12.18	5.16	0.334
Light Duty Diesel Trucks	4.38	13.80	6.08	0.291
Heavy Duty Diesel Vehicles	15.46	110.52	75.16	1.211
Motorcycles	50.44	517.20	2.38	0.035
Composite	89.82	1001.06	16.02	0.253

By combining the total avoidable delay with the composite emission factors, it is possible to generate potential emissions savings. Table 4 and Figures 4 and 5 show the estimated savings in emissions due to avoidable vehicle delay at the surveyed border crossings (both northbound and southbound and combined by port of entry) for VOC, NOx, CO, and PM in kilograms per day.

Table 4
Estimated Potential Emissions Reductions (kg/day)
Using MOBILE-JUAREZ (2000)

	VOC	CO	NOx	PM
San Diego	2,695	30,031	481	7.59
Nogales	539	6,006	96	1.52
El Paso	2,156	24,025	384	6.08
Laredo	1,257	14,014	224	3.54

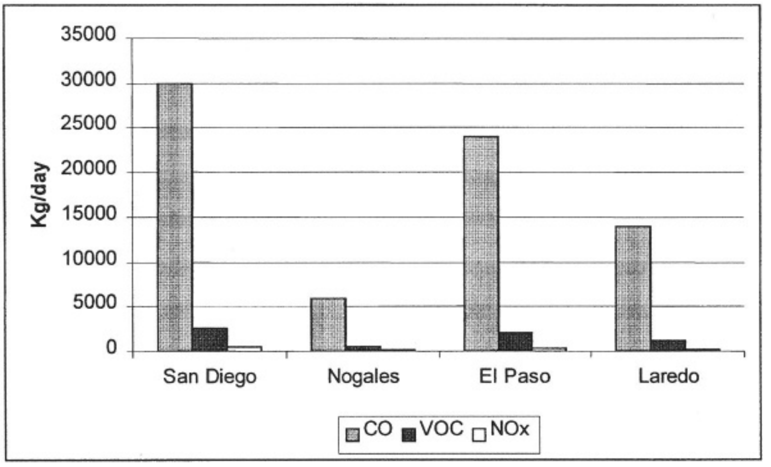

Figure 4. Estimated Potential Emissions Reductions from Avoidable Delay for VOC, CO, NOx in kg/day.

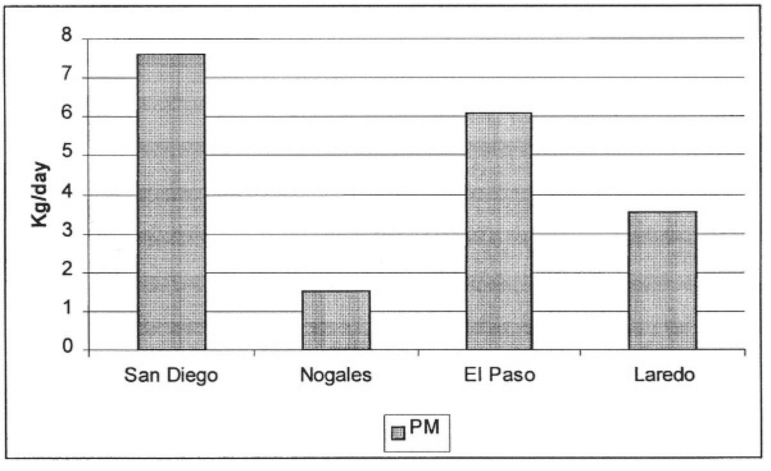

Figure 5. Estimated Potential Emissions Reductions from Avoidable Delay for PM in kg/day.

Conclusions and Recommendations

An important advantage of this study is that it combines field research and scientific modeling with the perceptions and experiences of those familiar with border congestion. At the San Antonio workshop there was open discussion, first about problems, needs, and causes, and then about potential opportunities. Participants were urged to identify the problems and needs most relevant to their businesses and other activities and to reach agreement on the problems, needs, and most beneficial and acceptable improvements to be pursued.

The workshop was successful in reviewing the problems and needs associated with movement of people and goods across the border. Although the participants came from a variety of backgrounds and represented widely differing interests, they were able to come to agreement on the problems and needs that need to be addressed to alleviate border transportation congestion, delays, and related air pollution. They were also able to reach consensus on opportunities that they believe can successfully address the problems and needs.

Problems and Needs

The workshop discussion of problems and needs generally confirmed the other discussions with inspectors, shippers, brokers, and elected officials, and the field observations. The workshop was also valuable for the sharing of information among participants about operations, experiences, and procedures to help better understand how border transportation works. The problems and needs listed in Table 1 are the consensus of the workshop.

A few of the problems may need some explanation for better understanding. For example, dead heading trucks are trucks that go across the border with a loaded trailer, but return with an empty trailer or without a trailer at all. Other trucks go in the opposite direction with a full trailer and also return empty. Two trucks each make a round trip, but make the equivalent of one loaded round trip. This creates extra traffic and extra exhaust emissions. While a certain amount of empty truck travel is inevitable because not all trucks can be matched with loads, current practices and regulations result in more empty truck travel at some locations than is necessary. For example, at the Laredo-Nuevo Laredo crossings, a survey showed that approximately 35 percent of the commercial vehicles were bobtails (trucks crossing without a trailer)[7].

Another problem that may warrant explanation is the long-range planning for border crossing locations along the U.S.-Mexican border. Many of the existing crossing locations are proposed independently of any planning for major transportation facilities that would provide access to the border. In addition, there should be specific planning for international trade corridors that connect adjacent countries via border crossings. Recently, there have been some improvements in border crossing planning. The formation of the Joint Working Committee now provides an ongoing binational workgroup related to border area transportation issues.

Reference under medium priority problems to insufficient physical capacity addresses the limitations of border station size resulting from a lack of sufficient long-range planning and federal policy on site acquisition for long-term needs. These two factors result in some border station sites becoming outmoded prematurely, thereby creating the need for additional border crossings to provide more inspection station capacity.

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[7] U.S. Customs Service, Port of Laredo, Daily Vehicle Survey for February 1999.

The issue of advances and information not being utilized borderwide pertains to practices, technologies, and findings that could help increase efficiency if they were known or available. Increased communication and information sharing both vertically, within agencies and organizations, and horizontally, across the border and between organizations, would be a significant step forward for everyone using the border system.

Prioritization of Problems and Needs

Once the list of problems and needs was agreed upon, workshop participants categorized them as high, medium, or low priority. The workshop was split into three discussion groups so everyone could have an opportunity to ask questions and voice opinions.

Discussions addressed each problem individually, including the statements of problems and causes, and in some cases led to revisions of the wording or emphasis of the problems. In some cases problem causes were added or modified. Each discussion group then went through the revised statements and was asked if they agreed. Consensus was considered to have been achieved if all, or virtually all, participants agreed with the statements or said they were acceptable.

After each of the three groups had completed their discussions, all participants reconvened as a single group and heard the reports of each discussion group. There was then further discussion on the differences in conclusions among the three groups followed by development of a workshop consensus on the problem and cause statements. Once all problems and causes had been individually reviewed and the participants formed consensus on the problem and cause statements, participants were asked to discuss the three group prioritizations into high, medium, and low categories. (A "no priority" option was available if they thought the problem was not significant or appropriate to address under this program). A priority was accepted when all participants approved or at least accepted the priority as being reasonable to report. The resulting consensus priorities are reflected in the list below and in Table 1.

High Priority

- Many vehicles crossing the border pollute excessively.
- Unnecessary delays in queues at border stations, primary inspection booths.
- Dead heading trucks produce additional congestion and exhaust emissions.
- Border crossing demands exceed capacity, resulting in congestion.
- No single agency has primacy to coordinate the inspection process.
- Congestion and delays result from inefficient or circuitous access.
- Inspection and transportation agencies do not always have the budget to make broad operational and infrastructural changes.
- There is no long range planning for international trade corridors and facilities serving border crossings.

Medium Priority

- Pre-cleared vehicles are delayed in primary inspection queue.
- Insufficient physical capacity results in excessive congestion and delays.

- Unnecessary delay occurs at primary inspection booths.
- Different operating hours at adjacent U.S. and Mexican crossings.
- Inspection and processing efficiencies should be examined.
- Some advances, improvements, and information at some POEs are not utilized borderwide.

Low Priority

- Operating hours at commercial border stations do not always fit shipping schedules.
- International railroad operational regulations can add to congestion.
- Bridge costs are excessive in certain areas.

Opportunities

Once the problems and causes had been agreed upon in the three discussion groups, the workshop discussion focused on potential opportunities contained in a preliminary version of Table 1. The opportunities were discussed as they related to an individual problem. The participants suggested some adjustments, and they were then asked whether they accept and support the opportunities for addressing the problems they had previously discussed. Through a facilitated process, consensus was reached. Table 1 contains the resulting list of opportunities acceptable to the workshop participants.

The suggestions for improvements in the table are oriented to moving vehicles more efficiently through delay points in approaching or leaving the border or within border inspection stations. The intent is not to suggest any changes in actual inspection procedures other than to encourage use of either current technologies and procedures or those planned for implementation on the border.

Clearly, not all strategies are applicable to all ports of entry. For example, the infrastructural needs and limitations at land-crossing ports are very different from those at bridge-crossing ports. However, many of the strategies that relate more to operational practices are applicable borderwide.

Consensus

Table 1 reflects the consensus opinion of the workshop participants on:

- Problems and needs.
- Priorities for addressing the problems.
- Viable opportunities.

Conclusions

The participants in the local workshops in the four POE study areas and those in the final workshop generally agreed on the congestion-related problems that need to be addressed along the border. They understand that not all opportunities are applicable at every location, but that those listed in Table 1 should be considered where the listed problems and needs exist. In addition, there was strong consensus that more information sharing among and within agencies on a borderwide basis and more long-range planning are necessary to avoid future congestion.

Those familiar with the workings of the border firmly believe that programs could be implemented to alleviate congestion without compromising the important national goals related to customs, immigration, and drug enforcement.

U.S. Transportation Responses to NAFTA: A Window on U.S.-Mexico Transport Issues

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When it went into effect on January 1, 1994, the North American Free Trade Agreement (NAFTA) created the world's largest free trade zone. The agreement was a landmark step in eliminatingtrade barriers among the United States, Canada, and Mexico, and supporters and opponents alike forecast that it would produce dramatic trade increases. Because the treaty established trilaterally most provisions of the U.S.-Canada Free Trade Agreement (CFTA) that existed before it, NAFTA's primary significance for the United States is its effect on U.S.-Mexico trade.[1] NAFTA also promised significant consequences for transportation, given the anticipated increase in goods movement and NAFTA trucking provisions that would alter the U.S. trucking industry.

This paper uses NAFTA as a starting point for discussing larger transportation planning issues related to freight movement between the United States and Mexico. In particular, the paper examines the U.S. transportation response to NAFTA, which has repeatedly heralded a transportation infrastructure deficit in America and which has been embodied in the extra funding devoted to so-called NAFTA corridors in the Borders and Corridors Program. This inquiry finds that incomplete goods movement data often hamper needed empirical evaluation of the projects proposed for such trade-related transportation funding. Without sufficient data, the distribution and degree of trade-related transportation impacts in competing corridors cannot be fully known. As a consequence, opportunistic political appeals for additional surface transportation (primarily highway) may play a larger role in funding decisions than any coordinated, prioritized response to the transportation challenges facing the United States and Mexico as binational trade increases. For more rational planning of the transportation investments serving U.S.-Mexico trade, the collection of enhanced freight movement data is needed. And although current trade flow data have limitations, they do indicate that the U.S.-Mexico border region experiences concentrated traffic, transportation and environmental impacts from U.S.-Mexico goods movement. Domestic trucking and travel data provide additional support for this finding.

Using NAFTA as a window through which to view U.S.-Mexico goods movement, this analysis aims to describe some general dynamics of cross-border freight flows and their planning implications. The Barton-Aschman series of border transportation studies, commissioned by Mexico and the United States, have been particularly useful in this analysis for their discussions of trade patterns, transportation infrastructure, and freight projections. Several studies produced by coalitions of border states, environmental groups, and the U.S. government also inform this analysis.

The paper is structured as follows: the first section provides some background on the treaty and the general ways in which it was expected to affect transportation. The salient treaty provisions illuminate NAFTA's role in accelerating trade between the United States and Mexico,

[1] Rhoades, Michael P. "NAFTA's Implications for the Transportation Industry," *Transportation Quarterly,* Vol. 48, No. 2, p. 135. Spring 1994.

L. Fernandez and R.T. Carson (eds.), Both Sides of the Border, 305-322.

as well as its potential to change how trade related transportation services are provided. The second section looks at the trade and transportation impacts that observers forecasted for NAFTA and at changes that have actually manifested since NAFTA's passage. The question of a transportation infrastructure deficit is a point of focus. While growing freight movements inarguably increase demands on highway infrastructure, many claims of NAFTA-related corridor needs lack empirical accounting of the extent of the increase. Section two also explores the fate of two NAFTA trucking provisions sketched in section one and considers their environmental implications. Section three uses NAFTA to sketch the broader dynamics of U.S.-Mexico goods movement, examining the role of *maquiladoras* and border clearance processes. The section also explores how incomplete goods movement data hamper efforts to understand fully U.S.-Mexico freight transportation and its impacts. In spite of the shortcomings of available freight data, the concentration of major U.S.- Mexico trade links in the border region suggests that border areas are particularly impacted by binational goods transport. Finally, section four focuses on the air quality impacts of intensified binational goods movement since NAFTA's passage. Establishing links between increased U.S.-Mexico commercial vehicle traffic and diminished air quality has proved difficult, particularly as distance from the border increases. Again, insufficient origin and destination data, along with absent or incomplete measures of air quality, hamper efforts to quantify the contribution of trade-related transportation to smog levels or particulate counts.

Improved data on truck movements and air quality are needed to quantify the strain of additional traffic in specific corridors and to measure air pollution from U.S.-Mexico freight trucks. Nonetheless, interim measures to reduce vehicle emissions in heavily trafficked areas like the U.S.-Mexico border region may achieve incremental air quality improvements.

I. NAFTA and Transportation: An Overview

To begin, a brief review of NAFTA's salient provisions illuminates the treaty's role in accelerating trade between the United States and Mexico, as well as its potential to change how trade related transportation services are provided.

The United States, Canada, and Mexico signed NAFTA seeking "to eliminate barriers to trade in, and facilitate the cross-border movement of, goods and services" between the countries.[2] First, by prohibiting the increase of existing customs duties or the adoption of any new tariffs, NAFTA ensures that any trade barriers in effect at its inauguration will not tighten. The treaty also provides a fifteen-year schedule by which the United States, Mexico, and Canada have agreed to reduce or phase out most existing customs duties, and also allows any two countries to accelerate the elimination of a particular import restriction if they mutually agree to do so. Tariff reduction has been particularly important for the automotive and electronics industries, two of the most dominant sectors in U.S-Mexico trade. The promise of the treaty, which current trends confirm, is to lower production costs (by allowing some firms to spatially reorganize production processes), increase trade, and boost employment, domestic productivity, and wages for all three countries.

A second important provision of the treaty is its promise to loosen restrictions on cross-border trucking between Mexico and the United States. While the United States under Clinton had delayed implementation of relaxed trucking rules through 2000, the Bush administration has supported granting Mexican carriers full access to American highways in accordance with NAFTA. Allowing Mexican trucks to bring goods directly into the United States, rather than

[2] NAFTA, Preamble.

handing them off to American rigs at the border as has been done heretofore, could bring significant changes to the logistics industry, as well as in surface transportation demand and, consequently, air quality issues. However, as of mid-2001, Bush administration efforts to implement cross-border trucking faced stiff Congressional opposition.

II. Considering Effects of NAFTA

Trade Effects

The rhetoric surrounding NAFTA's passage emphasized, among other themes, the increase in trade that the agreement would spur. However, NAFTA's role as a sparkplug for trade may have been overstated. To counter early criticisms of NAFTA that portended "the great sucking sound" of American jobs moving south, policy makers may have overemphasized the U.S. trade gains that NAFTA would deliver.

Trade between the United States and Mexico clearly has increased since NAFTA's passage, but it had been rising since well before NAFTA. Trade data compiled by Barton-Aschman shows that U.S.-Mexico economic activity has been growing steadily at least since the mid-1980s, when Mexico lowered tariffs and joined the General Agreement on Tariffs and Trade.[3] U.S.-Mexico trade grew steadily from $14.6 billion in 1987 to $50.8 billion in 1994, then increased at a slightly higher rate in 1995 due mostly to devaluation of the Mexican peso. For the same period, Mexico-U.S. trade grew steadily from $20.3 billion to $49.5 billion, with exports increasing at a higher rate in 1995 due to devaluation. Total trade between the two countries topped $100 billion for the first time in 1994 and now stands well above that. In 2000, Mexican exports to the United States alone neared $135 billion, and the United States sent over $110 billion in exports to Mexico.[4] The United States is Mexico's top trading partner, accounting for 80 percent of Mexico's total imports and exports. While the U.S. trading partners are more diverse, Mexico is the second largest partner, garnering 8 percent of total U.S. trading activity in 2000.[5]

The contours of recent U.S.-Mexico trade developments suggest that, rather than having ignited entirely new trade, NAFTA has been accelerating a trend that was firmly established well before the treaty. Because trade had been steadily increasing, transportation officials should have observed any trade-related transportation needs well before NAFTA. However, the passage of a high-profile and controversial trade treaty may have eased the way for transportation spending stakeholders to declare an infrastructure deficit and to call for increased transportation investment.

Infrastructure Deficit?

At the time of its passage, NAFTA attracted considerable and passionate attention from the U.S. surface transportation industry, and it continues to do so today. Given that 86 percent of

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[3] Barton Aschman. "Current Trade and Passenger Flow Data," *Binational Border Transportation Planning and Programming Study*. La Impresa Barton-Ashman. May 8, 1997, p. 21.

[4] Trade figures for 2000 reported by the U.S. Census Bureau, Foreign Trade Division, Data Dissemination Branch,Washington, D.C. 20233. See also http://www.census.gov/foreign-trade/balance/c2010.html.

[5] U.S. Department of Commerce, International Trade Administration. *U.S. Aggregate Trade Data.* Table 3," U.S. Trade in Goods, 1972-00." Table 9, " Top 50 Partners in Total U.S. Trade in 2000." www.ita.doc.gov

United States-Mexico trade is transported by truck,[6] and given that observers anticipated NAFTA would spur a great increase in goods flow by eradicating trading limits, transportation experts warned of tremendous growth in truck traffic at the U.S.-Mexico border, as well as on U.S. interstate corridors leading to and from Mexico and Canada. The increased trade would dramatically boost demand for U.S. roadway infrastructure, some argued, and if the United States did not enhance its highways, many of the economic benefits of increased trade would be lost to an inefficient transportation system.

During NAFTA debates, the choice phrase among elected officials, transportation specialists, and some academics became transportation "infrastructure deficit"—insufficient investments "to improve border crossings, widen highways, and construct new roads and bridges."[7] In the United States, the need for improved infrastructure was seen as particularly acute at the U.S.-Mexico border and roads serving it as well as north-south U.S. roads connecting Mexico and Canada; little attention was directed toward Mexico, where any deficit would surely have been greater. At a 1996 meeting of the Transportation Research Board, U.S. transportation experts universally agreed that NAFTA had quickened the rate of trade growth and also "increased pressure on the nation's infrastructure, especially for surface transportation."[8] One transportation scholar argued that infrastructure investments could "help facilitate this transition [to an open market]."[9]

While some experts acknowledged that simplified customs procedures and operational changes at the border could play an important role in improving trade flows, a majority of observers saw NAFTA as a justification to expand existing or develop entirely new border crossings as well as to improve so-called NAFTA highway corridors, such as I-35,I-69, or the CANAMEX corridor. This view was particularly pronounced among—albeit not limited to—elected officials in the border states that serve land traffic between the United States and Mexico; they saw in NAFTA an opportunity to call for increased transportation investment. At the 1993 Congressional hearings on NAFTA, Mayor of Laredo Saul Ramirez represented PRO-NAFTA, an organization of U.S. elected officials supporting the treaty. Ramirez testified that the group was

> dedicated to obtaining investment in public infrastructure to support the economic activity that NAFTA will generate. We believe that a key part of realizing this opportunity is adequate investment in transportation, communications and environmental infrastructure by both the United States and Mexico.[10]

As Mayor of Laredo, a major port of entry for truck and rail traffic between the United States and Mexico, Ramirez noted that traffic had increased dramatically since implementation

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[6] Barton Aschman. "Changes in U.S. and Mexican Cross Border Trade Flows by Land Transportation Systems, "*Binational Border Transportation Planning and Programming Study.* La Impresa Barton-Ashman. January 16, 1998. p. 65.

[7] Ibid.

[8] Schneider, Suzanne. "Crossing the Border: Transportation Issues Since NAFTA," *TR News,* No. 187, p. 52, November-December, 1996.

[9] Nozick, Linda K. "Trade between the United States and Mexico," *Transportation Quarterly,* Vol. 50, No. 2, p. 111. Spring 1996.

[10] Ramirez, Saul, "Statement of the Honorable Saul N. Ramirez, Jr." *Hearing before the Subcommittee on Investigations and Oversight of the Committee on Public Works and Transportation,* House of Representatives, April 29, 1993.

of the General Agreement on Tariffs and Trade (GATT) in 1986, and that Laredo anticipated southbound truck traffic to reach 772,000 conveyances in 1993. He argued that with NAFTA's implementation these numbers would skyrocket. At Laredo in 2000, northbound conveyances alone topped 1.5 million.[11]

Interior states also appealed for more spending. Several government bodies from I-35/I-29 corridor states—including Texas, Oklahoma, Iowa, Kansas, Missouri, North Dakota and South Dakota, and Minnesota—formed North America's Superhighway Coalition (NASCO) to lobby for special status and accompanying increased federal spending for the highway corridor. They maintained that

> I-35 and its significant connecting corridors, is the only central, existing interstate highway corridor linking the three NAFTA nations. Due to the significant amount of trade between Canada, the U.S. and Mexico, it is important to make improvements to the existing highway infrastructure and technology along the trade corridor.[12]

NASCO's arguments for the desired transportation dollars were tenuous. The group presented no empirical data identifying whether or how much truck volumes, shipment sizes, or tonnage-miles had increased in the corridor, or whether any observed increases were specifically attributable to U.S.-Mexico goods movement. While such data would indeed be difficult to collect, it is only by describing impacts in this fashion that the need for investment can be weighed among competing corridors and projects.

Calls to reduce the alleged infrastructure deficit did not fall on deaf ears. In 1995, Congress directed the U.S. Department of Transportation (USDOT) to give special consideration to NAFTA corridors in its National Highway System designation. In 1998, the Transportation Equity Act for the 21st Century (TEA-21) established a National Corridor Planning and Development Program and a Coordinated Border Infrastructure Program—known together as the Corridor and Border program—that would authorize $700 million in discretionary funding between 1998 and 2003 to "critical investments for the continued success of NAFTA."[13] When announcing the 1999 program grants totaling $126 million, U.S. Transportation Secretary Rodney Slater noted the money would "provide safer and more efficient movement of people and goods between Canada, Mexico and the U.S.," as well as "...create jobs and stimulate economic growth."[14]

Whether the projects paid for by the Corridor and Border program will deliver is a question for the future. A preliminary survey of recent Corridor and Border grants suggests it may do more to placate dispersed geopolitical interests than to direct funds in a coordinated way to achieve improvements. In total, the 1999 grants covered projects in 32 states from Kentucky to California. Three-quarters of the funds (over $90 million) were allocated for the design, right-of-way acquisition, or construction of additional highway capacity. Three percent ($3.5 million) was awarded for the preliminary planning of future corridor improvements. Ten percent ($12.5

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[11] See Table 1 in this article.
[12] North America's Superhighway Coalition. Mission Statement. www.nasco-itc.com.
[13] U.S. Department of Transportation Press Release, "DOT Secretary Slater Announces $124 Million in Fiscal Grants for Borders and Corridors Program," USDOT Office of Public Affairs. May 27, 1999. www.dot.gov/affairs/fhwa3699.htm.
[14] Ibid.

million) will be used for expanded border crossings or improved border facilities and procedures.[15]

In 1999, over $10 million was allocated to the future I-69 corridor for environmental, planning, routing, and location studies. The I-69 project would extend an existing interstate segment that currently stretches from Port Huron, Michigan, to Indianapolis, Indiana, in order to create a continuous superhighway connecting Canada, the United States, and Mexico. The project cost is estimated between $5 billion to $6 billion. Officials in the communities through which the corridor may be routed have latched on to the proposal, looking for a share of federal highway investment, yet failing to substantiate whether or how NAFTA-related highway movements justify the project. One local official of Texas' Coastal Bend region put local interests quite bluntly: "If we get the interstate, we will be on the map for international trade."[16]

Although the $700 million Corridor and Border effort is a small fraction of the nation's $198 billion guaranteed spending package for surface transportation from 1998 to 2003, it raises the question of how to ensure that the investments respond more to empirically ascribable trade-related transportation needs than to ordinary political pressure to bring home federal dollars.[17] As one stakeholder in the I-69 discussions noted, "...[O]ur biggest concern would be that the [route] decision be made for political reasons rather than for technical merit."[18]

Trucking Industry Changes

In addition to the threat of increased demands on U.S. transportation infrastructure, NAFTA also promised change for the U.S. trucking industry, especially in its business dealings with Mexico. Three NAFTA provisions set the stage anew for the cross-border trucking business: 1) the phase-in of cross-border operating access for motor carriers; 2) the liberalization of cross-border investment in the trucking and bus industries; and 3) the harmonization of truck standards. By mid-2001, none has been implemented. Nonetheless, these measures—in particular the first and third, discussed presently—could alter how trade related transportation services are provided, delivering greater efficiency as well as environmental benefits and costs.

First, NAFTA outlined a schedule by which U.S. trucking firms could access Mexican border states and eventually Mexico's interior for the transport of international goods. Likewise, the agreement also detailed a schedule for transport of international goods by Mexican truckers to American border states and, later, interior states. As well as being able to deliver goods across the border, trucks from both countries would be permitted to return home with a payload, provided that payload was destined for the truck's country of origin. By December 18, 1995, the United States and Mexico were scheduled to begin considering applications for permission to perform cross-border deliveries to border states, enabling Mexican carriers to make shipments to and from Texas, New Mexico, Arizona, and California. Under Clinton, however, the United States refused to act on any applications from Mexican truckers for cross-border shipping. Officials cited concerns about motor carrier safety and security, although news reports suggested that the administration aimed to placate the trucking industry, as labor interests traditionally supported Clinton. Fearing competition from lower-paid Mexican truckers, U.S. truckers have consistently opposed an open border.

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[15] Author's calculations of 1999 Border and Corridor Grants. See also U.S. Department of Transportation Press Release, "DOT Secretary Slater Announces $124 Million in Fiscal Grants for Borders and Corridors Program."
[16] Pappalardo, Joe. "Coastal Bend Vying for Spot on Interstate 69," Caller-Times Interactive, www.caller.com.
[17] U.S. Department of Transportation, FHWA, TEA-21 - Transportation Equity Act for the 21st Century, "A Summary – Investing in Our Future." http://www.fhwa.dot.gov/tea21/suminves.htm
[18] Pappalardo.

In mid-2001, the realization of seamless cross-border shipping appears closer under the Bush administration. A NAFTA tribunal ruled in February 2001 that the United States was out of compliance with NAFTA in refusing to consider Mexican applications for hauling goods into the United States. A Bush spokesperson responded that the President "believes the NAFTA trucking provisions should be implemented," and in May 2001, the USDOT proposed rules to implement the NAFTA entry provisions.[19] The rules outlined application requirements for Mexican carriers wishing to operate in and beyond the border area, and also crafted an oversight program that would evaluate a carrier's safety performance within 18 months of receiving conditional approval to operate in the United States.[20] However, Congressional opposition to the Bush effort makes the implementation of cross-border trucking yet uncertain; legislation proposed in June 2001 would prohibit federal transportation dollars from being used to process applications by Mexican-domiciled motor carriers.

Without cross-border trucking, U.S.-Mexico freight movements are cumbersome. U.S. truckers carrying southbound shipments must hand over trailers to drayage firms that transfer the trailer to the Mexican side. In some cases, the trailer itself is not permitted to cross the border, and its contents must be unloaded and then reloaded onto Mexican equipment. The same procedure is repeated for Mexican carriers with northbound shipments, causing handling delays, extra costs, and empty backhauls—a return trip without payload. The system has been described as archaic.

Though uncertain, the implementation of bilateral access for truckers on both sides of the border could spur noticeable transportation efficiencies and also reduce truck movements and related pollution at the border. First, most large U.S. trucking companies have already formed joint ventures with Mexican trucking firms to allow them to complete the delivery of a trailer from Mexico after it reaches the border. Presumably, other more logistically efficient and economical arrangements would result if cross border trucking were permitted. Second, eliminating the need for drayage could improve air quality at border crossings, as drayage vehicles at the border are usually Mexican trucks known for being old and unfit for long-haul trips.[21] One anticipated disbenefit of unfettered cross-border trucking relates to absent Mexican efforts to reduce truck emissions. New U.S. standards for heavy-duty vehicle emissions will take effect in 2004 and for low-sulfur diesel fuel in 2007, but no similar efforts are underway in Mexico. As the U.S. truck fleet grows cleaner coming decades, the Mexican fleet—which already has higher diesel emissions due to its greater average age—foreseeably will continue to emit harmful diesel pollutants without regulation or penalty.

Finally, NAFTA included a commitment from member countries to establish uniform truck size, weight and driver safety standards by 2000. This issue has been contentious, as U.S. weight limits (80,000 lbs.) and size limits (53 feet) on truck trailers are the most conservative among the three countries. U.S. carriers argue that the lower limits disadvantage them and that higher limits allow greater efficiency (i.e., they could carry larger loads). American safety and environmental groups fear NAFTA will bring larger truck size and weight limits, as well as lower driver standards. Over 90,000 large trucks and tractor-trailers are involved in crashes each year,[22] and the diesel engines used in heavy duty trucks contribute a substantial portion of the nitrogen oxide (NOx), particulate matter (PM), and, to a lesser extent, the hydrocarbon (HC)

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[19] Blustein, Paul. "NAFTA Ruling Opens Border to Mexican Trucks," *Washington Post,* February 7, 2001.
[20] *Federal Register.* May 3,2001, Volume 66, Number 86. 49 CFR Parts 365, 385, 368 and 387.
[21] Smith, Elliot Blair. “Mexican Truckers Face U.S. Obstacle Course,” *USA Today,* February 5, 2001.
[22] National Highway Traffic Safety Administration, “Traffic Safety Facts 1996: Large Trucks,” www.nhtsa.dot.gov.

emissions from mobile sources.[23] Moreover, raising weight limits without requiring truckers to add additional truck axles to distribute the load could accelerate pavement-wear and raise road maintenance costs.[24] U.S. rail interests also fear more generous truck standards; greater trailer carrying capacity would advantage truck transport and limit rail's ability to capture a share of increasing U.S.-Mexico trade shipments.[25] As of mid-2001, the governments have yet to develop unified standards and remain entitled to enforce national standards on foreign trucks that might travel on their soil.

III. A Window on U.S.-Mexico Goods Movement

To discuss what increasing U.S.-Mexico trade means for transportation and for the environment, it is important to note some prominent characteristics of U.S.-Mexico trade. For instance, that the goods exchange between the two countries happens predominantly by land bears directly on transportation. In fact, 86 percent of the import and export *value* traded between the two countries is transported by truck, and 7 percent is carried by rail.[26] While for transportation planning purposes, the *tonnage* of goods shipped between the two countries may be more important, such records are seldom and inconsistently available; most trade flow records use monetary value as the unit of measure. In addition to this fundamental observation, this section examines the role of *maquiladoras* and border clearance processes in U.S.-Mexico freight transport. Though incomplete freight data hamper efforts to understand fully goods movement and their impacts, the concentration in the border region of major links in U.S.-Mexico trade suggest that border areas are particularly impacted by binational goods transport, raising questions of equity that arise when locally concentrated impacts result from a treaty yielding national benefits.

Maquiladoras and Intermediate Goods

Maquiladoras are Mexican processing or manufacturing plants that perform additional processes on, or add value to intermediate goods still in the process of manufacture. Once the product has completed the step in the manufacturing process that is performed in Mexico, it is often exported to the U.S. for further processing. Some *maquiladoras* assemble imported parts into final goods for export back to the United States.

Maquiladora factories first established themselves in the mid-1960s in northern Mexico. Mexico's *maquiladora* program, begun in 1965 and formalized as the Border Industrialization Program in 1971, further institutionalized *maquiladora* arrangements. *Maquiladoras* reflect Mexico's attractiveness to U.S. and multinational companies as a location for labor intensive manufacturing, and *maquiladora* trade includes the electric appliances and machinery industries, as well as vehicles, optical instruments, plastics, and steel manufactures. The intrafirm trade (U.S. entities with plants in Mexico and the United States) of the *maquiladora* industry accounts for a substantial portion of total trade between the United States and Mexico. Additionally, many Mexican *maquiladora* operations are linked with sister plants located close to the border in

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[23] Environmental Protection Agency, "Emission Control Potential for Heavy-Duty Diesel," Fact Sheet, EPA 420-F-95-009b, June 1996. www.epa.gov/oms/noxfact2.htm

[24] Small, Kenneth, Clifford Winston, and Carol Evans. "Pavement Wear and Durability," *Roadwork.* Washington, D.C.: Brookings Institute, 1989. p. 37-68.

[25] Harper, Edwin, "Statement by E.L. Harper, President and CEO, Association of American Railroads," *Hearing before the Subcommittee on Investigations and Oversight of the Committee on Public Works and Transportation,* House of Representatives, April 29, 1993. p. 351-358.

[26] Barton Aschman. May 8, 1997, p. 21.

American border states. Thus, trade with Mexico may be described by origins and destinations that are generally more proximate than traditional trade. The prominence of *maquiladoras* in U.S.-Mexico trade means that much of the goods transport is concentrated in the border region.

Finally, traditional trade—involving products bound for final markets in the interior and elsewhere—also brings increased transportation activity to the border. Mexican and American producers commonly send large product shipments to centrally located import warehouses and distribution points before making smaller final deliveries. Because warehouse space in Mexico is scarce and costly, new facilities have been constructed north of the border, and many are in Texas.[27] While enabling hub-and-spoke style distribution to and from points in the U.S. interior, warehousing in U.S. border states increases freight traffic in those states, adding weight to the argument that NAFTA inspired transportation investments are most relevant to the border region.

The proportion of trade value captured by Mexican and American states also suggests that border states in Mexico and the United States see more activity than their interior counterparts. Trade flow data presented by Barton-Aschman suggest that freight traffic from U.S.-Mexico trade impacts the border region in both countries more than the interior. For example, in Mexico, Chihuahua—bordering New Mexico and Texas—accounts for 15 percent of northbound trade and 15 percent headed south. Tamaulipas, also bordering Texas, wins 8 percent of trade in each direction, and Baja California generates 10 percent of Mexico-U.S. trade. Distrito Federal, an interior state and home to Mexico City, is an exception to the pattern, attracting roughly 20 percent of activity in each direction. In the United States, Texas attracts a whopping 44 percent of the trade value from Mexico, and nearly one-quarter of U.S.-Mexico trade originates in Texas. Reflecting the automotive parts trade, Michigan accounts for 16 percent of the trade from the United States to Mexico, and captures 6 percent of shipments from Mexico. California captures 15 percent of trade in each direction, and Arizona sees 5 percent in each direction.

These data attest to the prominence of border states in U.S.-Mexico trade and transportation; however, Barton-Aschman have shown that the product origin and destination data used for these statistics are not wholly reliable and may emphasize border states at the expense of interior areas. First, shipping companies and customs officials in both countries define product origin differently. U.S. customs data traditionally track the export state and not necessarily the state where the item originated. The U.S. Customs Service has begun to collect more accurate product origin data, but it will be years until this information is complete and usable. Mexican trade data identify a shipment's origin by the location of the producer's headquarters. This presents obvious data weaknesses, as corporate headquarters may be far removed from an actual manufacturing site. Second, in cases of consolidated freight shipments, the point of consolidation—usually near the border—can mask the real origins of the shipment's components.

Accurate origin and destination data collected over a series of years are essential to understanding and assessing future transportation needs. Without accurate origin and destination information, it is difficult to assess which highway corridors are more heavily impacted by U.S.-Mexico truck traffic, to measure the extent of impacts with ratios of NAFTA to non-NAFTA truck volumes, and to evaluate the benefits of proposed corridor improvements. Such data are needed to evaluate claims that transportation infrastructure is inadequate and to determine where

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[27] Barton Aschman. "Changes in U.S. and Mexican Cross Border Trade Flows by Land Transportation Systems," *Binational Border Transportation Planning and Programming Study*. La Impresa Barton-Ashman. January 16, 1998. p. 65.

transportation dollars would be most wisely spent to facilitate NAFTA-related freight movements. In fact, a 1993 study of traffic in Laredo, one of the major ports of entry, concluded that the absence of regular origin and destination studies to define trade patterns and transportation needs was a severe shortcoming for local transportation planning.[28]

Given the advent of satellite-based global positioning systems (GPS) and automated vehicle identification (AVI), many shippers—primarily large American operators with sufficient capital—use technology to track their fleets' movements.[29] Private operators surely know more about trade-related truck movements than do customs or commerce officials. Yet, trucking interests do not share operations data, citing privacy and competition concerns. Instead, transportation planners rely on often incomplete data from bills of lading that accompany shipments. Because documentation of traffic flows beyond the border states is sketchy at best, the integrity of claims for NAFTA corridor designations and for associated transportation funds for highway upgrades is questionable.

National transportation statistics data provide an additional basis for questioning whether U.S.-Mexico traffic significantly burdens interstate corridor segments far from the border. Characteristics of personal travel, *domestic* freight shipments, and transportation system indicate that the overwhelming majority of trips in the United States are local—defined as under 100 miles.[30] Although long distance travel is increasing, the 1999 Transportation Statistics Annual Report indicates that 75 to 80 percent of all passenger trips are under 100 miles. In 1995, Americans logged 3.4 billion miles in local trips and 826 million miles in long distance trips—100 miles or over.

Data on domestic freight shipments (not including most domestic movements of imports) also suggest that long haul trips on interstates are less common, although they logically account for a large number of ton-miles. In 1997, local shipments constituted nearly 67 percent (7.7 billion tons) of shipments by weight, though only 9 percent of shipments by ton-miles (254 billion). Intraregional trips (between 100 and 1,000 miles) and interregional trips (over 1,000 miles) accounted for far less of domestic shipments by weight, but account for significantly more ton miles (over 2.5 billion) due to distances travelled.

Finally, use statistics on the U.S. transportation system indicate that interstates in urban areas have seen more travel growth than any other area. Between 1980 and 1997 urban vehicle-miles traveled (VMT) outpaced rural VMT growth—83 percent to 49 percent. Urban interstate travel increased the most during these years, about 4.9 percent annually, and urban arterials carried the most traffic. Additionally, studies of highway congestion show that it is rising in most urban areas.

This broad picture of road transportation in the United States puts U.S.-Mexico freight shipments in perspective. National travel is characterized predominantly by local trips less than 100 miles, with some long-distance trips trafficking longer stretches of interstate. Domestic freight shipments are mostly local too, although long distance hauls account for significantly more ton-miles. Additionally, most travel growth has occurred in urban areas, especially on urban interstates. Consequently, when NAFTA prompts claims of an infrastructure deficit on

[28] Harrison, Rob. "Summary Report: Truck Traffic in Laredo: A Case Study of Issues and Remedies," Center for Transportation Research: University of Texas. November 1993. www.utexas.edu/depts/ctr/article/innovate2.htm.

[29] For a useful description of technologies employed by trucking carriers, see *Partnership to Promote Enhanced Freight Movement at International Border Gateways: A Strategic Plan,* Volpe Center, U.S. Department of Transportation, February 2000. Available at www.volpe.dot.gov/infosrc/strtplns/nstc/brdrgtwy/index.html.

[30] U.S. Department of Transportation Bureau of Transportation Statistics, *Transportation Statistics Annual Report 1999,* BTS99-03, Washington, DC: 1999.

interstate segments far from the border, it is worth asking whether U.S.-Mexico freight movements present the true problem.

The Border Clearance Process

While statistics show that trade and trade-related border traffic was on the rise even before NAFTA's approval, the treaty's passage has increased concerns in border communities as to whether the roads approaching the border or the border facilities themselves can adequately accommodate growing traffic. Freight border-crossings conjure images of truck queues in the hundreds, delaying shipments and burdening border towns with idling heavy duty trucks. In 1993, annual truck conveyances at Laredo exceeded 800,000, and "truck lines at the downtown Laredo Bridge frequently stretch[ed] over 2 miles."[31] At Laredo in 2000, northbound conveyances alone topped 1.5 million (see Table 1), and southbound truck queues up to *5* miles were reportedly common.[32]

Table 1. Northbound Truck Conveyances at Texas Border Crossings

	1995	1996	1997	1998	1999	2000
Brownsville	115,828	118,171	122,883	121,255	265,462	304,108
Del Rio	28,926	29,695	33,042	35,456	59,843	62,157
Eagle Pass	31,747	36,261	40,628	49,072	101,242	108,186
Laredo	428,774	575,886	576,652	650,907	1,486,511	1,509,259
McAllen-Hidalgo	114,752	62,334	NA	NA	N/A	NA
Pharr	NA	77,394	156,516	167,077	325,352	377,624
Progreso	9,189	8,111	7,994	3,741	16,588	11,848
Rio Grande City	6,064	10,635	15,917	12,546	20,946	24,119
Roma	4,701	5,388	5,747	7,895	15,985	12,930
Totals	**739,981**	**923,875**	**959,379**	**1,047,949**	**2,291,929**	**2,410,231**

Source: Data provided by U.S. Customs Service, Inspection & Control Division, Laredo, TX, and compiled by Texas A&M International University, Texas Center for Border Economic and Enterprise Development.
Note: Figures represent loaded trucks only.

Indeed, the border crossing is a complex and slow process with many steps.[33] The “Description of Commercial Motor Vehicle Trade Flow Process” produced by Barton-Aschman reads like a surrealist labyrinth of bureaucratic hurdles. Shippers commonly cite duplicative inspections and documentation requirements and the attendant costs as a large problem. As a matter of strategy, many truckers have adopted a practice known as rushing; drivers make it a point to arrive at the border later in the afternoon, when customs officials, wary of letting rush hour queues escalate, feel pressured to process vehicles more quickly. Studies compiled by Barton-Aschman show that truckers who rush the border do receive faster processing.

[31] Harrison, Rob.
[32] Axtman, Chris. "Border Trade Beset by Big City Traffic Snarls," *Christian Science Monitor.* November 20, 2000.
[33] Barton Aschman. “Description of Commercial Motor Vehicle Trade Flow Process," *Binational Border Transportation Planning and Programming Study.* La Impresa Barton-Ashman. May 8,1996.

Maquiladora firms and customs officials have cooperated to streamline the border crossing process for *maquiladora* trade. Simplified paperwork (processed by the week instead of by shipment) and inspections combined with the considerably shorter travel time between the point of manufacture to the border, and on the other side, from the border to the destination manufacturing plant, means that on the whole *maquiladora* trade moves through the border much more quickly than traditional trade.

For traditional trade, more likely to be destined for the interior than the border region, the entire crossing process represents a smaller portion of total transport time than it does for maquiladora trade. Though border clearance for such shipments impacts the total trip time less, the cumulative time savings and environmental benefits of streamlined border procedures deserve attention. While certain products—agricultural products and hazardous materials, for example—require rigorous inspection, the streamlining adopted for *maquiladora* shippers could be applied to other more diversified shipments of final consumer goods.

Additionally, some advanced technologies promise to speed crossings, lower processing costs, reduce border congestion, and benefit government agencies operating at the border. For example, a $1 million Corridor and Border grant awarded in 2000 will help finance a $2.2 million electronic processing system for commercial vehicles at Otay Mesa, the third largest U.S.-Mexico crossing. The system will allow cargo shipped across the border to be pre-cleared, with customs, immigration, safety, and other inspection data entered into an electronic transmitter system. Provided no cargo tampering has occurred, the vehicle will receive direct clearance, eliminating from several hours to even days of waiting time. Streamlining the border-clearance for trucks often conflicts with other goals that find expression at the border, including national security, safety, customs enforcement, and illegal immigration, but this project suggests that electronic processing systems can serve various interests, while also reducing congestion, idling, and air pollution at the border. Their potential benefits notwithstanding, projects of this type represent a small portion of Corridor and Border grants in 1999 and 2000.

IV. Increasing Binational Transport and Environmental Impacts

Air pollution produced in the combustion process and the evaporation of unburned fuel is one of the primary environmental externalities of transporting binational goods via truck. NO_x and VOCs are emitted in vehicle exhaust, and they react in the presence of heat and light to form ground-level ozone, the main constituent of smog. Trucks also emit diesel particulate matter (PM), which is linked to respiratory ailments, cancer, and premature death. While NAFTA has crystallized interest in a range of environmental problems associated with increasing U.S.-Mexico trade, from hazardous waste generation and disposal to drinking water quality to pesticide use, few studies have examined the consequences of growing binational shipments accomplished largely by truck. This section reviews several studies on air quality issues surrounding U.S.-Mexico freight transfers. Findings further the rationale for improving data collection for freight shipments and air quality indicators alike, and enhance insights on how trade-related transportation particularly impacts border areas.

One paper, prepared for the North American Commission for Environmental Cooperation (CEC), sought to quantify the contribution of NAFTA trade to air pollution in five corridors serving Canada-U.S.-Mexico. The study is noteworthy for several reasons. First, in selecting corridor segments to examine, the study aimed "to define segments that are long enough to allow the capture of trade impacts beyond the immediate border area but short enough so that corridor freight activity is still dominated by NAFTA trade."[34] As a rule, the segments studied never extend more than 225 miles from the border, where the proportion of NAFTA vehicles in the traffic stream would likely be greater than in corridor segments further from the border. This suggests that the contribution of binational goods transport to corridor air pollution diminishes as distance from the border increases, a conclusion that finds support in annual travel statistics presented earlier. Second, in order to model corridor emissions from NAFTA trucks, the researchers had to use several proxies to calculate the number, weight, origins, and destinations of trucks crossing the border, as these data are not readily available from one source. Moreover, the study observes that the technical data needed to assess impacts of trade on transportation corridors "are unavailable or highly uncertain."[35]

Even where the transportation data are available, necessary air quality measurements may be lacking. The U.S.-Mexico border is one area where truck and trade data is sufficient to weigh the effect of NAFTA transportation on air quality. Increasing truck conveyances across the border and in the border region, along with border congestion and truck idling obviously compromise air quality with ozone precursors and diesel particulates. Nonetheless, as discussed in a Sierra Club study of air quality at the Laredo/Nuevo Laredo crossing, baseline data on air pollution trends at the border are not always available to substantiate the link between growing truck traffic and declining air quality. Moreover, even where data are available, favorable wind patterns may mask local emissions levels and carry smog elsewhere.

In a review of Border Smog Reduction Act efforts in San Diego, the Government Accounting Office also reported that it can be difficult "to establish a causal relationship between ozone levels and increased truck traffic... [T]he presence of ozone in the area is influenced by several factors, and fluctuations may or may not occur as a result of changes in truck traffic."[36] The Border Smog Reduction Act limits entry of foreign-registered passenger vehicles that have not passed California's rigorous vehicle inspection and maintenance standards in an effort to reduce emissions. In spite of the empirical difficulties in establishing links between vehicle emissions and ozone levels, air quality officials in San Diego have supported the Act and promoted its extension to commercial vehicles. Experts anticipate the Act will reduce ozone causing chemicals in San Diego by less than .05 percent, but Act supporters emphasize that even minor emissions reductions in the border area are important.

Concluding Remarks

A milestone in U.S.–Mexico trade relations, NAFTA committed the United States and Mexico to reducing trade barriers and promised to facilitate trade by lowering tariffs and trade limits between both countries. NAFTA's effect was to accelerate already growing cross-border goods exchange. The treaty also included provisions to change the nature of motor carrier operations by allowing Mexican and American trucks to operate beyond one another's respective border. As of mid-2001, these NAFTA provisions have yet to be realized.

At the time of NAFTA's passage, elected officials in U.S. border and interior states used the political opportunity provided by the controversial treaty to portray the nation's transportation infrastructure, particularly its border crossings and north-south highway corridors, as inadequate

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[34] ICF Consulting. "North American Trade and Transportation Corridors: Environmental Impacts and Mitigation Strategies." North American Commission for Environmental Cooperation. February 21, 2001. p. 4.
[35] Ibid. p. ii.
[36] Government Accounting Office. Air Pollution: The Border Smog Reduction Act's Impact on Ozone Levels. July 1999.

for serving the increased shipments the treaty would bring. Policy makers responded with the Borders and Corridors program, a fund of federal transportation dollars dedicated to projects at the U.S. border and in designated corridors associated with NAFTA trade. Freight data limitations, particularly the lack of consistent and accurate origin and destination information for truck shipments, however, make it difficult in many cases to evaluate whether transportation investments in the name of NAFTA are justified. The $700 million set aside for Corridor and Border projects is a small fraction of the nation's $198 billion guaranteed spending package for surface transportation from 1998 to 2003. Nonetheless, the dedicated funds raise question as to how to ensure that these and other investments respond more to empirically ascribable trade-related transportation needs than to ordinary political pressure to bring home federal dollars.

While incomplete goods movement data hamper efforts to fully understand U.S.-Mexico freight transportation, the broad dynamics shaping U.S.-Mexico trade suggest that related commercial vehicle traffic is concentrated first and foremost in the border region. First, the proximity of *maquiladoras* and associated plants and warehouses to the border suggests that a majority of U.S.-Mexico truck movements are concentrated in the border region. Second, border clearance processes, known to be cumbersome and inefficient, contribute to long truck queues, congested local roads, and significant vehicle idling at border-crossings. Furthermore, U.S. travel statistics suggest that long-haul trips between the U.S.-Mexico border and points far north represent a small portion of interstate use. In the United States, the overwhelming majority travel involves passenger trips of less than 100 miles, and most freight shipments are local. Attempts to attribute increased travel demand in a given corridor to U.S.-Mexico shipments overlook the tremendous demand for local trips, especially in metropolitan areas.

Establishing a link in specific corridors and at border crossings between increased commercial vehicle traffic and diminished air quality has proved difficult, particularly as distance from the border increases. Incomplete shipment origin and destination data, absent or incomplete measures of air quality, and the presence of other emissions sources hamper efforts to isolate and quantify the contribution of trade-related transportation to smog levels or particulate counts. While improved data on truck movements and air quality are needed to measure air pollution from trucks carrying U.S.-Mexico goods, interim measures to reduce vehicle emissions in heavily trafficked areas like the U.S.-Mexico border region may achieve incremental air quality improvements.

This analysis has described U.S.-Mexico goods transport while also wrestling with how to evaluate specifically trade-related surface transportation needs given data shortcomings and uncertain future developments. Aggregate trade statistics and studies present a general picture of increased transportation activity at the border, congested border facilities, cumbersome customs processes, and efficient and short-distance *maquiladora* movements. However, a more sophisticated description of freight origins and destinations across the border is lacking. Furthermore, some NAFTA transportation provisions have yet to be implemented. Cross-border trucking will allow private trucking firms on both sides of the border to restructure services, but until this treaty provision is realized, the exact response of transportation providers remains unknown.

Given the cross-border transportation market's many unknowns, sizable investments in fixed NAFTA infrastructure may be premature. The danger is that transportation investment decisions will be influenced more by political opportunism and self-interest than by well-informed assessments of what investments would have both national and local benefits. Yet, decision makers can seldom wait for complete information before committing resources to specific transportation investments. In light of this challenge, three general strategies are suggested: 1) Improved binational freight transport data are needed to enable analysis of the distribution of U.S.-Mexico truck trips on the nation's highway network. Data collection efforts must involve both Mexican and U.S. private motor carrier firms, particularly large firms that already use global positionining and other electronic devices to track vehicles and shipments. Special emphasis on the accuracy of shipment origins, destinations, and interim stops is vital. 2) Interim efforts to facilitate U.S.-Mexico freight transfers should focus on the border region, especially when addressing environmental concerns. Increasing trade movements bring to the border region concentrations of such transportation-related transportation externalities as congestion, noise, and air pollution. 3) The possibility of cross-border trucking raises concerns over absent efforts in Mexico to tighten heavy duty vehicle emissions standards, as is planned in the United States for 2004. This should not halt implementation of NAFTA's cross-border trucking provision. Cross-border trucking could produce more efficient transportation services, *reducing* some truck trips, particularly drayage at the border. A more productive U.S. approach may be to help Mexico plan for cleaner truck engines and to consider whether and how modal shifts could be encouraged in U.S.-Mexico shipping.

These general recommendations are offered as important issues for further research and policy design. The tasks ahead are to define specific courses of action and to identify individual entities—government, private, and civic—to effectively pursue each effort. The ultimate goal is to ensure that funds spent in the name of NAFTA transportation challenges address specific U.S.-Mexico transport problems and their environmental externalities, as well as the changing world of cross-border logistics.

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The US-Mexico Border Energy Zone*

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For many years, Mexican territory included most of what is now in Texas, New Mexico, Arizona and California. Once they established the present US-Mexico border, the two countries for 150 years followed largely independent paths. However, despite the political separation, the border region has developed into an interdependent subregion. All along the border, there are increasing similarities in demographic character, economic development, environmental challenges, and local way of life. The border has evolved its own unique identity. At the core of this growing homogeneity is a desire that each side has for something across the border. Among other things, Mexico wants a better, healthier and more prosperous way of life for all its people, and a safety valve to release the pressure of its burgeoning population. The U.S. desires low-cost labor and greater access to Mexican markets.

In recent years, the most obvious focus of attention at the border has been energy. More than any other, it is the common ingredient of every vision, plan, and activity for economic development along both sides of the border. The development and availability of affordable energy offers to the economy improvements in wealth, personal freedom, comfort, and industry, from shopping malls in the north to assembly plants in the south. It attracts new enterprises and new residents and helps shrink the socioeconomic divide that persists between the two countries. The potential for energy trade, the promise of energy reliability, the construction of energy projects, and the infusion of great amounts of capital that all these activities require, emphasize the economic universe that revolves around the nucleus of energy.

The fundamental influence that the supply of energy has on economic well-being is not unique to the border, as has become thoroughly clear since energy shortages threatened to plunge California into economic chaos from mid-2000. Since then state officials in both countries have anxiously examined their own relationship between energy demand and supply. The deeper they looked, the more vulnerable they found themselves and the more earnestly they began searching for solutions. One of the approaches being appraised has been the value of establishing along the border closer energy ties between the two countries.

The Border and the Binational Need for Energy

By the middle of the 20th century, Mexico's border population was less than 300,000. Today it numbers about 12 million, with three border cities of more than one million people. The rates of population and energy demand along the border are rising at rates that are among the fastest in either country (Figure 1). Both countries are facing similar problems of energy supply, especially in the form of shortfalls of electricity. In terms of population growth, economic conditions, and energy supply, we find that the people athwart the frontier have more in common

* I thank Soll Sussman of the Texas General Land Office for his important contributions to this chapter.

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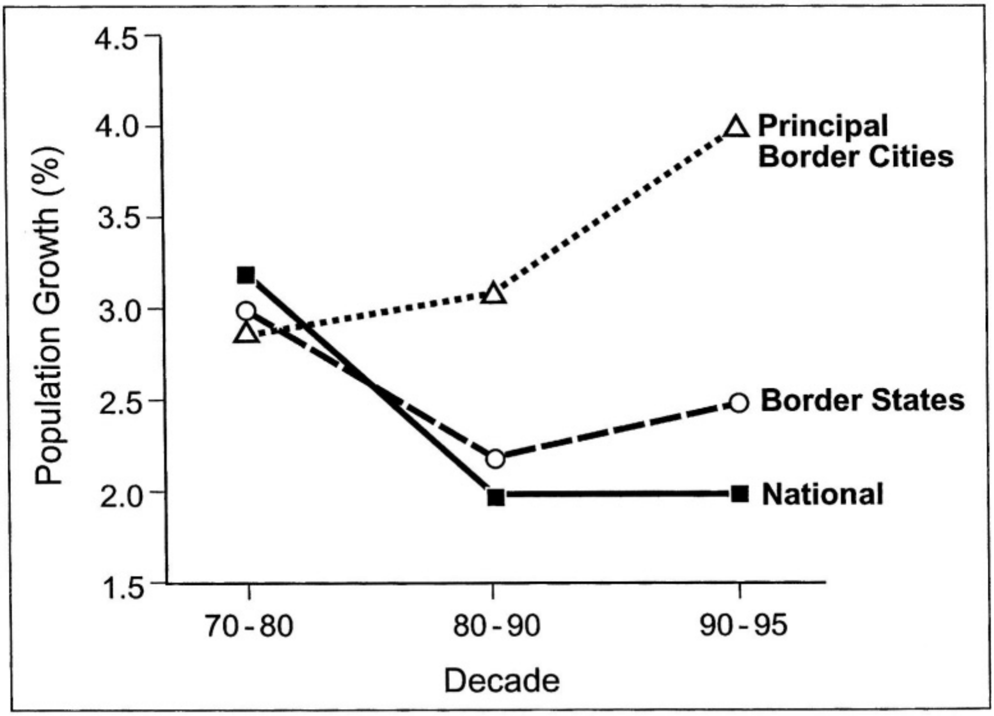

Figure 1 – Population growth and energy demand will be greatest in Mexico's northern border cities.
Source: El Colegio de le Frontera Norte

with each other than they do with their fellow citizens elsewhere. In this circumstance, greater cross-border cooperation has a certain attraction.

Natural conditions of topography, climatology, and hydrography magnify the potential for increased energy interdependence. The two countries are separated not by a mountain range, a lake, the open sea, or a formidable river, but by inked line. On land as on a map, it is an easy border to cross, one that is in large part empty and without obvious competition for energy projects. Placement of pipelines, electrical transmission wires, railroad tracks, and highways pose few technical difficulties across most of its distance. Installation of such equipment is in few places any more difficult than between the US and Canada. Such geographical convenience was not lost on the framers of the North American Free Trade Agreement when they aimed at facilitating trade among all three countries not by overcoming physical obstacles but by removing bureaucratic barriers.

Despite an improved atmosphere, energy trade with Mexico still must address the great cultural and socioeconomic differences between the two countries. NAFTA stimulated the construction of low-wage assembly plants called maquiladoras to serve the dual purpose of bringing jobs to Mexico and low-cost goods to the United States. As the maquiladora industries have expanded, their energy demands have gone up as well, both for the factories and for the job-seekers who have journeyed toward the border in great number to fill the new jobs. All these new workers have needed housing, and they have created thousands of ramshackle, minimal-service residential settlements called colonias which need but currently do not have adequate supplies of energy.

The problem of energy supply is common all along the border; few conventional energy resources exist anywhere along the frontier. Only the geothermal resources of the Mexicali Valley near the western extreme, and the mammoth Burgos Basin natural gas field to the east of Matamoros, can be considered “local” resources.[i] In order to meet the quickly increasing energy demand it will be necessary to invest substantially in infrastructure of all types, including power plants, transmission lines, and pipelines. The projections for a continued increase in demand are compelling. Javier Estrada, a commissioner with the Comisión Reguladora de Electricidad (CRE) has shown a need to attract investments totaling $50 billion to develop a project need of 25,000 MW during the next decade. With annual national growth rates of 5 percent, natural gas consumption must increase by 9 percent and electricity by 6 percent each year during the next decade. That would require an investment of $70 billion.[ii] Referring specifically to the northern border, Estrada noted that electricity demand from some border states is growing at 8 percent annually, and he explained that plants have reached the limit of their capacity, and foreign electric companies have established agreements to participate with the Comisión Federal de Electricidad (CFE) to develop new generating plants in the region. It has been estimated that between 1998 and 2007, there would be a 20% annual rise in the demand for natural gas in Mexico to generate the electricity for the maquiladoras concentrated along the border.[iii]

Thus, with few resources available in that location, the attention being focused on energy issues there is tied to new power plant construction, energy brought to the border region from other areas in each country, and energy moving north and south across the frontier farther into the interior or each country. There are, then, two categories of border energy projects under consideration: those planned for sites near the border, and those intended to move energy across the border.

Whether for transit or siting, considering the border as an energy zone has certain justification. For those in the US, Mexico is considered more attractive for new generating plants owing to simpler permitting and monitoring requirements. For their part, those in Mexico would welcome projects that create jobs and increase tax revenues. Many people see such developments as inevitable. Texas Railroad Commissioner Charles Matthews has said that "Within the next 15 years, the U.S./Mexican border infrastructure will be integrated through highways, rail, electric grids and pipelines. . . .We are beginning to see the move toward a 'seamless' border between Mexico and Texas through which electricity and natural gas could easily flow."

With all this in mind, it is well to reinforce that there are absolute differences in the degree of need within the border region. For example, despite having about three times the population of Mexico, US demand for electricity is about twenty times that of its southern neighbor. In 1999 Mexico's generating capacity amounted to 38,502 MW (1.2% of the world), compared to 775,884 MW for US (24.4%). To put this divide into perspective at the individual level, Mexico's 1993 demand for electricity was 1.2 megawatt-hours per person per year, expected to rise to 2.5 MWhr/person in 2015. In the same time period, they expect the demand in the US to rise from 11.1 to 12.6.[iv]

Identifying the Issues

With the great increase in the attention energy issues are receiving, the potential benefits of closer energy ties between the United States and Mexico have leaped to the top of many agenda. The three-day meeting of the Southwest Center for Environmental Research Policy in April 2001 focused exclusively on issues of border energy and environment.[v] In May of the same year, the 10th Annual Latin American Energy Conference, organized by the Institute of the Americas, devoted the majority of its attention to the potential US markets for Latin American energy resources.[vi] Both gatherings fell neatly within the visions announced by newly-elected Presidents Vicente Fox and George W. Bush to tie their country's energy futures closer together.

Although border energy issues received increasing public notice in the first half of 2001, they have actually resulted from discussions that have been going on between the US and Mexico for many years. The comments by Commissioners Estrada and Matthews quoted above, for example, were made at one of the Border Energy Forums organized by the Texas General Land Office. The GLO has been helping border energy dialogs for several years to help forge new partnerships, with the ultimate goal of working together on the twin goals of economic development and environmental protection along the border.[vii] Each year about 200 representatives of the U.S. and Mexico have come together from federal governments, state and local officials, private sector energy producers, universities, and environmental organizations. The most recent gathering, the 8th forum, was in Tucson, Arizona in October 2001.[viii]

The Forum series is but one example of the efforts being made to attract attention to issues of border energy supply and demand. Its purpose has been to encourage all stakeholders to work collectively to achieve a consensus on the best approaches to regional well-being. Many of the presentations emphasized the future contribution of natural gas, and urged more steps be taken toward greater energy efficiency and further use of renewable energy for those living in the states on both sides of the U.S.-Mexican border.

Prior to the first Forum, there was little public dialog about border energy issues, about the effects of energy trade and shortfalls, or about the impacts of energy projects on regional environmental quality. The dearth of such discussions had been testament to the complacency among the public and their governing agencies. This vacuum started to fill once the potential environmental impacts of projects near the border began attracting attention and, more recently, when energy price and availability began recently to become so apparent. Suddenly, everyone seemed to be talking about border energy issues.

The Border Energy Forum has been instrumental in initiating this new dialogue by combining publicity and education, and by raising several important questions for consideration. What, for example, are the current and future energy needs of northern Mexico and the southwestern United States? How will energy demand and production affect the region? What parallels can be drawn between utility deregulation in the United States and the opening of energy markets in Mexico? What projects for today and the future will strengthen the energy security of the region? What decisions must we make today that will be good for the economy and still protect environment quality well into the coming decades?

Some of the questions were addressed in a recent Forum in Chihuahua when Hector Olea, former chairman of the Comisión Reguladora de Energía (CRE), dramatically summarized the current situation.[ix] He pointed to: (a) projected annual growth in Mexican electric power demand of nearly 6 percent during the next seven years; (b) the need to construct more than 13,000 MW of generation capacity in order to satisfy projected demand, or one third of the entire current capacity of Mexico; (c) the need for $25 billion in investments by 2005, representing 25 percent of the total capital invested in the power industry during the past century throughout Mexico. The outlook for the future became even more vivid when Olea said that Mexico's northern border states would need 60 percent of the expanded capacity required for the country – or 7,600 MW - just to meet regional electricity demands. While most of the power demand were expected to be met by power plants constructed in Mexico, other supplies were expected to come from facilities in the United States if the capacity were increased. He pointed to the limitations posed by a transfer capability totaling less than 900 MW, with larger transmission lines in the region already saturated and U.S. grids that rarely reach the border.

Although many impediments to closer cross-border energy ties are technical, others are not. Mexico City financial analyst Luis Labardini, speaking at the Monterrey Forum, surveyed the risks involved with energy projects in Mexico's emerging economy: "For foreign investors and lenders," he said, "the risks must be commensurate with returns." Market risks connected to natural gas projects include the unpredictability of demand, the potential overuse of natural gas and what Labardini called its "staying power." He added, "It will require time for these issues to take shape in the Mexican case, for natural gas was discouraged in the past by subsidies to alternative fuels and the lack of market clearing mechanisms. There is no such thing as a market. Mexico should be compared more with the state of affairs in the United States about 40 or 50 years ago." Labardini, who spoke as a broker in charge of mergers and acquisitions for Ernesto Marcos and Associates, said it would be "a long time before we see a critical mass of capital being created to provide for resources that are required to fund infrastructure projects in Mexico. In the foreseeable future, resources must come from abroad, most likely from the United States."[x]

At Forum IV in Las Cruces, Dana Contratto, an attorney with Crowell & Moring in Washington who has worked extensively with natural gas cross-border trade, spoke of the need to work regionally to achieve the best results. "If border areas were seamless markets, energy production and delivery would have different dimensions, efficiencies and economies," he said. "Rather than energy systems designed for a market subset on one side of a political border or another, they could consider the totality of energy needs in a natural and integrated area." With this statement, he was emphasizing the notion of the border as a sub-region. He concluded by noting that the government could ease market integration by removing trade barriers, "so private enterprise can meet market demands on both sides of the border as though the border did not exist."[xi]

The implementation of the various proposals and suggestions that have been proposed and deliberated at the various conferences, the news stories, and the presidential meetings on border energy issues, while sensibly based on a sense of mutual benefit, rests on an understanding of what is best thought of as a matter of "border energy geography." I include in this phrase the physical geography of the border, the location and distribution of energy resources, the development of energy projects, and the environmental implications of all the activities whether in Mexico or the United States, or both.

Existing Energy Ties

The U.S. and Mexico, being large, complex, and conjoined countries, have without surprise developed into important trading partners for each other. If, as expected, trade between these two countries continues to grow, a large component of this intensification will be in the energy sector, and it will expand from existing trade, the most important of which is in oil.

Oil

Well-established energy ties existed between the US and Mexico by the first quarter of the 20th century, mostly involving the development of Mexico oil by US companies. To the consternation of these companies, Mexico nationalized these oil fields in the late 1930s, severing these ties. It was not until recent years that oil discoveries and rising demand collaborated to sweep aside the memories of these events and bring the countries closer again. This reconciliation began in earnest once Mexico made substantial discoveries in the wake of the Arab oil controls of the late 1960 and early 1970s and was looking to improve its economic stability by trading their newfound resources for hard currency. Today, Mexico's reserves are estimated at a least 40 billion barrels, placing them second only to Venezuela in the western hemisphere.[xii] By 1998, Mexico ranked 5th in the world in oil production, and by 2000, oil production was 3.5 million barrels per day (bbl/d), of which 3.0 million bbl/d was crude. Mexico is now a major player on the world oil scene once again, a position demonstrated by a recent agreement to act in union with Saudi Arabia and Venezuela to control production in accordance with world oil market conditions (Figure 2).

Mexico today relies on oil sales for a substantial portion of its foreign exchange. The fortunes of location find an ideal market for this product in the country immediately to the north, one which not only sustains a high demand for oil, but one that has the revenues to buy it and a growing worry that it does not have enough of its own oil to meet domestic demands. This geographical arrangement offers something for everyone; Mexico has the oil and wants to exchange it for the means to improve economic well-being at home, while the US needs the oil and is willing to pay just about anything to get it.

Today the 1.5 million barrels of oil per day (mb/d) delivered from Mexico exceeds the volume supplied by Alaska, and approaches the amount imported into the U.S. from Saudi Arabia (Figure 3). Although little if any oil is moved northward by land, its sale to the US provides the capital to allow economic flexibility for other projects, including energy developments of natural gas.

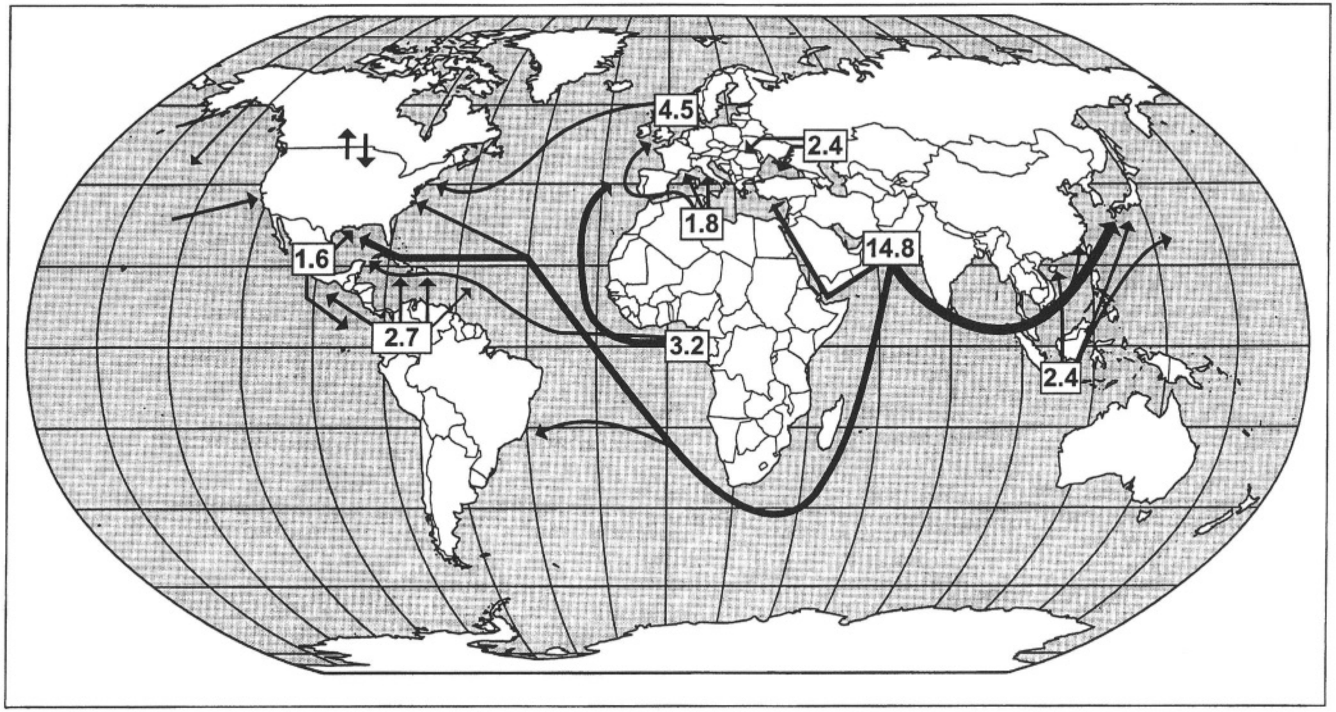

Figure 2 – World Crude Oil Flows 1997. 34.8 million barrels per day. Source: U.S. Energy Information Administration.

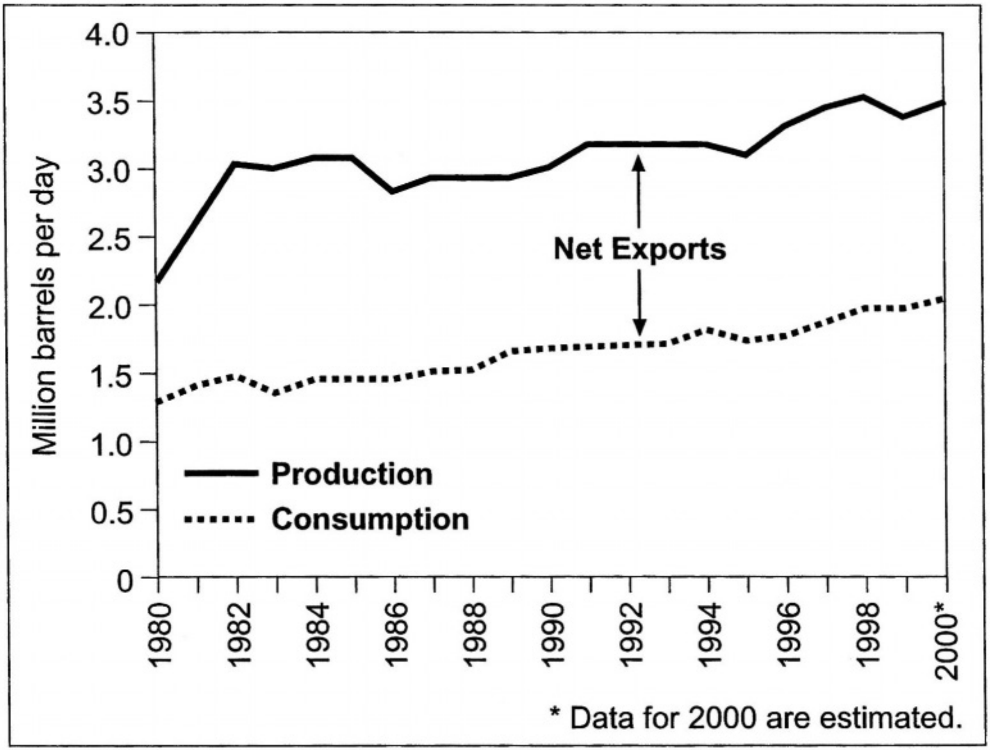

Figure 3 – Mexican Oil Production and Consumption, 1980-2000. Source: U.S. Energy Information Administration

Natural Gas

Natural gas has received lately a remarkable amount of attention in the U.S. and Mexico, especially from the electrical generation industry, a sector that is estimated to grow at about 20% per year (Bauer 2000). It is remarkable in part because until recently, Mexico had given natural gas little attention. With most of their gas reserves "associated" with oil production in the Cantarell fields in the distant Bay of Campeche, and with inadequate markets or sufficient means of distribution, the only option for the oil producers was to flare (burn) the gas as the rising oil brought the gas to the surface. This wasteful procedure has been diminishing as distribution, markets, and values have improved, and now that the non-associated reserves of the Burgos Basin off the northeast coast of Mexico are among the largest in the world.

More even than its newfound abundance, and more even than its familiarity in the U.S., the appeal of natural gas comes from its inherent characteristics. Industry specialists in both countries know how to handle and market it. In addition, natural gas can be moved by pipeline efficiently and without technical difficulty, and its preparation for use is virtually the same from one country to another. Most significantly of all, natural gas is one of nature's cleanest burning fuels, containing little sulfur and virtually no residuals.

These qualities favor its use in electrical generating stations, and have helped lift natural gas to a position of prominence on both sides of the border. The recently completed Samalayuca power plant receives natural gas through a 45-mile pipeline that starts 22 miles into the United States. The $35 million dollar pipeline, with a capacity of 212 MMBtu/d, supplies both Samalayuca I and II with fuel from El Paso Natural Gas Company's Hueco Compressor Station, located across the border. The $600 million, 700 Megawatt (MW) generating station has three 233 MW units. All of the electricity generated by the plant is intended for the Comisión Federal de Electricidad for the state of Chihuahua and will be delivered through the CFE power grid. The 24-inch gas pipeline, which crosses the Rio Grande River east of El Paso, Texas, was the first pipeline in Mexico owned in part by El Paso Energy (DeGrandis and Owen 1995), illustrating the increasingly close ties between the two countries.

As an attractive fuel, and as a fuel that is suddenly both in great demand and new abundance, several steps have been taken recently to increase the potential for its international sale. One of those changes was to reform Mexican regulations to allow, as of November 1995, the private sector more access to the processes of building, operating, and owning facilities for the distribution of natural gas. Along these lines, Mexico's Secretary of Energy recently initiated an Integral Fuel Policy, with the aim of reducing Mexico's concentration on fuel oil and increase its use of natural gas (Office of Fossil Energy 2001). Given the rising demand for natural gas and the electricity it can be used to generate, this liberalization has come at an ideal time.

The problem being faced by those who would increase the trade in natural gas between the U.S. and Mexico continues to be the limited capacity of the interconnections along the border. Despite several cross-border exchange points, they are of insufficient capacity to allow much increase in trade, and the volumes that can pass between the two countries are small compared to the trade of natural gas with Canada. Only at El Paso/Juarez and San Diego/Tijuana is the capacity substantial, and both links are tied to dedicated power plant consumption (Figure 4, 5; Tables 1,2).

Electricity

If oil comes into the US by ship, and natural gas moves in both directions by pipeline, what of electricity? This question takes on great importance as the curve of demand has angled

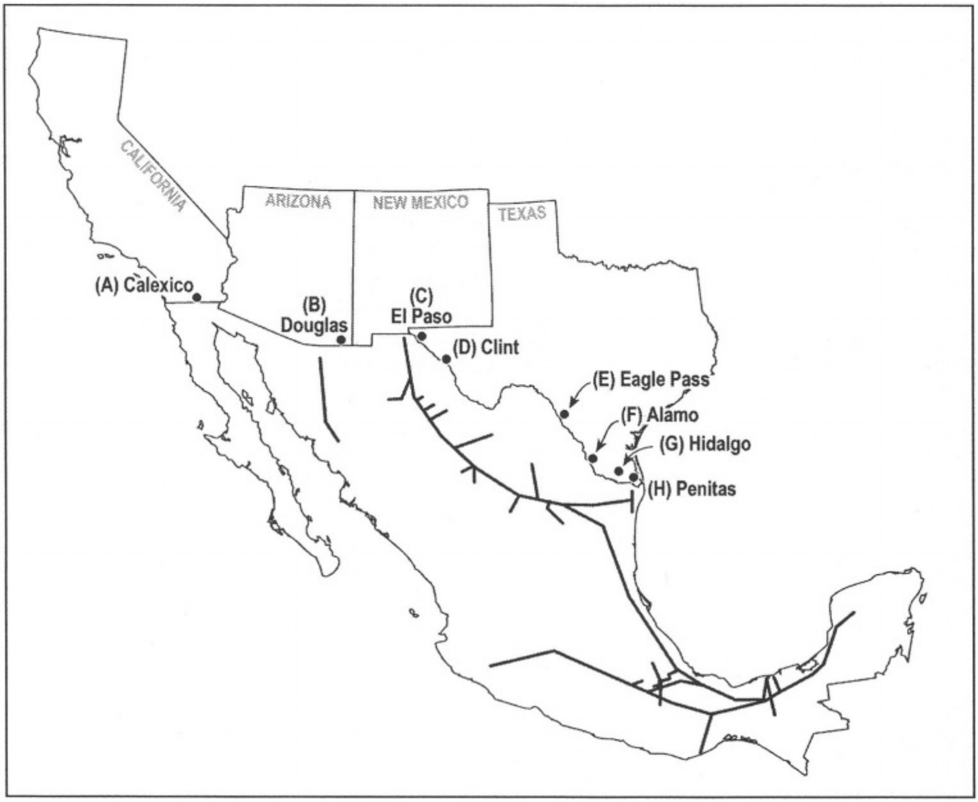

Figure 4 – Mexico's Natural Gas Trunkline System. Source Javier Estrada, Border Energy Forum VI, San Antonio, November 1999.

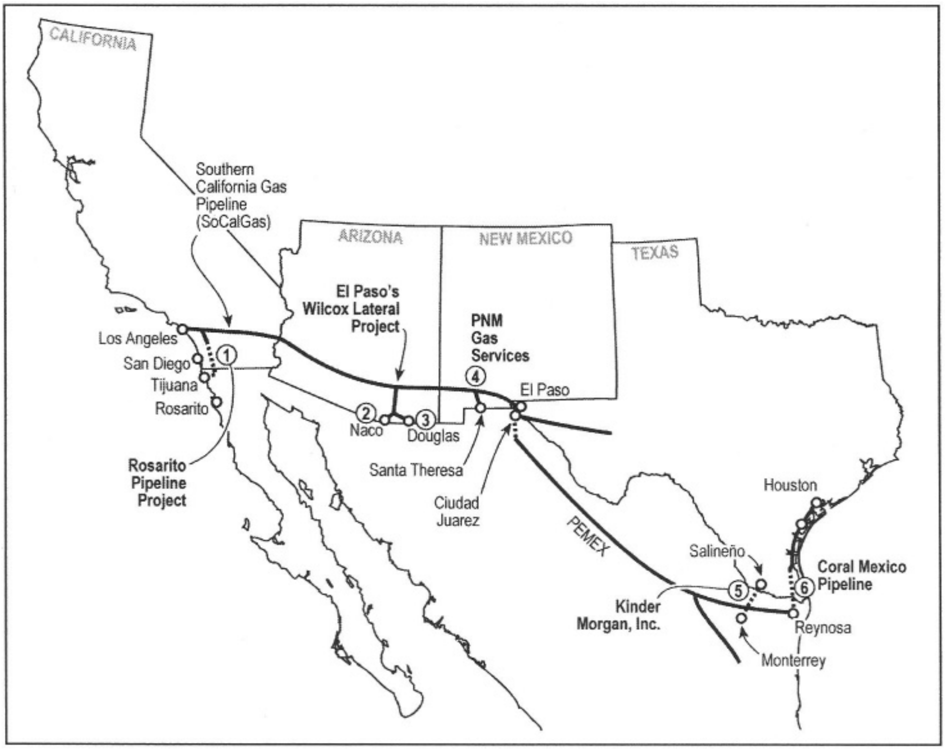

Figure 5 – Planned Natural Gas Pipeline Projects Designed to Facilitate Cross-Border Trade Through 2001. Source: Office of Fossil Energy, U.S. Department of Energy.

TABLE 1 - NATURAL GAS TRADING BETWEEN THE UNITED STATES AND MEXICO

EXPORT

Existing Exit Points	Pipeline	Est'd Cap (MMcf/d)	Est. Daily Load Factor							
			92	93	94	95	96	97	98	99
(A) Calexico, CA[1]	SoCalGas	25	0	0	0	0	0	2	6	10
(B) Douglas, AZ[2]	El Paso Nat Gas	35	4	4	4	7	9	11	11	10
(C) El Paso, TX	Norteño Pipeline	90	45	25	31	40	37	49	20	18
(D) Clint, TX[1]	Samalayuca	212	0	0	0	0	0	10	85	123
(E) Eagle Pass, TX	West Texas Gas[4]	38	2	2	3	2	3	3	4	5
(F) Alamo, Tx[5]	Tennessee Pipeline	220	0	0	0	0	0	0	0	0
(G) Hidalgo, TX	Texas Eastern	350	147	21	30	31	21	33	16	9
(H) Penitas, Tx[6]	PG&E Texas	400	62	52	62	88	23	8	3	0
	Totals:	1370	260	104	130	168	93	116	145	175

IMPORT

Existing Import Points	Pipeline	Est'd Cap (MMcf/d)	Est. Daily Load Factor							
			92	93	94	95	96	97	98	99
(F) Alamo, Tx	Tennessee Pipeline	220	0	0	0	0	0	0	0	4
(G) Hidalgo, TX[7]	Texas Eastern	350	0	3	5	16	37	47	40	145
(H) Peñitas, Tx[7]	PG&E Texas	400	0	0	0	2	1	0	1	0
	Totals:	970	0	3	5	18	38	47	40	149

1 Commenced operation on 7/31/97.

2 Table does not include 33 MMcf of LNG exports in 1998 made at this location, via truck.

3 Commenced operation on 12/20/97.

4 Formerly owned and operated by Valero Transmission Company.

5 This bi-directional facility commenced operation on 9/23/99.

6 Facility commenced operation on 8/1/92; formerly Valero Transmission.

7 Both of these import points have facilities that are bi-directional, but are being used primarily to import natural gas from Mexico.

Sources: Data derived from quarterly reports filed with Fossil Energy by natural gas exporters and filings before the FERC. Office of Fossil Energy (1999).

TABLE 2 - PROPOSED AND RECENTLY COMPLETED NATURAL GAS EXPORT PIPELINE

Delivery Point	Pipeline Sponsor	Est'd Capacity (MMcf/D)	Pipeline Diameter (inches)	Planned Markets
(1) Otay Mesa, CA	Sempra Energy	300	30	Industrial and commercial users in Baja, CA (primarily the Rosarito Power Station, S of Tijuana)
(2) Cochise Co., AZ (West Br-Monument 90 Meter Station)	El Paso Natural Gas Co.	80	16	Existing & planned power plants near the city of Hermosillo, Sonora (170 mi SW of Naco, AZ)
(3) Cochise Co., AZ (East Br-El Fresnal)	El Paso Natural Gas Co.	50	16	Planned El Fresnal power plant located near city of Agua Prieta, Sonora (7 mi. S. of Douglas, AZ)
(4) Santa Theresa, NM	PNM Gas Services	35	8	Plans to serve Santa Theresa Industrial Park in Chihuahua, Mexico
(5) Salineño, TX	Kinder Morgan, Inc.	275	24	Monterrey, MX (LDLs, industrial users, power plants)
(6) Hidalgo Co., TX* (King Ranch Meter Station)	Coral Mexico Pipeline LLC	300	24	U.S. and Mexico

* Intended to be bi-directional

Sources: Data derived from quarterly reports filed with Fossil Energy by natural gas exporters and filings before the FERC. Office of Fossil Energy (1999) sharply upward all along the border. There is, however, little that can be done to improve the situation quickly, either within each country or between the two countries. With the exception of the isolated northern Baja area, the electrical connections between the two countries are limited to nine border crossings and are of little consequence (Table 3, 4). That is not to say that electricity cannot pass from on country to another, but it is cumbersome. During emergencies, pre-existing lines can use a "block over" switching operation, but new ties could allow exchanges between the U.S. and Mexican systems without requiring a temporary break in service to the surrounding community. One of the most recent projects to address this problem has been the 2000 opening of the first asynchronous electrical tie between the United States and Mexico, allowing easier power trading between Eagle Pass, Texas, and Piedras Negras, Mexico.

Coal

Mexico's small coal reserves are concentrated relatively close to the border in the Sabinas Basin of Coahuila, about 100 km north of Monterrey. This coal is sub-bituminous in grade and high in ash. The reserves total about one billion tons, an amount roughly equivalent to the amount mined in the U.S. each year. With coal consumption in 1999 at 13.1 million short tons, Mexico is a net importer of 2.1 million short tons, with those imports coming mostly from the United States, Canada, and Colombia. If there is to be increased trade in coal, it seems likely that it will come from the ample U.S. coal reserves in Arizona or New Mexico, or conceivably from as far away as Wyoming. While this could help alleviate certain supply shortages in Mexico, particularly as a fuel for power plants, it would raise serious questions about increased air emissions that would be carried into the U.S. on the predominant southernly air currents.

<u>Border Energy Boom</u>

The energy circumstances in California that started attracting widespread attention in the second half of 2000 enlivened discussions about energy exchanges between the U.S. and Mexico, and turned the spotlight on the need for new projects and highlighted the progress being made on projects already underway. There are of three types: gas pipelines, transmission lines, and power plant construction.

In the lower Rio Grande valley, the Mexican system is experiencing significant growth in demand for electricity, and merchant power producers have announced plans to build new generating plants in Texas. This area may be a logical place to create "energy corridors" to flow either north or south to meet the needs of customers on both sides of the border. Jess Totten, Director of the Office of Policy Development for the Public Utility Commission of Texas, recently voiced his enthusiasm for this possibility: "The prospect of helping establish corridors for trade with Mexico is . . . exciting. Access for Texas producers to competitively priced power would contribute to economic growth in Mexico and make the Texas market more desirable for new competitors."[xiii]

Many projects would support such enthusiasm. For example, since the opening of the electricity generation and natural gas distribution sectors to private participation, $8.65 billion of investments in the energy sector have been announced.[xiv] The border states of Baja California, Sonora, Chihuahua, Coahuila, Nuevo Leon and Tamaulipas, received $3.56 billion for projects or 41% of the total investment in the energy sector in the last six years. Among the major investors participating in the energy sector include: Iberdola, Gas Natural de México, Gaz de France, Sempra Energy, InterGen, Electricité de France, Pegi, Enertek, Tractebel, and ENRON.[xv] As of February 2001, 12 Independent Power Producers permits have been issued for a total investment

Table 3 - Imports to U.S. Electric Utilities by North American Electric Reliability Council Region and Hawaii, 1995 Through 1999
(Thousand Kilowatthours)

North American Electric Reliability Council Region and Hawaii	1995	1996	1997	1998	1999
ERCOT	-	5,566	526,185	738,369	204,136
WSCC (U.S.)	4,017,709	9,764,193	10,061,509	9,107,024	10,871,142
Contiguous U.S.	**42,852,428**	**43,495,343**	**43,029,601**	**39,512,366**	**43,213,697**
U.S. Total	**42,853,530**	**43,496,528**	**43,031,230**	**39,513,358**	**43,215,110**
From Canada	40,596,119	42,233,376	43,008,501	39,502,108	42,911,308
From Mexico	2,257,411	1,263,152	22,729	11,249	303,802

Source: Office of Fuels Programs, Fossil Energy, Form FE-781R, "Annual Report of International Export/Import Data." (1999).

Table 4 - Exports from U.S. Electric Utilities by North American Electric Reliability Council Region and Hawaii, 1995 Through 1999
(Thousand Kilowatthours)

North American Electric Reliability Council Region And Hawaii	1995	1996	1997	1998	1999
ERCOT	925,370	1,029,628	1,103,530	1,026,672	1,153,213
WSCC (U.S.)	1,877,904	949,907	3,970,568	4,539,167	7,380,946
Contiguous U.S.	**3,622,665**	**3,301,986**	**8,974,039**	**12,729,923**	**14,221,742**
U.S. Total	**3,622,665**	**3,301,986**	**8,974,039**	**12,729,923**	**14,221,742**
To Canada	2,468,244	1,986,361	7,470,332	11,683,276	12,953,488
To Mexico	1,154,421	1,315,625	1,503,707	1,046,647	1,268,254

Source: Office of Fuels Programs, Fossil Energy, Form FE-781R, "Annual Report of International Export/Import Data." (1999).

of $3 billion. They expect the projects to add more than 6,000 megawatts of capacity by 2004. Of the 12 IPP projects in progress at the end of 1998, 10 were in northern Mexico, five of them totally dependent on natural gas imports from the US, while the other five are partially dependent on US imports.[xvi]

The prospect for new natural gas projects always draws the quickest attention because they can usually be brought to completion most quickly. One example is a new interconnect. Tennessee Gas Pipeline Company, a business unit of El Paso Energy Corporation announced in September 1999 plans to build this new interconnect between the US and Mexico at Reynosa. The 24-inch bidirectional pipeline lateral is the third pipeline to link El Paso's pipeline systems with those of PEMEX-Gas. More are expected.

Several other projects have been proposed to increase the supply of electricity to the borderlands communities and their maquiladora plants. Energía Industrial Río Colorado is a 35-company self-supply partnership intending to build and operate a 470 MW generating station to generate 3,000 GWh annually largely for facilities located at San Luis Río Colorado, Sonora. The first stage is to be completed by September 2001, while the second is scheduled for completion by June 2002.[xvii] In the same location, an import permit was granted to Mecox Resources, which will invest $400 thousand to import a 1.6 MW maximum demand from the US-based Arizona Public Service Company.[xviii] The recently completed Samalayuca power plant is fueled by natural gas imported via a pipeline from the United States.

In Baja California and California, a consortium formed by US firms Enova and Pacific Enterprises and Mexico's Proxima in 1996 was granted the first concession to deliver natural gas in the Mexicali area. Since then, several additional projects have been proposed. The CRE announced in August 2000 that an IPP permit was granted to Energia Azteca X, a subsidiary of InterGen. Their Rosarito 10 and 11 stations will be located near Mexicali and will have a 895-megawatt gross generating capacity. Although the IPP permit authorizes the generation of up to 497 MW that will be sold to the CFE, InterGen plans on exporting the remaining capacity to the United States.

The projects just outlined represent three types affecting both the US and Mexico: (1) a coal plant generating electricity for Mexico but producing air emissions that enter the US (Carbón 2); (2) a gas-fired plant that generates power for Mexico using fuel from the US (Samalayuca); and (3) a gas-fired plant that generates power for both countries using US fuel (Rosarito 10 & 11). A fourth arrangement was announced recently. A subsidiary of utility holding company Sempra Energy Inc. reported that it would build a $350 million 600-megawatt natural gas-fired power plant in Mexico, 9 miles west of Mexicali and three miles from the US-Mexico border. There are two unique aspects to this project. First, it will be fueled by natural gas brought in from a connection to be made near Blythe, including 77-mile leg in the US and 135-mile leg in Mexico. Named Termoelectrica de Mexicali, it should be commercial by 2000, and it will be connected to California through a 230-kv interconnect.

The unique characteristics of this plant are worth noting because other similar plants may be constructed in the future. Not only is it to be the first in Mexico to be entirely foreign owned and operated, it will also be the first time all of the electricity from a Mexican power plant will be marketed in the US. Normally, all electrical plants in Mexico are owned and operated by the Mexican government's CFE. The Sempra plant is exempt from this because it will not serve Mexican consumers. Building in Mexico should also allow the project a shorter planning phase because in Mexico they can acquire all the building permits in six months while it takes 12 to 18 months or longer in California to get all the necessary permits[xix]. Darcel Hulse, President of

Sempra International, illustrated this and other differences recently at the 10th Conference on Latin American Energy when he compared two power plants, one permitted in California and one being built by his company in Mexico. (Table 5).

Another prominent energy project near the border is the announcement that Liquified Natural Gas regasification docking facilities will be constructed to allow import of natural gas from distant markets, including Australia and Bolivia. Plans for one of the LNG plants would place it on the west coast of Baja California, with a new dedicated gas pipeline from that spot across the border and into San Diego County.

Border Energy Issues

There is no question that the US/Mexico border is going to be hosting a spectrum of energy projects in the near future. These will include laying natural gas pipelines, stringing electrical transmission lines, constructing conventional and alternative electrical generation stations, and installing LNG regasification facilities. Every project will benefit the border region in terms of economic development and energy supply, but each will also tax area natural resources, place demands on local and regional environmental quality, and attract even more people. The environmental costs of energy develop is at the center of a brewing controversy that is gaining increasing attention in both countries. In Mexico, for example, some worry that a concentration of energy projects near the border could turn their country into a "door mat" for the benefit of the US. For their part, those in the US wish to avoid the air and water pollution that would tend to travel northward from energy projects constructed in Mexico. Although both countries want the economic advantage of development without the environmental costs, such costs seem inevitable in five categories of concern, namely air quality, water allocation, rights-of-way, population growth, and industrialization.

As is widely accepted, natural gas is preferred as a power plant fuel because its combustion releases little sulfur oxides, especially in comparison to oil and coal. This attribute, combined with the newfound reserves of the Burgos Basin and energy revenues that would swell the Mexican treasury, is stimulating the regulatory changes in Mexico to favor its quicker route to the marketplace. The significance of natural gas' low emissions has been underscored in recent years by controversial coal-burning power plants in northern Mexico. These power plants, including Carbón II now operating close to the US border, produce emissions that waft northward into the U.S. When they enter the U.S. through Big Bend National Park, they raise the alarm for other similar projects proposed for the border region. National Parks such as Big Bend are, by US law, subject to the highest standards of air quality. For this reason, when visibility in the park started to decline in the 1990s it was a noted environmental cost linked with all future border energy development. With this project, for perhaps the first time, the United States is suffering the impacts of transboundary pollution that seemed to plague only smaller and more closely spaced countries on other continents.

Water quality is the second obvious environmental concern in the border area. The entire 2000 mile length is considered a desert, and only part of it has a river of any size, the Rio Grande, a river that is already over-subscribed. This means that any farther use of the water coursing through its lower reaches from El Paso to Brownsville will require subtracting water from some other user, either agricultural or domestic. Were many power plants plugged into the water budget along the border, it diminishes water availability even more because all thermal power plants need prodigious amounts of water to operate efficiently. The consumptive water use of a natural gas power plant is about 15 acre-feet (about 5 million gallons) per megawatt-yr; thus, a

Table 5 - Mexico and California Permitting

Project Location	Mexicali, Mexico	Taft, California
Main Permitting Agency	SEMARNAT / INE	CEC
Scope of Review	• Air Quality • Water Quality • Risk Assessment • Solid and Hazardous Waste • Threatened & Endangered Species • Noise	• Air Quality • Water Quality • Risk Assessment • Solid and Hazardous Waste • Threatened & Endangered Species • Noise • Visual Impacts • Water Resources
Expected Time Frame (submittal to receipt)	4 – 6 months	15 months
Actual Time Frame	5 months (includes change in administration)	22 months
Permits Required from Other Agencies	• Zoning • Export/import • Water discharge • Right of way	• Zoning • Export/import • Water discharge • Right of way.

Source: Darcel Hulse, Sempra Energy International, 10th Conference on Latin American Energy, May 21-22, 2001

100MW power plant would require 1500 AF/MW-yr. The Carbón II plant, at 1400 MW requires roughly 21,000 ac-ft/yr, about what 40,000 urban dwellers use per year in central Arizona cities. That same amounts of water would be sufficient to supply at least 250,000 people on the Mexican side of the border just about anywhere along its length. Thus, water sources for all power plants located near the border must depend upon water resources that are not easily available.

If the problems of air quality and water supply are satisfied, any power projects within the border region, excepting those based on solar power, will require new rights-of-way for transmission lines and pipelines. The placement of these corridors will be contentious, especially in the U.S. There is no easy solution to this problem in the United States. Widening existing rights-of-way is not always possible or acceptable, and creating new corridors is an even more troubling prospect. Despite this, several projects of this type have already been announced, a sampling of which include:

- A 300-mile line proposed by Public Service Company of New Mexico to link the switching yard at the Palo Verde Nuclear Generating Station 50 miles west of Phoenix to CFE's system in Sonora, Mexico.
- A transmission line into southern Arizona constructed by Tucson Electric Power Co (TEP) to boost reliability of electric service in that region. The company also has filed for approval from the US Department of Energy (DOE) to extend the line into Mexico. A primary subsidiary of UniSource Energy Corp., TEP plans to build the $70 million, 345,000-volt transmission line 50 miles south to Nogales, Arizona, and then connect to an existing electric substation in the Mexican state of Sonora.[xx]
- Transmission facilities proposed by Wilson-7 Energy Systems Inc. in Texas, would allow export of power to Mexico. As proposed, the project would consist of transmission lines capable of carrying direct current. The facilities would be found in Hudspeth County, Tess, just southeast of El Paso. The lines would cross the Rio Grande from Fort Hancock to Guadalupe-Bravos. The power would come from three as-yet-to-be-built 2,000 MW power plants in Hudspeth. The power would be sold into Mexico and unnamed Central American countries.[xxi]
- In July 2000, a cable from Eagle Pass, Texas to Piedras, Mexico connected US utility AEP and CFE's transmission systems. This is a new kind of electric connection, using asynchronous (high-voltage direct-current) technology to combat the problem of differing power currents between countries.[xxii]
- Coral Mexico Pipeline, L.L.C. has proposed facilities consisting of 1,375 feet of 24-inch pipeline which will connect with existing and new natural gas pipelines operated in Mexico by PEMEX. Coral would build a 97-mile, 300,000 Mcf/day pipeline between Kleburg County and Hidalgo County, Texas to the border that will serve PEMEX downstream at Arguelles, Mexico. The new 97-mile pipeline would be operated wholly within the two Texas counties which connect upstream with Tejas Energy pipeline facilities.[xxiii]
- El Paso Natural Gas Company Willcox Lateral pipeline project consists of a 20-inch pipeline to be constructed 56-miles downstream from its California mainline where it would separate into two branch lines that will end about 15 miles apart at the US/Mexican border. The two 16-inch branch lines would have a daily pipeline capacity of 80 MMcf for the West Branch and 50 MMcf for the East Branch. The gas is intended for existing and proposed gas-fired electric powerplants located in the Mexican State of Sonora -- serving utilities near the cities of Hermosillo and Agua Prieta.[xxiv]
- KN Energy, Inc., of Lakewood, Colorado plans to build a new cross-border natural gas pipeline near Salineño, Starr County, Texas, and Ciudad Miguel Aleman, Tamaulipas. The facilities would consist of an 800 foot, 24-inch diameter pipeline and meter. The proposed new cross-border facility would interconnect with 15-miles of new pipeline to be built upstream in Texas by KN Energy’s MidCon Texas Intrastate Pipeline, and new pipeline facilities to be built in Mexico by KN Energy’s Mexican affiliate, MidCon Gas Natural de México, S.A. de C.V. (MidCon México). MidCon México would take delivery of the natural gas near Ciudad Miquel Alemán, and transport the gas 100 miles to Monterrey, Mexico. The capacity is to be 275 MMCF.[xxv]
- Public Service Company of New Mexico plans to construct and operate a new pipeline facility at the United States/Mexico border near Santa Theresa, New Mexico. The pipeline would connect with a PEMEX pipeline and would supply an industrial park just across the border in Chihuahua, Mexico.[xxvi]

These projects will be augmented by many others, as has been discussed informally at many of the recent border energy conferences. Aside from the impacts of that will result from power plant construction and operation, and the problems that will prevail in identifying new rights-of-way, energy development will is likely to enliven the maquiladora sector by supplying needed additions of power. This will, turn, also drive up population and the local demand for electricity. Jobs, employment, and new population will put additional strains on an already overtaxed border environment. The intensity of any new strains will depend upon the restrictions and controls that are put in place and enforced as such projects are developed. Mexican officials have said that they will not allow energy projects to degrade conditions on their side of the border for the benefit of the U.S. However, the present lenient environmental requirements, plus the energy projects that are already under construction in Mexico, suggest this going to be easier to proclaim than to perform.

Opportunities and Needs

Border energy infrastructure and development have been topics for discussion for many years, privately within companies which desire a stake in such developments, and publically at meetings such as the Border Energy Forums. With Presidents from both countries encouraging closer energy ties, and now that questions of supply and reliability are on the front page, the potential for border energy developments has reached the point of serious financial commitments and political risk. While it is difficult to predict the consequences of such activities, several steps would increase the chance of success. One suggestion has been to develop a border-wide plan that integrates all proposed projects with existing and predicted demographic conditions. Working on this scale, while more challenging, has more value. It would coordinate projects to improve compatible allocation of existing resources and rights-of-way, and improve the efficiency of connections between disparate infrastructures, and increase reliability and compatibility. One could think of it as a Border Energy Plan.

The initial elements of such a plan could be modeled after the EPA's U.S.-Mexico Border XXI Program, one that does not seem to address energy specifically but which nevertheless seems to have the appropriate goal of bringing "together the diverse U.S. and Mexican federal entities responsible for the shared border environment to work cooperatively toward sustainable development through protection of human health and the environment and proper management of natural resources in both countries."[xxvii] Another EPA program, the US-Mexico Border XXI Environmental Health Workgroup, aims "to identify and address, in a binational framework, environmental factors that pose the highest risk to human health so that exposure to such factors may be reduced."[xxviii] Both programs are already in place and could be pressed into service for the benefit of quicker energy coordination.

Another element of international cooperation is to put to use the potential of the border region for the development of promising alternative energy resources. Already, geothermal energy is well advanced in Cerro Prieto, south of Mexicali, where more than 700 MW are on line or near completion. As well, abundant solar energy is available all along the border, and its use to generate electricity or at least to provide hot water, is obvious by its absence. In an area where insolation rates exceed 1,000 watts per square meter, there is little use of solar energy for any purpose. At today's prices, hot water heating seems a particularly appropriate application along the border. Under certain scenarios, it would also be economically sensible to installed photovoltaics systems in remote areas, at least to provide minimal electrical service. Sandia National Laboratory of Albuquerque, New Mexico has been assisting with the costs, siting, and installations of small-scale demonstration of solar cells in isolated Mexican communities,[xxix] but much more use of solar renewables should be part of any regional energy planning exercise.

Such discussions have been initiated. Reporting on improvements in technology has been a priority at the Border Energy Forums, with the assumption that these can only serve to remove obstacles not only to cross-border trade but also in the use of energy on both sides of the border. Technologies involving renewable energy, alternative fuels and energy efficiency have been at the forefront of these discussions. Although in some cases the cost effectiveness of new technology may present an obstacle to their use, in others the rate of adoption may be slower simply from the lack of information or priority on the part of the industrial or residential consumer. For this reason, energy education has a strong role to play in the future of the border energy region, especially in terms of its ties to environmental quality.

Tied closely to discussion of alternative energy development and energy education is the institution of energy efficient technologies. Efforts are under way to increase the availability of targeted information on these systems and components. In one project, for example, the Western Governors Association has established a Border Energy Task Force that has planned a bilingual, cross-border Internet site to match up energy service companies with maquiladoras and other mid-size to large public and private sector energy consumers. The General Land Office also is working in partnership with the New Mexico State Land Office and the Comisión Estatal para el Ahorro y Uso Eficiente de Chihuahua to develop bilingual energy education materials that emphasize the shared sustainable resources like wind and solar energy that are available in this region. All these elements----alternatives, education, and efficiency----should be coupled a full evaluation of salient land use parameters. These would include the identification of likely power plant sites and energy “corridors,” that is, the pathways for pipelines, transmission lines, and (perhaps) rail connections.

The sensitive environmental circumstances along the border demand careful consideration of air sheds and water resources. As impacts on either resource will tend to drift northward, the U.S. has a vested interest in energy projects in Mexico.[xxx] This was illustrated earlier by the example of air emissions wafting from the Carbón coal plants over Big Bend National Park, but it has yet to stimulate much visible attention regarding water resources. It is difficult to image how new power plants in any significant number can be located along the border given the scarcity of water for cooling purposes unless some compromise is struck to reduce water currently being used for other purposes. This suggests that using the border for energy transfers is more likely than using the border for the siting of multiple new power plants. At best, it would seem to relegate plans for power plant construction to a role secondary to the construction of pipelines, transmission lines, railroads, and highways.

Coordination is important, and a possible approach to border energy issues was to suggest at the Chihuahua Border Energy Forum in 1998 by Dr. Michelle Michot Foss, director of the Energy Institute at the University of Houston’s Bauer College of Business. She said that the border region might serve as a laboratory for new systems that could meet both countries’ energy needs. She suggested that the electric cooperative approach similar to the Rural Electrification Administration in the United States in the 1930s could be a model for Mexico to get distribution and transmission systems built. The co-op approach also would lend itself to the use of local revenue tools and could take advantage of small-scale technology and distributed generation to deliver electricity at a price close to cost. Northern Mexico, Foss concluded, might be an ideal location for a pilot project testing the benefits of decentralization.

Conclusions

With all projections showing continued growth in population, industry and trade near the US-Mexico border, opportunities lie ahead for significant changes in regional energy trends and patterns. It also can be expected that concerns about national autonomy and energy interdependence will continue to influence efforts to develop cross-border programs for regional energy planning. The Border Energy Forum and several periodic conferences and other meetings focusing attention on border energy issues, a tradition has been established of increasing the development and accessibility of data; this should help in meeting energy needs on both sides of the border. “Projecting future problems and market trends is far easier when everybody’s at the same table,” Texas Land Commissioner Dewhurst has said. “To solve tomorrow’s problems, there is a need to have ongoing annual discussions regarding energy and its impact on the environment.” However, it is already clear from several years of discussions that future energy developments, including trade, power plant construction, and consequences of these activities near the border will require not only infrastructure improvements, but innovation, attention to environmental consequences, and regulatory diligence. Coordinating such needs will be neither automatic nor simple.

Within the context of the geography of energy at the US-Mexico border, the issues which should receive the highest priority in border energy zone fall within three categories, two of them----facility siting and environmental impacts----closely related. Facility siting subsumes power plants and transmission corridors. Environmental ties to these decisions include influences on the siting itself and the impacts once these facilities are constructed and are operating. These impacts will include concern about air and water resources, visibility, aesthetics, biological resources and a host of indirect impacts produced from any attracted population increases.

U.S. laws usually require some form of environmental impact assessment be completed for projects on the northern side of the border, even if they are intended to send products south, but it is not as clear whether the reserve is true or how stringent such requirements might be. This discrepancy by itself warrants close scrutiny because of the influence it can have on the siting of power plants, and perhaps their concentration, just south of the border. There are also ramifications of these differences appearing already in the suggestion that an LNG regasification facility will be built on the northwest coast of Baja California in order to supply natural gas to the state of California where the permitting of such an industrial plant would face long delays and perhaps defeat.

Transmission facilities----both for electricity as well as natural gas----pose a different type of environmental challenge. Instead of concerns about specific locations, air pollution, and water demands, their linear influence is largely aesthetic. As such, these corridors, particularly transmission rights-of-way, have been facing increasingly long delays in the permitting process. The shorter the distance they traverse in the U.S., the shorter will be the debate over their location. This would favor the concentration of U.S. users as close to the border as possible.

Many of the potential problems of land use, demands on air and water, aesthetics, health and safety, pose significantly smaller concern when attention turns to alternative energy resources, particularly solar. Rather than face the expense and time necessary for an conventional energy developments, including bringing in the fuel and dealing with the water and air impacts, solar energy is local and abundant, particularly for water heating and low-wattage electrical needs. This is a border energy option that deserves further evaluation.

Currently, there seems insufficient planning accruing to the various energy plans at the border, and there is not a plan to establish one. Local businesses, state and national governments all the way to the Presidents of both countries, seem content to unshackle entrepreneurial zeal, point it at the border and hope for the best. This approach has no long-term hope for success.

Endnotes

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[i] Production in the Burgos field reached 4.8 billion cubic feet per day by 1999, and the total reserves may amount to 21-75 Tcf, or roughly 3-10 times the current proven reserves, according to the Gas Technology Institute of Arlington, Virginia (*O&GJ Online*, Jan 8, 2001). The future may also witness greater use of the substantial solar resource that strikes the ground across the entire distance with 1kW of per square meter. One kilowatt is enough to power most houses, minus air conditioning.

[ii] Javier Estrada, Border Energy Forum VI, San Antonio, Texas, Nov. 9-10, 1999.

[iii] U.S. Department of Energy, *Quarterly Focus*

[iv] U.S. Energy Information Administration, 1998; U.S. Energy Information Administration, 1993; U.S. Energy Information Administration, 1996; United Nations, 1994

[v] The internet site is: www.scerp.org

[vi] The internet site is: www.iamericas.org

[vii] I am grateful to Soll Sussman of the Texas General Land Office for information about the Border Energy Forum.

[viii] For more information, refer to: http://www.nri.state.tx.us/border/

[ix] Hector Olea, Border Energy V, Chihuahua, Chihuahua, Nov. 16-17, 1998.

[x] Luis Labardini, Border Energy Forum III, Monterrey, Nuevo Leon, Nov. 21-22, 1996.

[xi], Dana Contratto, Border Energy Forum IV, Las Cruces, NM, Oct. 21-22, 1997.

[xii] The Oil and Gas Journal (Jun 13, 2000) puts their reserves at 41.495 bbl. (US EIA, *Mexico Fact Sheet).*

[xiii] Jess Totten, Director of the Office of Policy Development for the Public Utility Commission of Texas

[xiv] *Mexican Intelligence Report* 2000

[xv] *Mexican Intelligence Report* 2000.

[xvi] U.S. Energy Information Administration, 2001.

[xvii] Comisión Reguladora de Electricidad, 2000

[xviii] CRE 2000

[xix] *Mexican Intelligence Report* 2000; see also Darcel Hulse's presentation at 10th Conference on Latin American Energy, La Jolla, CA May 21-22, 2001,

[xx] *Mexican Intelligence Report* Aug 2000

[xxi] *Energy Online Daily News* 1998.

[xxii] U.S. Energy Information Administration, 2001

[xxiii] Office of Fossil Energy 1999, U.S. Department of Energy

[xxiv] Office of Fossil Energy 1999, U.S. Department of Energy

[xxv] Office of Fossil Energy 1999, U.S. Department of Energy

[xxvi] Office of Fossil Energy 1999, U.S. Department of Energy

[xxxii] http://www.epa.gov/usmexicoborder/ef.htm

[xxviii] http://www.epa.gov/orsearth/mission_objectives.html.

[xxix] The internet site is: http://www.sandia.gov/pv/mexpro.htm

[xxx] The U.S. Environmental Protection Agency CLEAN AIR TECHNOLOGY CENTER sponsors the CICA, the *Centro de Información sobre Contaminación de Aire.* The CICA provides technical support and assistance in evaluating air pollution problems along the *U.S.-México* border. *The internet site is:* http://www.epa.gov/ttn/catc/cica/

Whither Hazardous-materials Management in the U.S.-Mexico Border Region?

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Introduction

In recent years, the subject of hazardous materials—their production, transport, disposal, and impacts—near the U.S.-Mexico border[1] has gained increasing attention (cf. Carter et. al, Pezzoli, Sánchez 1994). Because, as the name itself implies, hazardous materials can be harmful to human health, a number of environmental and community-based nongovernmental organizations (NGOs) have considered the handling of these substances to be a top priority. Growing pressure by these groups has helped propel transboundary hazardous-materials issues onto the agendas of governments in the two countries and of numerous relevant binational institutions. During this time, as awareness of the inherent dangers of hazardous materials has risen, there have been important changes in how such chemicals are tracked and treated.

Several significant events and developments are likely to affect the treatment of hazardous materials issues in the U.S.-Mexico border region. They include the changing government administrations in both the United States and Mexico and their environmental policies. Additionally, in 2001 the mandate of NADB, the North American Development Bank, and BECC, the Border Environment Cooperation Commission, has expanded beyond water, wastewater, and solid waste management projects to include hazardous-waste management issues. Finally, as of 2001, NAFTA rules have changed, giving maquiladoras more incentives to nationalize and to abandon their temporary import and foreign corporation status. If maquilas choose to nationalize, they will no longer be bound by previous legal requirements to return hazardous materials to the country of origin. These three major developments will be discussed in turn. First, however, the "picture" of hazardous materials at the U.S.-Mexico border is important to paint.

Hazardous Materials in the U.S.-Mexico Border Region

Definition of hazardous materials

The U.S. Environmental Protection Agency (US EPA) defines a material (or waste) as hazardous "if it is ignitable (i.e., burns readily), corrosive, or reactive (e.g., explosive).… Waste may also be considered hazardous if it contains certain amounts of toxic chemicals. In addition to these characteristic wastes, US EPA has also developed a list of over 500 specific hazardous wastes. Hazardous waste takes many physical forms and may be solid, semi-solid, or even

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liquid" ("Frequently Asked Questions about Waste, US EPA website, 2001). Similarly, Mexican environmental law defines hazardous materials as substances with corrosive, reactive, explosive, toxic, flammable, and biologically-infectious characteristics (CRETIB) that—independently of their physical state—represent a risk for natural resources, environment, and human health. Risk is defined as the probability that negative environmental impacts on population and ecosystems (receptors) occur as a result of the exposition to hazardous materials. In recent years authorities have recognized that the negative impact depends on the quantity of materials to which receptors are exposed as well as on the time and frequency of exposition (INE, 2000: 23).

Amount, kinds, and fates of hazardous materials generated

Hazardous materials can be the end products or byproducts of manufacturing processes. Tires, batteries, oils, and solvents are examples of hazardous materials that require care in handling, transporting, use, and disposal due to their potential hazard to human and environmental health. In many accounting schemes, attention is focused on hazardous wastes rather than on the more general category of hazardous materials. Where possible, we will try to maintain our discussion on hazardous materials in general; however, much of the data collected by both the United States and Mexico describe hazardous wastes.

On the U.S. side

Hazardous-waste production

The US EPA reports that 40.68-million tons of hazardous waste were generated in the United States in 1997 (US EPA September 1999). Most of this waste was produced by "large-quantity generators," manufacturing plants that produce more than 1,000 tons of hazardous waste per month on average. Many of these large quantity generators are located in border states (cf. Applegate & Bath). As is evident from Table 1, the amount of hazardous waste generated in the four U.S. states bordering on Mexico became proportionately larger than that generated in the rest of the U.S. between 1993 and 1997. The majority of this waste is produced in petrochemical and chemical industries.

Table 1: Percent of hazardous waste generated and managed in U.S. states bordering Mexico

State or region	% Generated '93	% Generated '95	% Generated '97	% Managed '93	% Managed '95	% Managed '97
Texas	*24.6*	*32.0*	*46.6*	*22.4*	*36.0*	*46.0*
California	*5.4*	*5.2*	*1.7*	*5.4*	*6.5*	*3.1*
All U.S. border states (Texas, California, Arizona, New Mexico)	*30.2*	*37.3*	*48.6*	*27.9*	*42.6*	*49.6*

Source: U.S. EPA, The National Biennial RCRA Hazardous Waste Report, August 1995, August 1997, and August 1999, adapted from Jacott, et al., 2001.

Hazardous materials exports and imports

The United States exports hazardous materials and hazardous waste to Mexico. According to the INE (Instituto Nacional de Ecología, Mexico's national institute of ecology, which has been responsible for studying and maintaining records on these substances) website, some 158,500 tons of hazardous wastes were exported to Mexico from the United States in 1995. That number increased to 254,500 tons by 1999 (Jacott, et al., 2001). Hazardous-waste export has increased significantly since NAFTA, according to Texas, U.S., and Mexican government data (Jacott, et al., 2001). Most of the waste exported to Mexico by the United States is electric arc dust (EAD), a byproduct of the U.S. steel industry. This increase in export is attributed, in part, to changes in U.S. regulations, which favor treatment over landfilling; most of the exported EAD is sent to recovery plants in Mexico. Also, the cost of treating hazardous materials in Mexico is believed to be much less than in the United States; therefore, U.S. companies have a greater incentive to export materials in order to keep costs low (Jacott, et al., 2001). In addition, the steel industry itself has experienced substantive changes: production of EAD overall has increased as manufacturers have come to rely more heavily on recycled steel, which uses more kilns than does integrated steel.

Hazardous wastes also cross the U.S.-Mexico border going north. In compliance with NAFTA regulations, approximately 800 Mexican maquiladoras reported shipping either hazardous or non-hazardous waste from Mexico back to the United States in 1997 (Jacott, et al., 2001). A substantial amount of this material was from Ciudad Juarez and Tijuana.

<u>On the Mexican side</u>

Hazardous-waste production

The amount of hazardous materials produced in the United States continues to dwarf that generated in Mexico; however, similarities in the regional patterns of hazardous materials production in the two countries are striking. In Mexico the region bordering the United States has become the second most important generator of hazardous materials in the country.[2] For example, estimates of hazardous wastes in the border region as a whole indicate that the amount increased by nearly a third between 1994 and 1997 [Table 2][3].

Table 2. Mexico: Estimated Hazardous Waste Generation (thousands of tons)

States	Estimated generation in 1994	Estimated generation in 1997	Change (%)
Baja California	160	395.1	*146.9*
Coahuila	300	298.2	*-0.6*
Chihuahua	210	388.5	*82.6*
Nuevo Leon	800	733.1	*-3.4*
Sonora	145	207.4	*43.1*
Tamaulipas	150	232.8	*55.2*
Mexican Border	1,765	2,295.1	*31.1*
National	8,000	12,700.1	*59.1*

Source: ITESM/INFOMEXUS/SEMARNAP (1999, 250-252)

Table 3: Estimated Versus Reported Hazardous Waste Generation in Mexico in 1997
(thousands of tons)

States	Estimated waste generation in 1997	Reported hazardous waste generation in 1997	% reported in relation to estimated
Baja California	395.1	29.5	*7.5*
Coahuila	298.2	2.4	*0.8*
Chihuahua	388.5	779.2	*200.5*
Nuevo Leon	773.1	47.8	*6.2*
Sonora	207.4	4.1	*2.0*
Tamaulipas	232.8	218.6	*93.9*
Mexican Border	2,295.1	1,081.6	*47.1*
National	12,700.0	3,328.1	*26.2*

Source: ITESM/INFOMEXUS/ SEMARNAP (1999, 250-252),
website http:ine.gobmx/dgmrar/ri/generation.htm

As Table 3 indicates, there is a significant difference between the estimated waste generation and the reported waste generation for most of the Mexican border states. As we discuss in greater detail below, the reporting of hazardous waste materials in Mexico—though requisite semiannually under Mexican law—appears not to be consistent.

In Mexico, the hazardous materials generated most frequently in the border region are residual liquids from production processes (27.9%), used oils (22.9%), sludge (18.0%), and solvents (12.7%), as well as corrosive substances, dross, pitch, volatile organic compounds, and heavy metals (18.5%) (Sánchez 1990).

Table 4. Kinds of Hazardous Wastes
(thousands of tons)

State	Residual liquids	% of total	Used oils	% of total	Sludge	% of total	Solvents	% of total	Others*	% of total	Total
Baja California	112.0	*28.3*	92.3	*23.4*	72.2	*18.3*	51.0	*12.9*	67.6	*17.1*	395.1
Coahuila	81.8	*27.4*	67.3	*22.6*	52.6	*17.6*	37.2	*12.5*	59.3	*19.9*	298.2
Chihuahua	107.3	*27.9*	88.4	*23.1*	69.2	*18.0*	48.9	*12.6*	69.7	*18.2*	383.5
Nuevo Leon	219.6	*28.4*	180.9	*23.4*	141.5	*18.3*	100.0	*12.9*	131.1	*16.9*	773.1
Sonora	55.6	*26.8*	45.8	*22.1*	35.9	*17.3*	25.3	*12.2*	44.8	*21.6*	207.4
Tamaulipas	61.9	*26.6*	50.9	*21.9*	39.9	*17.1*	28.2	*12.1*	51.9	*22.3*	232.8
Mexican Border	638.2	*27.9*	525.6	*22.9*	411.3	*18.0*	290.6	*12.7*	424.4	*18.5*	2290.1

Source: ITESM/INFOMEXUS/ SEMARNAP (1998, 251-253). *Including corrosive substances, dross, pitch, volatile organic compounds, and heavy metals.

Driving forces and proximate causes

The main proximate causes of hazardous-materials generation in the Mexican border region are agriculture, mining, manufacturing, maquilas, and services (hospitals and medical care). In some states like Nuevo Leon and Chihuahua, chemical and wooden furniture enterprises are the most important generators of hazardous materials; in the assembly sector the main producers of these substances are electronic parts, equipment, and textile and car parts enterprises.[4] The environmental problems related to these activities in the Mexican border region arise from a complex combination of regional, national, and international driving forces, namely patterns of economic growth and trade, urbanization, public policies, and demographic and social dynamics.

Economic development, industrial enterprises and maquiladoras

In economic terms, the gross national product of the Mexico's six border states grew 3.8 percent between 1993 and 1997 alone. Manufacturing and assembly have been some of the most important drivers of this growth, in addition to industry (chemical, agribusiness, and wood enterprises), mining, and agriculture. Regional maquilas contributed 37% of the national aggregated value of manufacturing and assembly, regional industries generated 22.7% of the industrial national aggregated value, and regional farmers generated 21.2% of the agricultural national aggregated value (Table 5, INEGI/SEMARNAP 1999, 387).

Table 5: Industry in the Mexican border states: some indicators

	1993			1998	
	Number of Enterprises	Number of Employees	Aggregated value (thousands of Mexican pesos)	Number of Enterprises	Number of Employees
Mexican border states	38,654	962,147	109,502,821.0	48,525	1,408,368
National	265,427	3,246,042	482,154,705.40	361,579	4,213,566
Percent attributable to border states	14.6%	29.6%	22.7%	13.4%	33.4%

Source: INEGI (1989), INEGI (1994), and INEGI/SEMARNAP (1999, 417)
Data correspond to the states of Baja California, Coahuila, Chihuahua, Nuevo Leon, Sonora, and Tamaulipas.

Table 6: Maquiladoras in Mexico (1990 to 1998), some indicators

Indicator	1990	%	1995	%	1999	%
Number of maquiladoras:						
In border municipalities	1,299	*76.2*	1,446	*67.9*	2,001	*60.7*
In the rest of the country	405	*23.8*	684	*32.1*	1,296	*39.3*
Total	1,704	*100.0*	2,130	*100. 0*	3,297	*100.0*
Employment (annual avg.)						
In border municipalities	342,556	*76.7*	465,071	*71.7*	714,715	*62.7*
In the rest of the country	103,881	*23.3*	183,192	*28.3*	425,813	*37.3*
Total	446,437	*100.0*	648,263	*100.0*	1,140,528	*100.0*
Aggregated value (millions of Mexican pesos)						
In border municipalities	7,631	*76.9*	23,662	*71.3*	80,845	*63.0*
In the rest of the country	2,288	*23.1*	9,521	*28.7*	47,420	*37.0*
Total	9,919	*100.0*	33,183	*100.0*	128,265	*100.0*

Source: INEGI/SEMARNAP (1999: 419)

As Table 6 indicates, maquiladoras in Mexico's border municipalities account for a large share of the maquila industry in number, employment, and value. Furthermore, as both Table 6 and Figure 1[5] demonstrate, the increase over the past decade in the number of maquilas both in Mexico in general and in the border region (a 54 percent rise) has been substantial. Even so, the maquila sector remains a small component of the industrial sector as a whole: Maquiladoras in the Mexican border states account for only 3.9 percent of regional enterprises and generate just 7.3 percent of the region's industrial aggregated value. Maquilas' most important regional impact is related to the quantity of jobs created (33.4 percent, Table 5) and not to the quality of these jobs, which is more closely a function of economic growth as a whole rather than a characteristic specific to the Mexican border region. The reason for this is that there has been a downside to job creation in the maquila sector, as wages are low and have declined in real terms over the last decade. This phenomenon has been compounded by the border's "dollarized" economy and by very high costs of living.[6]

Maquilas have been induced to locate in the border region through subsidies, tax holidays, and other governmental strategies. One unintended consequence of these policies is that they have reduced the already low capacity of communities to deal with environmental issues in general and hazardous materials in particular. In spite of recent gains in Mexico's economy, financial resources throughout the country and in its border region remain scarce. Further, Mexico's strongly centralized governmental structure distributes funds to the states formulaically and according to tradition, a procedure that inhibits regional and local revenue collection and use. Against this backdrop, as Tables 5 and 6 show, the industrial sector and the maquila sector have grown appreciably. This growth has partly spawned and been accompanied by a marked rise in the population of border states—a trend that began in earnest in the 1960s, when border industrialization first was seriously promoted in Mexico and the United States (Figure 2).

But constrained by insufficient resources—even after the advent of NAFTA and the creation of the North American Development Bank—construction of infrastructure has not kept pace with the region's industrial growth and population increase.

Mining and Agriculture

Mining and agriculture have declined in economic significance in the Mexican border region as employment and profits in industrial and service sectors have increased (cf. Lorey). Nonetheless, they remain important activities at the national level and as such, they are generators of hazardous materials. Agriculture in Mexico's border states contributes almost a fifth of the national agricultural value of production. It is significant that this activity is very intensive in the use of two hazardous materials: fertilizers and pesticides.[7] Similarly, mining, which remains an important sector in the border region, generates tailings from the extraction and refining process, and uses solvents whose ultimate fate is often unaccounted for. It is estimated that during 1996, agriculture and ranching generated 0.8 percent, while of the national output of hazardous materials, mining and oil production generated 11.1 percent.[8] Beyond that, there exists no reliable regional data regarding hazardous materials generated by both agriculture and mining.

Population growth

Driven by large-scale northward migration, population growth is more pronounced in the border region of Mexico than in any other Mexican region. In 1980, the population in the border

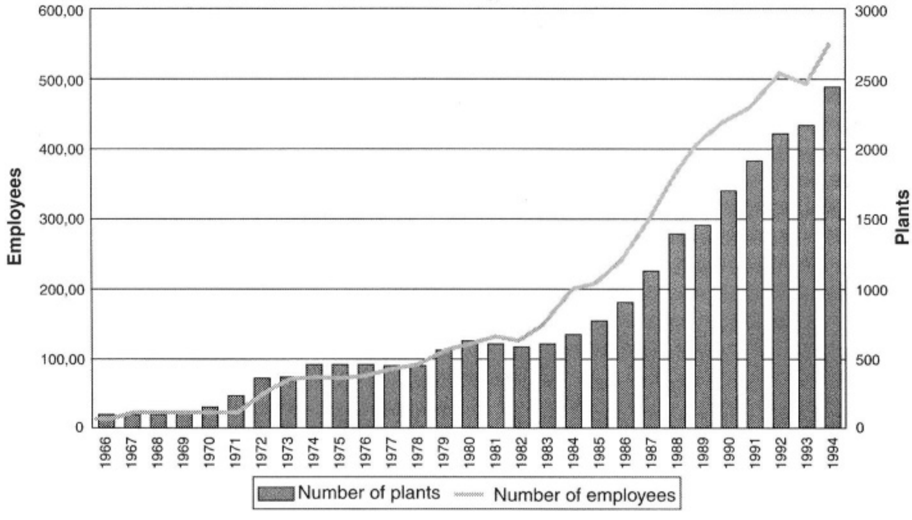

Figure 1: Growth in maquiladora manufacturing in Mexico (data from Lorey DE, ed.1993. United States–Mexico Border Statistics Since 1900: 1990 Update. Los Angeles: UCLA Lat. Am. Cent. Publ., UCLA Prog. Mex.), reprinted from Liverman, D., R. Varady, O. Chavez, and R. Sanchez (1999), "Environmental Issues along the U.S.-Mexico Border: Drivers of Change and Responses of Citizens and Institutions." *Annual Review of Energy and the Environment*. Vol. 24, Nov. 1999.

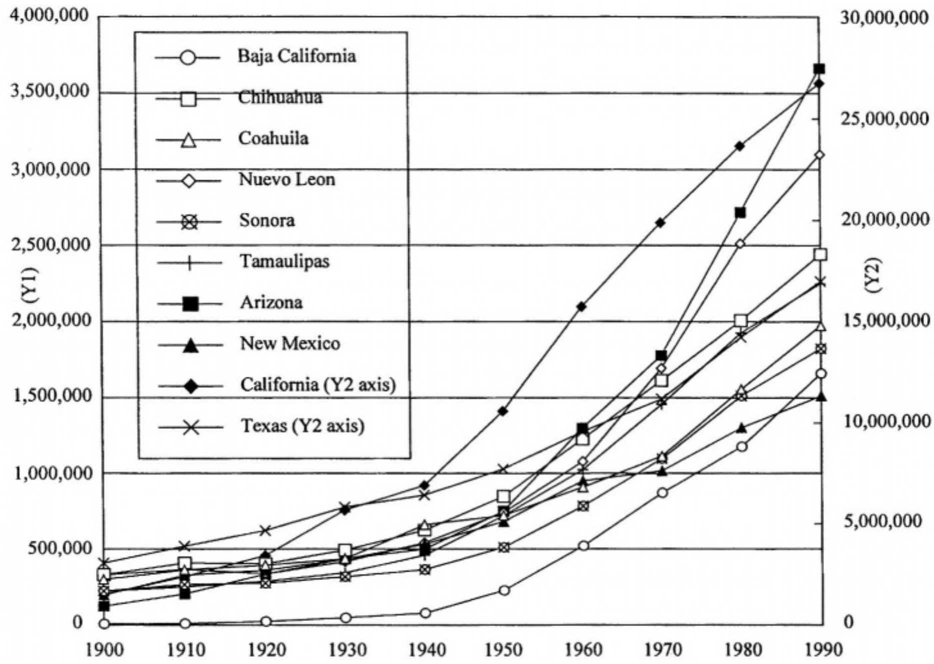

Figure 2: Population of United States-Mexico border states (data from Lorey DE, ed.1993. United States–Mexico Border Statistics Since 1900: 1990 Update. Los Angeles: UCLA Lat. Am. Cent. Publ., UCLA Prog. Mex.), reprinted from Liverman, D., R. Varady, O. Chavez, and R. Sanchez (1999), "Environmental Issues along the U.S.-Mexico Border: Drivers of Change and Responses of Citizens and Institutions." *Annual Review of Energy and the Environment*. Vol. 24, Nov. 1999.

states of Mexico was 2.9 million, whereas by 1995, the population had increased to over 4.7 million. Population growth in and of itself is not necessarily a driver of hazardous-materials production, but it places burdens on municipal infrastructure to maintain environmentally sound living conditions, most particularly sanitation and wastewater treatment. Only about a quarter of the water consumed in Mexico's border states and a fifth in the region's municipalities is treated.[9] Thus, if sludge from the treatment of more sewage water was produced, population growth could be a more important driver of hazardous-waste generation.

Use and release of hazardous or toxic substances can affect a community's quality of life in different ways, most commonly as follows:

- Via the risks of pesticides to human life and ecosystems in intensively cultivated regions, especially irrigated areas in Baja California, Chihuaha, Sonora, Tamaulipas, as well as in the workforce in industrial plants;
- Through the exposure to toxic substances associated with industrial plants and illegal disposals, which with poverty and inadequate housing, contributes to health problems in urban zones, particularly in unplanned communities, or colonias (Liverman, et al., 1999).

Clearly, hazardous materials constitute an important environmental threat in both the United States and Mexico. For a number of reasons—industrialization, urbanization, and susceptibility to flooding—the border region presents distinct challenges to resolve these concerns. We include here some management solutions that have been proposed at various times.

Management Methods of Hazardous Materials

In the United States

Methods

The major hazardous-waste management methods in the United States relate to the recovery of metals and solvents for reuse, incineration, energy recovery, fuel blending and stabilization, and landfills. Table 7 indicates the number of tons managed in the United States with those methods.

Table 7: Tons of RCRA Hazardous Waste Managed in 1997

Off-site management method	Tons managed	Percentage of total
Metals recovery (for reuse)	819,868	*12.0*
Solvents recovery	530,703	*7.8*
Incineration	531,693	*7.8*
Energy recovery (reuse as fuel)	901,439	*13.2*
Fuel blending	1,324,814	*19.5*
Stabilization	1,119,623	*16.4*
Landfill	946,673	*13.9*
Deep well/underground injection	488,340	*7.2*
Other	147,776	*2.2*
Total	6,810,929	*100.0*

Source: U.S. EPA, National Biennial RCRA Hazardous Waste Report, 1997.

The hazardous-waste management industry

Many large petrochemical and chemical companies manage hazardous materials and wastes on-site. These include companies such as DuPont, Exxon, Shell, and Dow Chemical. Companies that specialize in the treatment of hazardous materials offsite include Safety-Kleen, Burlington Environmental Services, and U.S. Ecology. In addition, cement companies engage in energy-recovery methods and in the incineration of hazardous wastes.

In Mexico

Less than seven percent of the 48,500 industries in Mexican border states reports to their hazardous materials generation and handling environmental authorities. Those enterprises that do report appear to be the ones that have the largest quantities judging by the fact that the 3000 or so industries that supply this information account for nearly half of the amount reported. In general, few data exist regarding the amount or portion of hazardous materials that are adequately managed (so as to minimize risk to humans or to the environment) in Mexican border states. The Mexican government estimates that 12 percent of the hazardous waste generated in the whole country is adequately managed.[10] The rest is commonly disposed of improperly or illegally into the environment, threatening water bodies, soils, aquifers, and other natural resources, as well as workers and residents in many border communities. Of the 166 illegal hazardous waste sites found by PROFEPA (Mexico's environmental enforcement agency) between 1995 to 1997, 65 were located within the six border states.[11]

During the 1990s the hazardous-materials-management sector grew considerably in Mexico. Just over half of the enterprises that manage hazardous materials are in the border region. Of these, 60.3 percent recollect and transport the materials, 17.1 percent confine them, 15.9 percent recycle them, and 0.8 percent treat the materials (Table 8). These enterprises manage not only hazardous materials generated in Mexico but also those imported from the United States. In 1998, for example, 284,800 tons of hazardous materials generated in the

United States were imported and managed in Mexico, while only 21,800 tons generated in Mexico were exported to the United States (INEGI/SEMARNAP, 1999).

The growth of this sector has been driven by Mexican policies (such as the Integrated Centers for Handling, Recycling and Disposal of Hazardous Waste, CIMARIs), the infrastructure available in Mexican states, lower costs for management and transport than in the United States, a relatively weak regulatory environment,[12] and the interests of U.S. and Mexican enterprises in this market. The key problem, as Table 8 suggests, is that the border region lacks a comprehensive, coordinated treatment strategy that includes treatment, recycling, or technically adequate confinement.

Table 8: Number of companies managing hazardous wastes in Mexico

State	Recollect & transport	%	Confine temporally	%	Recycle	%	Treat & incinerate	%	Confine	%	Total	%
Baja California	25	*59.5*	9	*21.4*	8	*19.1*	0	*0.0*	0	*0.0*	42	*100.0*
Coahuila	10	*58.8*	0	*0.0*	6	*35.3*	1	*0.0*	0	*0.0*	17	*100.0*
Chihuahua	18	*66.7*	6	*22.2*	2	*7.4*	1	*0.0*	0	*0.0*	27	*100.0*
Nuevo Leon	63	*61.8*	11	*10.8*	19	*18.6*	8	*1.0*	1	*1.0*	102	*100.0*
Sonora	6	*46.2*	4	*30.8*	2	*15.4*	0	*7.7*	1	*7.7*	13	*100.0*
Tamaulipas	22	*57.9*	9	*23.7*	1	*2.6*	6	*0.0*	0	*0.0*	38	*100.0*
Mexican border states	144	*60.3*	39	*16.3*	38	*15.9*	16	*0.8*	2	*0.8*	239	*100.0*
Mexico	279	*49.2*	94	*16.6*	127	*22.4*	63	*0.7*	4	*0.7*	567	*100.0*

Source: INEGI/SEMARNAP (1999, 535)

The reporting behavior of maquiladoras has varied widely from one industry to another, from one state to another, and according to management approaches of individual facilities. Taken as a whole, the maquiladora sector often is not in compliance with existing statutes. According to available data, in 1996-1998, between 60.1 and 64.8 per cent of the maquiladoras reported waste returned to the United States, while in 1997-1998, between 37.6 and 40.1 percent of the maquiladoras reported having shipped hazardous wastes back to the United States. The picture gets worse when considering that the amount of returned hazardous wastes decreased continuously from 19.8 percent in 1996-1997, to 2.2 percent in 1997-1998, and to –4.3% in 1998-1999, while the imported inputs increased an average annual rate of 25.3 percent during 1996-1999 (INEGI/SEMARNAP, 1999, 419 and 534; cf. Perry et. al).

We have attempted to paint a picture of hazardous materials in the U.S.-Mexico border region to better understand how current and proposed policies and institutional changes may affect the progress that has been made in treating hazardous materials. As mentioned above, we have identified three key institutional processes that may significantly alter how hazardous materials are treated: changes in government, transnational institutional developments, and the liberalization of NAFTA rules.

Government Policies through the Year 2000

In both Mexico and the United States, elections in the second half of the year 2000 brought new governments, each representing the party previously in opposition. In both countries the incumbent administrations signaled major ideological and policy changes in numerous arenas. In Mexico, electors put an end to seven decades of rule by the Revolutionary Institutional Party (PRI) and provided Vicente Fox with the opportunity to introduce across-the-board political and procedural reform. In the United States, the administration of George W. Bush, operating on much less of a mandate, nonetheless determined to review and revise previous policies, especially in regard to environment and energy.

In each case, approaches to confronting such transboundary problems as water management, environmental protection, and hazardous-materials management are likely to undergo significant alteration. At the time of this writing, it is too early to determine the exact nature of such changes. If preliminary indications are a guide, Mexico seems poised to promote increased openness, transparency, and public participation in environmental decisionmaking—even while strongly supporting economic development. United States policy toward the border is less clear, but by mid-2001, although the Bush administration had established good rapport with its southern neighbor, it had evinced little commitment to environmental sustainability. A brief review of past policies regarding hazardous materials can help set the stage for a look at recent developments.

Policies in the United States

In the United States, state and federal regulation of hazardous materials began in earnest in the 1970s. Until that time, most industrial waste was disposed of in landfills, stored in surface impoundments, discharged into surface waters, or incinerated (Jacott, et al., 2001). Three major federal laws now regulate the management of hazardous materials. Table 9 outlines these laws:

Table 9: Major federal laws that guide the management of hazardous materials

Resource Conservation and Recovery Act (RCRA) of 1976 (reauthorized in 1980 and 1984)	▪ Creates step-by-step management approach restricting and controlling the treatment, storage, and disposal of hazardous waste ▪ Mandates a permit system ▪ Implements tracking system for hazardous waste from the point of generation to disposal
Safe Drinking Water Act of 1974 (amended in 1986 and 1996)	▪ Protects groundwater sources of potable water ▪ Regulates the injection of industrial and hazardous wastes underground and into deep wells
The Comprehensive Emergency Response, Compensation and Liability Act (CERCLA) of 1980 (amended in 1986 as the Superfund Amendment and Reauthorization Act)	▪ Created $1.6-billion-dollar Superfund to address spills of hazardous materials and cleanup of abandoned hazardous waste sites ▪ Requires major industries to report releases, transfers, and recycling of toxic chemical to the US EPA.

Source: adapted from Jacott, et al., 2001.

With these baseline laws, under the Clinton administration (1993-2000), the U.S. government significantly tightened the regulation of hazardous materials; at the same time it loosened some of the reporting requirements. According to analysis by the Texas Center for Policy Studies, the Land Disposal Restrictions Phase II, III, and IV (LDR) Rules were among the most important hazardous-waste measures taken since 1994. These regulations raised the treatment levels required for waste generated in the United States. The impact of these US EPA rules in addition to others that were passed between 1994 and 2000 ranged from the shifting of materials management to commercial off-site facilities to more specialized treatment regulations (Jacott, et al., 2001).

Inspection rates for these US EPA rules and other environmental regulations have varied within the United States. In particular, during the most recent years, inspection rates in the U.S.-Mexico border region consistently have remained lower than the national average. Table 10 indicates the proportion of treatment, storage, and disposal (TSD) facilities that were inspected by the US EPA and state agencies between 1995 and 1999. Perhaps because of these relatively lax inspection rates in the border region, the percentage of facilities found to be in serious noncompliance is not shown to be higher than elsewhere (Table 10).

Table 10: Percentage of treatment, storage, and disposal (TSD) facilities inspected by the US EPA and state agencies

Region	Texas (%)	California (%)	US/Mexico Border states (%)	US total (%)
% TSDs inspected				
1995	*61*	*53*	*59*	*65*
1996	*34*	*29*	*34*	*21*
1997	*33*	*24*	*29*	*33*
1998	*48*	*33*	*42*	*59*
1999	*50*	*34*	*44*	*63*
%TSDs in significant non-compliance				
1995	*18*	*7*	*15*	*4*
1996	*10*	*2*	*7*	*7*
1997	*9*	*1*	*5*	*6*
1998	*16*	*1*	*10*	*14*
1999	*15*	*0*	*8*	*13*

Source: FY 95-FY97 US EPA, State-by-State Enforcement Data Summaries -adapted from Jacott, et al., 2001.

During the late 1990s, the US EPA placed greater emphasis on enforcing hazardous-materials transportation regulations. For instance, between 1996 and 1998, the US EPA filed enforcement actions against transport and TSD companies that did not comply with export or import regulations (Cooke, 1998 as cited in Jacott, et al., 2001). In July 2000, the U.S. EPA fined Chambers Belt Company of Phoenix, Arizona; Broker Inc. of Nogales, Arizona; and Maquiladora Chambers de Mexico, S.A. de C.V. of Pitiquito, Sonora, Mexico for illegally shipping flammable hazardous wastes to facilities not authorized to receive the waste. Additionally the companies were fined for improperly labeling, packaging, and completing the documentation for the waste (US EPA Region 9, July 25, 2000). This action represented the first time that a Mexican company was fined under U.S. environmental law. These policies and actions indicated an important move by the Clinton administration toward regulating hazardous materials and enforcing relatively progressive environmental policies.

Tracking hazardous materials: HAZTRAKS

As indicated, hazardous-materials accounting has proven inadequate in both the United States and Mexico. In an attempt to track hazardous materials (hazardous wastes in particular), the U.S. EPA developed a computer-based system known as HAZTRAKS, which traces industry-specific data for hazardous wastes shipped from Mexico. Mexico's tracking system, until recently relying upon so-called Guias Ecologicas, or Ecological Permits, offers different data. The reason for the discrepancy in reporting is due to the differing definitions of hazardous wastes in the United States and Mexico. Also, the shipment manifests for hazardous wastes leaving Mexico reports permitted amounts shipped rather than actual amounts (Jacott, et. al, 1999). Table 11 underscores the great divergence in reported data cited by the U.S. and Mexican environmental authorities.

Table 11: Reports of hazardous materials transport from Mexico to the United States by HAZTRAKS versus INE (in tons)

Year	HAZTRAKS (EPA)	Border Maquilas (INE)
1995	8,510	33,187
1996	6,983	72,113
1997	11,057	76,808

Source (EPA 1998) Source (INE 1999)

More recently, Mexico changed its hazardous waste export permit requirements for maquiladoras to a five-day return warning (Aviso de Retorno) and unveiled a still incomplete tracking system, SIRREP (Sistema de Rastreo de Residuous Peligrosos), which reports actual rather than permissible shipments. This tracking system is designed to be complementary to HAZTRAKS, which itself has been updated and reorganized. Cyrus Reed of the TCPS cautions that, "until we have a full year of SIRREP operating it will be difficult to see if the discrepancies will be worked out" (personal communication, 9/01).

Maquila-generated hazardous materials obviously form only part of all hazardous materials generated in the region. Procedural orientations account for a portion of the difference in the figures; for instance, of the more than 2,000 maquilas located in the border region in 1997, fewer than 40 percent could be found in the HAZTRAKS 1997 database (Jacott, et al., 1999).

Individual U.S. states are responsible for a large part of environmental regulation enforcement of hazardous materials facilities. Table 12 shows the border state breakdown of facilities inspections and noncompliance:

Table 12: Number of facilities, facilities inspected, and those in significant non-compliance in U.S. states, the U.S.-Mexico border region, and the United States as a whole

State	# Facilities	# Facilities inspected	# Facilities in significant non-compliance
Arizona	8	6	1
California	16	7	0
New Mexico	4	4	0
Texas	34	18	7
Total 100 kilometer zone	62	35	8
National	3,096	1,961	354

Source: Office of Enforcement and Compliance Assistance, U.S. EPA. Adapted from Jacott, et al., 2001.

U.S. Customs personnel are the primary enforcers of environmental laws and regulations for the transboundary crossing of hazardous materials; the US EPA is not represented at the ports of entry (see Mignella, 1997). In addition to U.S. Customs officials, several states have endeavored to implement transborder shipment inspections of trucks crossing the U.S.-Mexico border. For example, the Arizona Department of Environmental Quality recently began the Hazardous Waste Border Surveillance, Compliance and Enforcement Program (Border SCEP), in which U.S. customs officials are trained by officials from the Pima County Department of Environmental Quality on RCRA regulations, sampling procedures, and proper inspections (Jacott, et al., 2001).

U.S.-sponsored research on hazardous materials

Even while, at various levels, numerous government agencies in the United States design and implement a complex array of public policies on the management of hazardous materials, the federal government has been sponsoring basic and applied research on the subject. At the national level, where most research is conducted or commissioned, the most influential agencies have been the U.S. EPA, the National Institute for Environmental Health Sciences (NIEHS), and the Agency for Toxic Substances and Disease Registry (ATSDR), sometimes working in tandem. In keeping with the nation's model for conducting scientific research, the work is done either directly at government laboratories like those at US EPA's Research Triangle Park in North Carolina, or under contract at major universities.

Because of the human-health implications of the presence of hazardous substances in the environment, the U.S. Department of Health and Human Services plays an important role in defining the research agenda and funding its execution. Within the Department's National Institutes of Health, NIEHS is the agency charged with advancing the state of knowledge. Following the mandate accorded by the 1986 amendment and reauthorization of CERCLA, NIEHS established a Superfund Basic Research Program (SBRP). The agency operates this program via a network of 17 university-based centers encompassing 70 collaborating institutions. Funding for this effort has grown from less than \$5 million in its first year to \$30 to \$40 million annually since 1992. Of the 17 centers, three are in the southwestern United States, including the newest affiliate at the University of California at San Diego (Figure 3). Of the two others—at The University of Arizona and at Texas A&M University—the one in Arizona primarily has been responsible for conducting research on U.S.-Mexico transboundary toxics.

The special attention to the border region and, by extension, to hazardous-materials problems elsewhere in Mexico has been driven by several factors. First, NIEHS and its sister

Figure 3: NIEHS-funded university-based Superfund Basic Research Program centers, 2000-05.
Source: NIEHS/EPA (http://benson.niehs.nih.gov/sbrp/Program2000/Progloc2000.cfm)

agencies have recognized the importance of and the potential impacts of industrialization in the border region. Second, they have tried to address the paucity of basic research conducted on the fate, transport, and effects of metals and other toxic substances that are commonly present in the area. And third, they have been mindful of the gaps in infrastructure, expertise, and university-based capacity in Mexico. Partly in response to these priorities, since the early 1990s the work at the Arizona center has been achieved through a series of binational conferences and workshops, cross-border training and educational exchange programs, peer-reviewed basic research projects, and publications. Beginning in 1998, in collaboration with the other regional SBRP centers and researchers in Mexico, the Arizona program has attempted to promote the establishment of a binational university-based consortium directly charged with (1) conducting research on hazardous-materials issues affecting the two countries and (2) with narrowing the gap in capacity between the two countries (Varady, et al., 2000).

Policies in Mexico

Since 1988 the Mexican government has undertaken some significant efforts to define and manage hazardous materials more clearly. Under President Carlos Salinas de Gortari (1988-1994), authorities concentrated only on the risky features of hazardous materials themselves, i.e., on the CRETIB criteria. However these agencies rarely considered other factors that also can influence the danger of a substance, such as the features of its disposal site. Under Ernesto Zedillo's administration (1994-2000), Mexican authorities applied the concept of "life cycle" to hazardous materials. The life cycle concept is a relatively more comprehensive approach that leads to regulation of hazardous materials from cradle to grave—their production, transport, use, and final disposition (SEMARNAP, 1997; INE, 2000). Officials distinguished between "priority" and "non-priority" substances, and stated that priority toxic substances are generated by humans, and have three features: toxicity, persistence, and bioaccumulativity.[13]

Mexican authorities have designed a number of laws, instruments, and programs aimed at managing hazardous materials. The schemes designed during the Salinas administration tended to concentrate on the features of hazardous materials and wastes. Seven Mexican Official Standards (NOMs)[14] characterized the features of these substances and listed the requirements to be fulfilled by landfills and sites for hazardous wastes. This approach to management identified waste disposal as the preferred means of managing hazardous materials. The 1988 General Law for the Ecological Equilibrium and the Protection of the Environment (LGEEPA) gave federal authorities total control of the management of hazardous materials (their management is hence centralized), banned the import of hazardous wastes for final disposal and landfill into Mexican territory, and imposed on maquilas the obligation to send their wastes back to the country of the input's origin (Articles 150-153), which was described previously.

In keeping with the life cycle approach advocated by the Zedillo administration, the government introduced revisions to the LGEEPA related to hazardous materials. The revised general law emphasized preventive actions like reuse and recycling, and stipulated that the generators of hazardous materials would be responsible for their management. The law distinguished between "low," "medium," and "high" levels of hazardous materials, and opened the doors for state authorities to manage the low-level materials—an early sign of the Zedillo government's attempt at decentralization of responsibilities and resources. The original law's prohibitions regarding import and export of hazardous wastes and their return by maquiladoras were maintained. Streamlining the implementation of the 1996 modifications permitted exporters and importers of these materials to obtain a single annual authorization instead of authorizations for each shipment, as was previously required (Articles 145-153 and INE 2000).

Other relevant regulations were introduced during the government of Zedillo. For example, early in his term, in 1995, the government approved a NOM for the management of medical waste. But at times, specific ad-hoc decisions were made, as when 26 cement kilns and electrical plants received temporary authorizations to incinerate hazardous wastes, without any standard to regulate this action. At other times, official made decisions in order to simplify management procedures. For instance, since 1998, instead of having to follow ecological guidelines (Guias Ecologicas) for returning their hazardous wastes, maquilas now are simply required to inform environmental authorities about their shipments. In contrast to those of the U.S., Mexican requirements for reporting hazardous-waste generation and transport are irregularly enforced or complied with, and reporting is voluntary under the new PRTR (Pollutant Release and Transfer Registry).

Since the late 1980s a number of the federal agencies responsible for management of hazardous substances have taken steps to coordinate their efforts.[15] The most notable attempts have been the establishment by the Commission for the Control of the Process and Use of Pesticides, Fertilizers, and Toxic Substances (CICOPLAFEST, 1987) at the national level and the State Committees of Pesticides, Fertilizers, and Toxic Substances (COESPLAFEST) at the state level.

For the past five years Mexican authorities have promoted the establishment of an institution to dispose, recycle, and treat hazardous wastes (SEMARNAP, 1996). This proposed institution, the Integrated Centers for Handling, Recycling and Disposal of Hazardous Waste (CIMARIs), is intended to rely on a National Atlas of Risk. The atlas was expected to identify appropriate sites for the establishment of CIMARIs on the basis of geological, climatic, hydrological, seismic, and ecological characteristics, but was never released publicly as had been announced. According to a recent report by the Texas Center for Policy Studies, "as of 1998, eight Mexican companies – most of whom have a U.S. partner – had been approved by INE as meeting the technological requirements to set up a CIMARI, though the standards have yet to be approved. However, the first company to attempt to open a CIMARI failed, due to citizen opposition and irregularities in the approval of an Environmental Impact Assessment" (Jacott, et al., 2001: 27).

Notwithstanding these efforts, Mexico still faces serious limitations and challenges to managing hazardous materials. First, the nation lacks accurate or reliable information regarding amounts and types of hazardous materials generated in the different regions and by the various economic sectors. Then, what little information is available tends to concentrate on hazardous wastes and not on the entire life cycle of these materials. And, as with the Atlas of Risks, most information of hazardous materials remains unavailable to the public-at-large.

Expectedly, management schemes designed during the Salinas and Zedillo administrations are sometimes contradictory and frequently prone to gaps. Some of these plans consider hazardous wastes, while others try to regulate the full cycle of hazardous materials. Moreover, Mexico lacks potent statutes such as CERCLA (the U.S. Superfund Law) to regulate the use of these substances and to improve civil responsibility for environmental damages related to hazardous materials. Management instruments also exhibit problematic contradictions. For example, some strategies such as the authorization to incinerate hazardous wastes are antithetical to the emphasis other strategies assign to preventive actions. What these strategies often have in common is that they tend to lack standards for their regulation.

Mexico's ministry of environment has traditionally been accorded less decisionmaking power, smaller budgets, and fewer resources than other Mexican ministries. This relative weakness is reflected in the frequent changes in mission assigned to the ministry and the accompanying name changes. Since 1990, it has been incarnated as SEDUE (environment and urban affairs), SEDESOL (environment and social development), SEMARNAP (environment, natural resources, and fisheries), and most recently SEMARNAT (environment and natural resources). During 1999, for instance, SEMARNAP only received 5.9 percent of the part of the federal budget provided to the ministries; it allocated 77 percent of its resources for the management of water infrastructure (via the water commission, CAN) and distributed the remaining quarter among too many divisions for these programs to prove effective. More insidiously, the policies of other ministries and the sometimes antithetical requirements of international trade agreements and multinational institutions often counteract the piecemeal impacts of the ministry’s environmental strategies (Romero, 2000). That was the case with the manufacturing firm Metalclad. On August 30, 2000, the International Centre for Settlement of Investment Disputes (ICSID), a decentralized arm of the World Bank, ruled that the Mexican government had to pay US$ 16.7 million to Metalclad for not having allowed the company to open its hazardous-waste landfill in San Luis Potosí.

The implementation of designed schemes is further limited by insufficient communication and cooperation among federal and border-region agencies, a lack of social legitimation for many actions, and a continuing shortage of human and technical resources and equipment to enforce environmental regulations. The Metalclad case illustrates the first limitation. The case of Metales y Derivados provides an example of weak enforcement of existing environmental laws. Metales y Derivados was a subsidiary of New Frontier Trading Company, a wholesale metals company based in San Diego that handled toxic and dangerous chemicals. After repeated attempts of the Mexican environmental agencies to force Metales y Derivados to treat or repatriate its hazardous materials to the United States, the owner of the company simply abandoned the site. According to PROFEPA (1999) only 52 percent of the nation’s hazardous-waste generators, 44 percent of their management companies, and 60 percent of the medical-waste-management companies comply with environmental regulations. On three occasions, within the framework of Articles 14 and 15 of the North American Agreement for Environmental Cooperation, NGOs filed complaints against Mexican authorities for failing to enforce environmental laws against companies managing hazardous wastes.[16]

Finally, until recently policies have not featured transparency, public participation, or conflict management. As a result, Mexican citizens have palpably less access to environmental information and to courts than their northern neighbors.

As presently administered, Mexican environmental regulations try to promote social involvement by means of the following techniques:

- Public consultation and agreements (LGEEPA, Articles 157-159).
- The practice of “denuncia popular,” which is the right of any citizen to report to PROFEPA any actions that can damage the environment (LGEEPA, Articles 189-204).
- A petition of review (“recurso de revisión”), which any affected citizen can present so that authorities might reconsider, suspend, or nullify any governmental action or program that might adversely impact the rights of individuals, society, or ecosystems (LGEEPA, Articles 176-181).

These mechanisms for accommodating social involvement are driven by democratic impulses, but in practice their effectiveness remains limited. One obstacle is bureaucratic thinking conditioned by generations of slow change. As a manifestation of this entrenchment, many officials see social involvement as limited to garnering support from targeted groups by implementing temporary programs, rather than working with communities to address fundamental issues. This approach commonly leads to strong public opposition—often based on fundamental issues of social and economic acceptability rather than on technical grounds—that might have been resolved earlier through a more solicitous approach. The last two mechanisms of participation, "denuncia popular" and "recurso de revision," face structural implementation problems. Citizens and social organizations are required to present evidence that the agent in question actually has caused environmental, social, and/or individual damage. It is not easy to establish such direct relations—a situation compounded by the difficulty of successfully pursuing demands within Mexico's arcane, bureaucratic justice system. In the end, as many plaintiffs have discovered, PROFEPA is not armed with enough decisionmaking power and resources for it to guarantee the compliance of statutory environmental regulations.

The Role of Binational and Trinational Institutions

The United States and Mexico, by virtue of their proximity and shared border, have long maintained a set of binational agreements governing mutual relations and shared resources. In the realm of environment and natural resources, the earliest such accord concerned what has been arguably the border region's most valuable commodity: water. In 1889, the International Boundary Commission began operating. That commission merged in the early 1930s with the International Water Commission, forming the present International Boundary and Water Commission (IBWC) in the United States and its Mexican counterpart the Comisión Internacional de Limites y Aguas. Since the establishment of the IBWC, particularly over the past 20 years, the two countries have adopted a number of diplomatic, administrative, and legal arrangements—sometimes in the form of new organizations—that address environmental and natural-resources issues in the border region. Additionally and simultaneously, interest in and promotion of action on those issues has grown markedly in the informal sector, among NGOS and community-based organizations (CBOs).

Some of the institutions that have arisen to address environmental problems are broadly construed while others feature narrower, more specific agendas. In view of the above-stated importance of water, nearly all of these address some aspect of water management–allocation, sanitation and assurance of quality and human health, habitat preservation, infrastructure and financing, fisheries exploitation and protection, industrial and agricultural use, and navigation. Several but not all of these institutions and agreements include provisions to address problems concerning toxics and hazardous materials. These include, most relevantly, IBWC/CILA, the La Paz Agreement, Border XXI, NAEEC/CEC, BECC, and NADB. Below, we include a brief review of the salient characteristics of these institutions as they relate to the subject of this chapter.

- *IBWC/CILA.* These two commissions, which work in tandem from headquarters in El Paso, Texas, and Ciudad Juárez, Chihuahua, respectively, are broadly responsible for allocating the waters of the border region's two large rivers: the Rio Grande/Río Bravo and Colorado. In addition, over the years they have provided for some of the region's wastewater-treatment infrastructure via binational treatment plants; constructed dams; and storage, flood-control, and hydroelectric facilities. In view of their broad mandate, IBWC and CILA have had little involvement with hazardous-waste issues, except insofar as these have related to the handling of such substances in sewage-treatment plants.

- *La Paz Agreement.* Also known as the Reagan-de la Madrid Accord, for the two signatory presidents, it was intended as the first comprehensive environmental instrument between the two countries. The accord addresses a slate of issues of mutual concern and functions by means of a series of technical working groups. Nine such groups now function, including one that deals with solid and hazardous waste rather than the larger category of hazardous materials. Unlike previous treaties negotiated by diplomats, the La Paz Agreement is not limited to representatives of the foreign ministries and stipulates the inclusion of the two environmental ministries and the 10 state governments.

- *Border XXI Program.* This binational framework for transborder environmental cooperation was initiated during the Clinton and Zedillo administrations. It was intended as a successor to the flawed Integrated Border Environment Plan (IBEP), promulgated in the last years of the Bush and Salinas governments. Border XXI primarily has been administered by the US EPA and SEMARNAP (now SEMARNAT), with participation from other relevant ministries such as the U.S. Department of the Interior and the Mexican Secretariat of External Affairs. The program was intended to guide cross-border environmental policy. It stipulates nine areas of concern, each to be addressed, as in the La Paz Agreement, through a binational technical working group. Several of these groups have responsibilities for some aspects hazardous materials: hazardous and solid waste, contingency planning and emergency response, environmental health, and cooperative enforcement and compliance.

- *Commission for Environmental Cooperation (CEC).* The CEC is the trinational (United States, Mexico, Canada) organization created in 1993 by the NAFTA environmental side agreement (North American Agreement for Environmental Cooperation, or NAAEC). Its purpose is to address North American environmental concerns, help prevent conflicts between trade and environment, and promote effective enforcement of existing environmental statutes in the three participating countries. CEC's focus is not on the U.S.-Mexico border region, but rather on the entire North American continent. In the realm of hazardous materials, CEC has established a working group on environmental enforcement and compliance, and maintains a program on law and enforcement cooperation. In 1995, in its first year of operation, the CEC initiated a project to inventory and enforce North American laws regulating transboundary movement of hazardous wastes and chlorofluorocarbons (CFCs). The Commission also has facilitated a number of regional agreements on "sound management" of dangerous materials such as PCBs, mercury, and dioxins (Jacott, et al., 2001). With new governments in Mexico and the United States, the CEC may be in a state of transition and, under U.S. influence, may weaken its charter provisions permitting citizen complaints.

- *Border Environment Cooperation Commission (BECC) and North American Development Bank (NADB).* These two organizations were created in conjunction with NAFTA, through binational executive agreements between the United States and Mexico. Since their establishment, the two sister institutions have been charged with strengthening environmental infrastructure in the 200-km-wide border region. The two organizations were given different but complementary missions: The commission was to solicit proposals from needy border communities while the bank was to seek financing for those projects. For their first six years of operation, BECC and NADB limited their agenda to projects involving water supply, water pollution, wastewater treatment, municipal solid waste, and "related matters." Until 2001, by mutual agreement, the two institutions excluded projects addressing hazardous-materials management. As of this writing, BECC has certified 49 projects, 20 on the Mexican side and 29 on the U.S. side, at an estimated cost of US$1 billion dollars, and according to projections affecting nearly eight million borderlands residents.

- *Expansion of BECC/NADB mandate as of 2001.* Under pressure to extend their services, in mid-2000 BECC and NADB began exploring the possibilities of extending their mandates and thereby their zone of operation. In December 2000, in what could prove to be a meaningful development for hazardous-materials management in the border region, the boards of directors of the two organizations issued a resolution that, among other things, (1) defined projects qualifying as "related matters" to include industrial and hazardous-waste projects to the extent that the waste presents a pollution threat to water or soil, and (2) specifically extended BECC's purview to include environmental infrastructure projects of the "related matters" type (BECC/NADB, 2000). Although the boards did not act on another potential expansion, they left open the possibility that in the future, they would consider extending the BECC/NADB mandate beyond the currently accepted 100-km strip on either side of the frontier. Such a geographical expansion, coupled with the already-adopted topical expansion, could further increase the resources available for remediation of hazardous-materials-related problems.

- *Land Transportation Standards Subcommittee (LTSS).* The LTSS, like CEC, was created by NAFTA. Its purpose is to harmonize standards related to truck, bus, and rail operations and the transport of hazardous materials among the United States, Mexico, and Canada. While the LTSS was to have completed its work by 2000, the subcommittee's lifetime extends beyond this deadline. In the area of hazardous materials, the three NAFTA countries agreed to a set of hazardous materials transportation regulations, which has, according to the LTSS, substantially harmonized regulations regarding land transport of hazardous materials in the three countries. To supplement this action, and to provide consistent information, in 1999 the LTSS published the *Emergency Response Guidebook 2000.*

- Transportation Consultative Groups (TCG). Also a NAFTA-created institution, the TCG was established to address non-standards issues that affect cross-border movements among the three nations and other issues not specifically assigned to the LTSS. In regard to hazardous materials, the TCG is meant to facilitate cross-border information-sharing and exchange new technologies related to transportation, including the movement of hazardous substances.

As part of the binational framework described above, in December 1999, the US EPA and INE representatives to the Border XXI Hazardous and Solid Waste Working Group established a new "consultative mechanism." This new agreement commits the two countries to public disclosure of any information regarding existing and proposed hazardous- or radioactivewaste sites within 100 kilometers of their border. The protocol delineates the types of facilities in both countries that U.S. and Mexican governments must share information about. The implication is that each country—and by extension its citizens—should be able to participate in the decisionmaking process for proposed hazardous-waste treatment and recycling sites in the border region.

The Liberalization of NAFTA Rules on Movement of Hazardous Materials

A large portion of the total tonnage of hazardous material within the border region is itinerant, moving from one destination to another on its way to being used, processed, and eventually disposed of. The transient nature of these toxics makes them particularly difficult to track, monitor, and account for. This elusiveness combined with the marked dangers these materials can pose prompts special attention to knowing the location of hazardous substances throughout their life cycles. Accordingly, as the previous section has shown, a number of the institutions that oversee and regulate binational environmental conditions feature provisions requiring strict accounting of transport and residence of dangerous chemicals and other materials.

The original La Paz Agreement did not include specific language addressing the above issue, but Annex III of that accord (1986) fills this lacuna. That amendment states that so long as applicable, national, hazardous-waste regulations are met, each country must accept the return of such substances generated by production from raw materials imported under temporary import regimes.

NAFTA states that major bilateral and multilateral agreements on hazardous-waste transport and disposal should take precedence over NAFTA itself (Jacott, et al., 2001). Although NAFTA does not address maquiladoras specifically, many of the provisions in NAFTA have regulated the activities of maquiladoras' trade. As of January 1, 2001, the export requirements of maquiladoras changed under Article 304 of NAFTA. For instance, the stipulation that a certain percentage of goods sold must be exported outside of Mexico has been phased out. Without this requirement of export, some have suggested that maquiladoras may nationalize in order to avoid the repatriation requirements of hazardous wastes under the La Paz agreement. The extent to which this has impacted the maquiladora industry and the hazardous-waste repatriation is yet to be seen; however, if maquiladoras do nationalize, the picture of hazardous materials in Mexico may be even grimmer.

Prospectus

In this chapter, we have attempted to depict the status of hazardous-materials management in the U.S.-Mexico border region. For each of the two nations, we reviewed the principal problems and their major causes. And because this issue is embedded within the larger domain of binational environmental problems, we have discussed the most relevant policies and most commonly-used procedures for dealing with toxic substances. We also have strongly recognized that management of waste and toxics is controversial and that remediative measures are subject to large societal and political forces.

In this prospectus, informed by what has occurred over the past decades, we look ahead to the next several years. In particular, we try to gauge the impact of the two national elections of 2000 on environmental decisionmaking and on hazardous-materials policy.

U.S. government policies, post-2000

In preceding sections we have described briefly the most important U.S. laws that apply to hazardous-materials management in the border region. We have considered, too, the most recent attempt by the federal government to track the location of transboundary shipments of such substances, HAZTRAKS. But of course, national policies regarding environment--indeed all policies--change continuously. This process can only be understood within a fluid context shaped and reshaped by new administrations, legislatures, and local elected officials; shifting mid-level decisionmakers; and evolving public preferences and priorities.

In the United States the 1990s was a decade characterized by economic growth and prosperity; post-Cold War relaxation of international tension; a palpable rise in the level of activity and influence of environmental NGOs; and during the Clinton administration, a mostly sympathetic view of environmental protection. Within the executive branch of government, the relevant institutions—the US EPA, Department of the Interior, National Oceanic and Atmospheric Administration, and other agencies—exhibited a predominantly progressive approach toward problems of pollution, species protection, land preservation, global change, and environmental health. In a similar spirit, bilateral relations with Mexico were usually cordial, and in matters of mutual interests on the environment, largely constructive. In regard to the border region, the period was marked by a notable recognition of the value of public participation, transparency, and sustainability–attributes specifically assigned to the Border Environment Cooperation Commission (BECC; Milich and Varady, 1999). Public and official concern over transboundary hazardous-materials issues grew, propelled by the promise of increased, NAFTA-driven industrialization and commerce. In response, during the immediate post-NAFTA years, the two countries initiated a number of instruments and specific actions aimed to address those concerns (see section on binational and trinational institutions above).

Notwithstanding such generally pro-environmental official attitudes, some NGOs felt the administration did not go far enough in confronting issues such as cattle grazing, mining leases, growth containment, and toxics management. At the opposite pole, an appreciable number of property-rights advocates, resource-exploitation enterprises, ranchers, and developers opposed many of the policies and actions of the mid- to late-1990s.

As noted earlier, at the time of this writing, the current administration in Washington remains in its formative phase. But in regard to environmental positions in general, it has emitted a number of early signals: ultraconservative cabinet and senior-level appointments, many of them drawn from extractive industries or the energy sector; quick redirection of past policies and actions; notable reversals of campaign statements (most prominently, the cancellation of plans for carbon-emissions reductions, the repudiation of the 1997 Kyoto Accord; and the weakening of arsenic standards in drinking water); and pronouncements on possible future directions (greater emphasis on energy than on environment, increased drilling offshore and in protected areas, less public-lands protection, and more attention to property-rights demands).

As concerns Mexico, the current Bush administration has acted swiftly to strengthen economic ties, taking advantage of the ideological proclivities between the U.S. Republican Party and Mexico's newly-empowered conservative National Action Party (PAN). In another quickly-assumed posture--this one less favorably received in Mexico--the United States has moved rapidly to reaffirm its hard-line approach to illegal immigration and smuggling. But where does the new U.S. administration stand on environmental relations with its southern neighbor? More specifically, what can be expected in regard to hazardous-materials policy? Lacking firm declarations, it is necessary to extrapolate from some of the administration's early actions. Below, we list some of the emerging features of U.S. environmental policy and hazardous-materials policy for the border:

- The economic downturn that began in mid-2000 coupled with a corporate-friendly administration has already begun and is likely to continue to devalue environmental protection, citing its high cost. As the Superfund Program has demonstrated since its inception, hazardous-materials treatment and site remediation are extremely costly and lengthy procedures.

- The California energy crisis that began in the winter of 2000-01 has mobilized a strong reaction from fuel-exploration and development corporations, and a largely sympathetic U.S. administration. That reaction is marked by emphasis on developing new sources of energy over protecting fragile landscapes and ecosystems. The consequent push to extract more coal, oil, and gas–again justified in terms of reducing costs, this time of energy–militates against spending the amounts necessary to reduce the dangers of toxics.

- The professed emphasis on decentralization and devolution of authority to states and communities would strengthen local and regional autonomy. But in the western United States especially, that process also would embolden already strong private-rights groups, builders, developers, antigovernment activists, and antiimmigration advocates. Those and other similar interests typically oppose habitat preservation, environmental-infrastructural improvements in Mexico, the increased regulation and enforcement needed to reduce the prevalence of toxics in the border region, and tax expenditures on remediation of hazardous-materials sites.

- The Bush administration's quick about-face on raising arsenic standards for drinking water revealed two probable aspects of its policies. First, the action showed that the new head of the US EPA was easily and quickly overruled, raising doubts about the degree of influence she and the US EPA are likely to wield between 2001 and 2004. Second, the reversal indicates that tighter environmental standards and tougher regulation are unlikely policies.

- Finally, even in the first months of the new administration, there have been indications that the existence of the commission that certifies environmental infrastructure projects in the border region, BECC, may be challenged. The progressive features that distinguish BECC from most other transboundary environmental institutions may be the very ones that are objectionable to conservative critics. Thus, even while BECC moves to implement an expanded mandate that allows it to address hazardous substances, it may have to struggle to maintain its existence.

Of course, in view of the insufficient data on U.S. border policies toward hazardous materials, these conjectures could prove to be off the mark. Administrations, regardless of their initial ideologies, often change course to adjust to public opinion and to achieve re-election. Six months into its tenure, the Bush administration already may be feeling some of these pressures as the public-at-large reacts to what seem to be unpopular stances on environment and energy. And perhaps, in an attempt to gain favor in Mexico, the U.S. government will agree to continued cooperation on environmental issues.

Mexican government policies, post-2000

As in the United States, in mid-2001 the environmental policies of Mexico's PAN government have not fully crystallized. President Fox, like President Bush, heads a party that draws much of its support from conservative, business-oriented, landholding, and religious constituents. But because of the controversial legacy of the predecessor party, the PRI, Fox was elected with a substantial majority and expected to reform Mexican government, if not society.

In his early actions, the Mexican president has been mercurial and sometimes surprisingly unconventional. His ministers span the political spectrum–from PANistas on the right to ex-members of the socialist opposition on the left. By and large, the strongest ministries--those that feature the largest budgets and the most influence--have been awarded to neoclassical economists, business leaders, and other influential leaders. The secretariat of external affairs (SRE, the counterpart of the U.S. Department of State), by contrast, is run by a former member of the Revolutionary Democratic Party (PRD), the socialist opposition. That ministry plays an important role in transboundary affairs, especially in regard to water management (see IBWC above) and other issues requiring negotiated solutions.

In view of these early revelations, we can hazard a number of likely policies on hazardous-materials management. First, in general terms:

- President Fox's expressed desire to raise workers' salaries in the long run, to achieve parity with the salaries of their northern neighbors would reduce the advantageous position Mexico's borderlands in hosting maquiladoras. That decline would in turn reduce the amount of hazardous waste generated and material handled. However, achieving such parity is not presently considered realistic.

- The administration's determination to promote industrialization, productivity, and commerce in order to increase the GNP is a policy that, if successfully implemented, is likely to lead to increased generation of toxics.

- The external affairs secretariat, as noted, will remain influential in binational matters of all types, including water, environment, natural resources, and toxics issues. The ministry includes at least two environmental ambassadors. One, Ernesto Ruffo Appel, is a former governor of Baja California who was appointed as Mexican "czar" for North American issues. The other official, Alberto Székely, was the chief negotiator of the 1983 La Paz Agreement. Both can be expected to emphasize comprehensive, negotiated solutions to transboundary environmental problems. These appointments underline the importance of border environmental matters in the Fox administrations.

- Some Mexican authorities, who are dissatisfied with the design and implementation of Border XXI have suggested that this binational program should be replaced by another one—a step that could undermine the continuity of efforts undertaken by the working group on solid and hazardous wastes (see discussion of Border XXI above).

- As with the Bush administration, the Fox administration emphasizes decentralization and greater regional and local authority. In Mexico, with its strong tradition of centralized decisionmaking and resource allocation, devolution is a novel development and carries little of the political connotation of such moves north of the border. For hazardous-materials management, decentralization holds the promise of additional, easier-to-come-by financing and greater citizen participation in decisionmaking.

More specifically, early developments concerning the environmental ministry allow the following observations and conjectures:

- SEMARNAT was restructured and streamlined immediately after the President's inauguration. Following the recommendations made in early 2000 to candidate Fox by the "Grupo de 25," an ad-hoc group of influential citizens with environmental and political interests, the divisions that oversaw and regulated forestry and fisheries were moved to the agricultural ministry. The national water commission, CNA, also will likely be excised from SEMARNAT. These and other related alterations allow the ministry to focus more clearly on environmental protection, but they also reduce its budget and therefore its political clout.

- The President has named progressive Victor Lichtinger to head SEMARNAT and allowed him to appoint other like-minded subordinates. But notwithstanding President Fox's insistence that the ministries work as a team and that environmental issues will be integrated within Mexican public policies, SEMARNAT remains relatively weak and is vulnerable to domination by stronger and better-endowed secretariats (e.g., agriculture, commerce and industry, and finance). The issue of hazardous-materials management illustrates one such tension, since the "cleanup" forces and the economic-development forces typically oppose each other.

- As of mid-2001, SEMARNAT had not yet clearly and officially articulated the environmental-management strategies to be pursued for the next six years. During her participation in the influential Third Environmental Encuentro in Tijuana in April 2001, Isabel Studer, SEMARNAT's General Director for North America stated that the ministry has yet to finalize its objectives. In a signal that the secretariat wants to encourage public input, she invited participants, especially Mexican NGOs, to contribute to framing the agenda.

- In its first few months, the new SEMARNAT recruited and secured the services of a number of well-respected persons from academia and civil society. The secretariat was restructured to accommodate the views of these individuals and those of the minister. The organizational chart reveals, among other things, the establishment of a Coordination Unit for Social Participation and Transparency, an apparent and decidedly new commitment to openness, public input, and transparency– attributes not often associated with past administrations. These changes, along with Secretary Lichtinger's declarations to be ready to "give people the opportunity to complain in Mexico, modify the rules, or work for resolutions," suggest a less self-assured and more democratic approach to decisionmaking. The new administration recognizes the importance of hazardous-materials regulation, management, and remediation. The question is whether they will have the wherewithal to be effective.

- According to Secretary Lichtinger, hazardous materials will remain one of the top priorities of Mexican border environmental policy. But beyond this assurance, signals are vague and sometimes contradictory. Although the minister recognized that a new approach is needed to emphasize reduction of hazardous wastes—in addition to their disposal--he is not yet clear about how to change the regulations. His assistant secretary for environmental management, Raúl Arriaga, has indicated that any changes to the regulations should allow industry and other interest to invest securely.

- Minister Lichtinger committed to finalizing negotiations for a North American Agreement on Transboundary Environmental Impact Assessment. The draft agreement "requires federal authorities to notify their counterparts across the border of any project proposal they receive that has potential for significant adverse environmental impact in the neighboring country. Authorities and even citizens in the other country then would have a chance to provide input during the decision-making on the permit" (Nauman T., 2001). It is not clear whether Lichtinger will be able to secure final approval for this agreement, which has been delayed for almost three years.

- SEMARNAT, as one of its first major steps, redefined the mission of the Instituto Nacional de Ecológia (INE). The institute was granted additional autonomy and at the same time, it narrowed its focus to research. It previously had authority over a diverse set of environmental affairs, including, until recently, protected areas. INE also was instrumental in shaping government policies on hazardous materials since the national laboratories have been housed in that institute. Scientific work on that subject will now continue at INE, but standards development, regulation, and enforcement–once partly undertaken by INE staff–will be shifted entirely to the main offices of the secretariat.

How are we to read the signals of the new Mexican administration? As with the United States, cautiously but perhaps with a little more evidence of proclivities and likely policies. There is a delicate balance between corporate and "green" interests that has been carefully built into the federal government. Early steps by his administration suggest that President Fox wants to have it both ways: strong steps to build the economy and simultaneous efforts to improve environmental conditions and human health. Residents of the border, a region that voted strongly to oust the PRI, probably wonder if both objectives can be achieved.

Taken as a whole, our speculations imply a period of exceptional flux and uncertainty as the two neighboring governments struggle to define their environmental policies and their approaches to dealing with hazardous substances. But based on public pronouncements, available information, and actions during the first half-year of the two administrations, two trends concerning hazardous materials are discernible. The United States, under conservative leadership, likely will be reluctant to initiate innovative, new policies. Mexico, under pressure to make good on its promises for reform, can be expected to act more boldly and progressively.

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Endnotes

[1] The border region is often defined as a band extending 100 kilometers along each side of the U.S.-Mexico boundary; however, it should be noted that many statistics are generated, maintained, and reported at different levels of administration, such as U.S. states, counties, and communities and Mexican municipios.

[2] According to Cortinas (1998, 43) the central area of Mexico generates 65% of the total amount of hazardous wastes, while the northern border area generates 25%.

[3] It must be stressed that for both the United States and Mexico, and especially in the case of Mexico, statistics are spotty, irregularly maintained, and often unreliable.

[4] In the entire country, the generators are metal and machinery (26.1%), food (24.1%) and chemical enterprises (23.9%) according to INEGI-SEMARNAP (1998, 277) and Mercado, Alfonso (1998, 9).

[5] While Table 6 and Figure 1, which are drawn from different data sources, do not agree on numbers, they clearly show the same trend.

[6] According to ITESM/INFOMEXUS/SEMARNAP (1999: 93), 48.1% of Mexico's economically active population in the border states and 50.6% in the country at large receives around US$ 6.00 per day or US$ 2,190 per year in Mexican border states and in the whole country respectively. With this income they "can satisfy approximately 60% of their basic needs for food, dress, health, education, and transport." Although "minimum wages are approximately eight to ten times higher in the United States than in Mexico," workers in the Mexican border region have to pay for and live in a dollarized economy. Ganster, P. et.al. (2000: 9).

[7] The average intensity in the application of potasium and calcium of the regional agriculture (kg/hectare) exceeds the national media. INEGI/SEMARNAP (1999, 145).

[8] INEGI/SEMARNAP (1999, 530). According to Cortinas, C. (1998: 41), around 300- to 500-thousand tons of tailing are generated per day in Mexico. Between 1994 and 1999 nationwide use of pesticides increased 16.9%. INEGI/SEMARNAP (1999: 410).

[9]ITESM/INFOMEXUS/SEMARNAP (1999: 162, 163). Most of these treatment facilities (41%) are simple oxidation lagoons.

[10] ITESM/INFOMEXUS/SEMARNAP (1999: 214-215). According to INEGI/SEMARNAP (1999, 536-537), enterprises located in the Mexican border states are able to recycle 654,105 tons per year, but there is no precise information regarding the percentages of hazardous wastes managed (confined, treated, etc.).

[11] PROFEPA, (1998: Chapter V, Table 1). The principal wastes at these sites are solvents, hydrocarbons, heavy metals, foundry slag, chemical compounds, biological/infectious materials, and used oils and tailings.

[12] "Environmental controls for high temperature recovery units like Zinc Nacional – Monterrey – are significantly less than in the United States. For example, there are no financial assurance requirements associated with opening a metal recycling plant and liability costs are much lower. These differing regulations may give Zinc Nacional a cost advantage" Jacott, et.al. (2001, 57).

[13] Persistent substances have an average life in the environment of "two days in the air, six months in water, one year in sediments, and six months in the soil, and/or can be transported in long distances." SEMARNAP (1997, 13). Within the framework of NAFTA (Resolution 95-5), Mexico has taken actions aimed at reducing and – if possible – eliminating the use of polychlorinated biphenyls, DDT, chlordane, and mercury. SEMARNAP (1997, 36).

[14] i.e. NOM-052 to 058-ECOL-1993.

[15] The participating ministries are: Environment and Natural Resources (SEMARNAT); Health (SS); Agriculture, Livestock and Rural Development (SAGAR); Commerce and Industrial Promotion (SECOFI); and Communications and Transport (SCT).

[16] The companies are Metales y Derivados, based in Baja California, and CYTRAR and MOLIMEX, both in Sonora.

List of Acronyms

ATSDR: Agency for Toxic Substances and Disease Registry
BECC: Border Environment Cooperation Commission
Border SCEP: Border Surveillance, Compliance and Enforcement Program
CBOs: community-based organizations
CEC: Commission for Environmental Cooperation
CERCLA: Comprehensive Emergency Response, Compensation and Liability Act
CFCs: chlorofluorocarbons
CICOPLAFEST: Commission for the Control of the Process and Use of Pesticides, Fertilizers, and Toxic Substances
CIMARIS: Integrated Centers for Handling, Recycling and Disposal of Hazardous Waste
COESPLAFEST: Committees of Pesticides, Fertilizers, and Toxic Substances
CRETIB: corrosive, reactive, explosive, toxic, flammable, and biologically-infectious
EAD: electric arc dust
IBEP: Integrated Border Environment Plan
IBWC: International Boundary Water Commission
ICSID: International Centre for Settlement of Investment Disputes
INE: Instituto Nacional de Ecología, Mexico’s national institute of ecology
LDR: Land Disposal Restrictions
LGEEPA: General Law for the Ecological Equilibrium and the Protection of the Environment
LTSS: Land Transportation Standards Subcommittee NAAEC: North American Agreement for Environmental Cooperation
NADB: North American Development Bank
NGOs: Non-governmental organizations
NIEHS: National Institute for Environmental Health Sciences
NOMS: Mexican Official Standards
PRD: Revolutionary Democratic Party
PRI: Revolutionary Institutional Party
PROFEPA: Procuraduría Federal De Protección al Ambiente, Mexico's environmental enforcement agency
RCRA: Resource Conservation and Recovery Act
RMALC: Red Mexicana de Acción Frente al Libre Comercio
SBRP: Superfund Basic Research Program
SEMARNAT: Secretaría de Medio Ambiente y Recursos Naturales, previously SEMARNAP (environment, natural resources, and fisherie), SEDESOL (environment and social development), and SEDUE (environment and urban affairs)
SIRREP: Sistema de Rastreo de Residuos Peligrosos
SRE: Mexico’s Department of State
TCG: Transportation Consultative Groups
TCPS: Texas Center for Policy Studies
TSD: treatment, storage, and disposal
US EPA: United States Environmental Protection Agency

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PART V

BIOLOGICAL RESOURCES, TERRESTRIAL AND AQUATIC HABITAT PROTECTION

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Divergence in Californian Vegetation and Fire Regimes Induced by Differences in Fire Management across the U.S.-Mexico Boundary

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Introduction

Every year California experiences cycles of disasters produced by wildland fires that result in denudation of hillsides, flash floods, accelerated erosion, and destruction of homes. Modern fire suppression strategy in California and the United States, intended to prevent such disasters, is based on a nineteenth-century view that wildfire is wholly unnatural in ecosystems due to human ignitions. This mindset is popularized in slogans such as "Only you can prevent forest fires." The simplicity of this perspective presupposes man's power over nature. Indeed, no other natural hazard has been more underestimated than wildland fire. This is illustrated in the following word substitution game when Smokey the Bear says: "Only you can prevent earthquakes, only you can prevent volcanic eruptions, or hurricanes" – truly absurd perspectives. In large conflagrations, the energy release exceeds the energy of suppression by many orders of magnitude. Fire control is effective only in putting out very small fires or the very end of large dissipating fires. Society recognizes the power of geologic and atmospheric processes, yet is oblivious to the power of fire.

Evidence indicates that suppression aggravates the threat of wildfire by increasing fire size and levels of intensity that make it impossible to protect property and resources. Yet, the impact of suppression was never seriously questioned for most of the twentieth century because its legacy on ecosystems is one of unintended consequences that emerged slowly and subliminally. Only by 1970 did important debate emerge, after an outbreak of enormous conflagrations throughout southern California, including the 60,000 ha Laguna fire near San Diego.

Fire policy failed to recognize that in this Mediterranean-type climate, fire was a natural part of ecosystem evolution, and periodic fire was necessary for the maintenance of plant communities (Barbour and Minnich, 2000). The natural ecological role of fire is to rapidly oxidize the complex organic molecular structure of wood and foliage into simpler components, while releasing large amounts of heat. Fire is also essential in maintaining nutrient cycles in which organic matter, produced by photosynthesis from simple compounds, is ultimately decomposed and recycled back into simple compounds.

Decomposition is the slow oxidation of plant materials through grazing animals and ultimately by soil microbes and fauna. In California's mediterranean climate, however, decomposition of organic matter proceeds slowly because temperatures are too low for microbial

L. Fernandez and R.T. Carson (eds.), Both Sides of the Border, 385–402.

activity when moisture is available in winter. Thus, fuel tends to accumulate because the vegetation itself produces more organic matter—dead leaves, branches, and desiccated living material—than is decomposed. Fire becomes inevitable because of ecosystem properties that lead to the conservation of biological mass, in which photosynthesis is balanced by both slow oxidation and rapid oxidation in the form of fire. Although this equation describes a balanced budget, there is typically a time lag between fuel accumulation and burning so that the budget is balanced over longtime scales. How long depends on the ecosystem and management policy.

Today, the role of natural disturbance is widely recognized, and during the past 30 years, there has been a proliferation of research that address significant questions concerning fire regimes (number of fire events, size, intensity, vegetation damage, postfire successions). These include the following: (1) what was the baseline (presuppression) vegetation and fire regime; (2) what would happen without suppression (a corollary); (3) how has suppression altered that baseline; and (4) how can fire management optimize protection of watersheds, property, and resources. However, because suppression has been universally practiced for a century, the quantitative dimension of fire suppression impacts is difficult to study at the landscape scale because no pristine forests in California exist with unmanaged fire cycles to serve as comparative controls. Hence, scientific evidence on the extent to which suppression led to altered ecosystems and anomalous fuel buildup is uncertain to this day. Published reconstructions of past fire regimes and vegetation dynamics in California are usually indirect and involve the interpretation of local evidences that may not capture fire as a spatial process. Without concrete answers to these challenging inquiries, we cannot even address the most pertinent question: How can fire be reintroduced to restore stable ecosystems and ultimately to protect property and resources?

For these reasons, our research group has undertaken several studies in adjoining Baja California, Mexico (BCA) because a presuppression vegetation and fire regime baseline is a modern condition. Grasslands, chaparral, conifer forests, and desertscrub similar to that in Alta California cover northern Baja California (Minnich and Franco-Vizcaíno, 1998). The regions remoteness has helped to preserve a rural land-use pattern dating back to the Dominican mission period in the late eighteenth century: mostly cultivation of fruit trees and gardens near ranchsteads and transhumance cattle grazing by families rooted in the regions open-range livestock economy. Isolation has been accompanied by little or no fire control. This enduring traditional land-use system has resulted in a distinctive relationship between humans and nature that is unique within the Californian floristic province.

Societal differences in land management agendas have resulted in a natural experiment that has caused vegetation and fire regimes to diverge to the north and south of the U.S.-Mexico boundary (Minnich and Bahre, 1995). Our research has developed spatial databases to described uncontrolled fire regimes, using time-series aerial photographs from the present back to the 1930s. Vegetation change was also compared with transborder ground surveys. This study compares transborder vegetation and fire regimes in California, using chaparral and mixed conifer forests as examples. We describe vegetation and fire history on the Mexican side for comparison with similar ecosystems on the California side. The focus is on chaparral in cismontane San Diego County in southern California (SCA) and in northern Baja California (BCA) as far south as Ensenada and the conifer forests of the San Bernardino Mountains (SBM) in California and the Sierra San Pedro Mártir (SSPM) 100 km southeast of Ensenada. We then evaluate how management can be optimally applied toward the protection of property and resources in California, as well as changing Mexican fire policy in relation to rapid development in BCA.

The modern landscape

Vegetation maps show that SCA mediterranean ecosystems extend 200 km into BCA (Minnich and Franco, 1998; Barbour and Minnich, 2000). Grasslands, coastal sage scrub, and maritime desertscrub in the coastal valleys and foothills are replaced by chaparral and conifer forests in the higher mountains. Pinyon-juniper woodlands cover leeward escarpments before being replaced at lower elevations by Sonoran Desert scrub. The chaparral consists of a contiguous layer of evergreen sclerophyllous shrubs 1-5 m tall forming extensive carpet-like stands. It covers around 700,000 ha^{-1} on the coastal slopes of the Peninsular Ranges of SCA and BCA. Californian mixed conifer forest, which occupies 14% of California and 100,000 ha in BCA, including 40,000 ha in the SSPM, comprises a diverse mixture of tall coniferous trees including Ponderosa Pine (*Pinus ponderosa*), Jeffrey pine (*P. jeffreyi*), sugar pine (*P. lambertiana*), white fir (*Abies concolor*), and *Calocedrus decurrens* (Barbour and Minnich, 2000).

The climate is mediterranean characterized by winter rain and summer drought. Mean annual precipitation increases from 20-30 cm along the Pacific coast to 50-80 cm in the mountains.

Transborder contrast in fire and vegetation dynamics

The chaparral and mountain pine forest landscape of BCA may seem exotic to those accustomed to similar landscapes in SCA. Almost any afternoon during summer there are a few smokes that can be seen in the distance. Beneath a smoke column is a flame line creeping along a slope. Thunderstorms form almost daily along the mountains, the lightning triggering small fires, most of which burn out in a day or two. The chaparral appears as a diverse, fine-grained patch mosaic, much like that of a quilt. From any view, a dozen patches of different ages are visible—from fresh burns, to medium-statured thickets, to impenetrable old-growth stands. In the highest mountains are extensive open parks of large pines—the subcanopy having only a few young trees and scattered shrubs. Many trees bear large burned-out cavities (catfaces) on their lower boles that were created by ground fires. Recent burns had left skeletons of burned shrubs and tree saplings as large as 10 to 20 m. The old surviving pines display an umbrella-like canopy. By evening the large fires fade in the cooler temperature and rising humidity, but many will reestablish from burning logs and dead trees the next afternoon, and the next—with a few burning for weeks or into the autumn until ultimately doused by winter rains.

North of the international boundary, the mountains support unbroken carpets of dense, old-growth chaparral that are sliced by an occasional fuel break along a ridge, and interspersed with a few extensively denuded watersheds from a recent conflagration. Pine forests are thick with young shade-tolerant firs and cedars, an immense accumulations of ground litter and decomposed logs. The old trees show high levels of mortality from disease and insect attacks. Forests are becoming increasingly fragmented and divided by post-burn patches of oak woodland and timberland chaparral as a result of intense stand-replacement burns.

The sharp transition between the two regimes cannot be explained by natural gradients in flora or weather; it follows the international border. Climatic gradients including temperature and mean annual precipitation cross the border at right angles, and the prevailing winds are everywhere westerly. Without distinctive suppression systems, changes in fire regime should be expressed in a continuum along environmental gradients, and not as the discontinuity seen between the two countries.

Differences in the landscape are seen in the fire history of chaparral in BCA and SCA (Fig. 1). Perhaps the most conspicuous outcome of the transborder experiment is a discrete transformation of chaparral stand configuration—from a fine-grained patch structure in BCA to a coarse patch structure in SCA (Minnich and Chou, 1997). The small size of fires in BCA has been accompanied by high burn densities (about 7 kha^{-1} 50 yr^{-1}), with most burning accomplished by fires less than 3,000 ha. In SCA fire densities are only 1.0 kha 50 yr^{-1}, with most burned area accomplished by a few events over 10,000 ha. Despite these differences, the fire rotation periods in both countries are about the same, about 70 years, i.e. the past century of suppression has not altered the pace of fire disturbance in chaparral at the landscape scale.

In the mixed conifer forest belt at higher elevations, there are large differences in fire return intervals. In the SSPM fires have burned virtually all forests at least once since 1925 with fire intervals averaging twice a century (Minnich et al., 2000). Fire size frequency distributions are similar to those in the chaparral in BCA. In contrast, few mixed conifer forests have burned in California under fire suppression because fires spreading into them from adjoining chaparral and other ecosystems are readily extinguished in the forest. In the SBM, less than 10% of forests have burned since records began in 1910 (Minnich, 1988). Comparable burning rates have occurred in extensive mixed conifer forests of the Sierra Nevada (SNEP, 1996).

How patch mosaics work

An important aspect in developing fire disturbance theory to explain the divergence in fire history in SCA and BCA is choosing an incontrovertible starting point that leads in directions productive for research. The model in Minnich and Chou (1997) is based on the fact that fire requires fuel; this reveals that the *cause* of fire is fuel energy accumulation in vegetation (chemical energy) by fixing CO_2 into carbohydrate. Fire occurrence in chaparral is time-dependent as a result of cumulative fuel buildup. How stored energy in chaparral is released reflects primarily vegetation growth, structure, and cumulative fuel buildup, and secondarily weather and terrain. This new starting point requires a reversal from the standard perception of fire in the following axiom: During the passage of a flame line, *vegetation is not burned by fire; it burns itself by releasing stored photosynthetic energy.* The focus on ignitions in the initiation of fire is akin to the tail wagging the dog. Ignitions are ubiquitous and most fail to establish fires because they are too abundant relative to slow fuel accumulation rates (Minnich et al., 1993; Minnich and Chou, 1997).

This cross-border difference is explained by a time lag that exists between fuel accumulation burning, making fire self-limiting, and thereby time-dependent (Minnich and Chou, 1997). Fire occurrence is constrained in space and time by the rate of fuel accumulation in previous fire history. Chaparral brings low fire hazard during the first years after fire because it has low combustible biomass. Fire hazard increases with time, resulting in a variable fire hazard from stand to stand, depending upon their age. As a result, fires preferentially burn old stands (more than 40-50 years old), the younger stands constraining the progress of burns. As a result, mosaics of fire-created patches assume a self-organizing spatial process where the occurrence of fires is influenced by previous fire history, and also affects fires at some later stage. In BCA, numerous small to medium-size fires (mostly less than 5,000 acres) create a heterogeneous fragmented patch structure that resists the development of large fires. In SCA, initial attack suppression reduces the number of medium-size fires, resulting in a coarse patch structure that encourages large fires, some as large as 20,000 to 60,000 ha. Fire intervals in both countries are similar, about twice a century. The similarity of fire return intervals in SCA and BCA supports

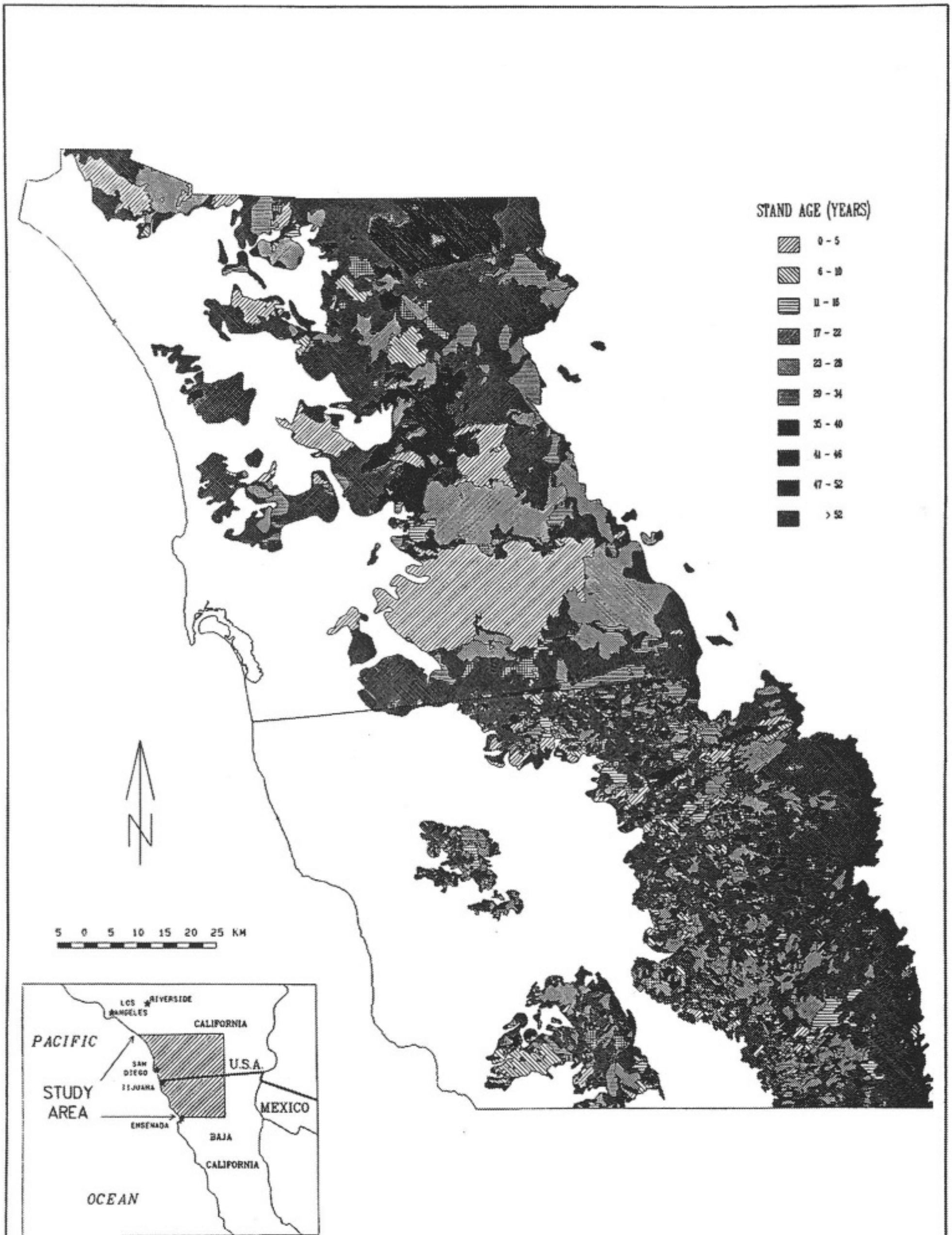

Figure 1. Chaparral patch mosaic (time-since-fire) in 1971.
Published with permission from CSIRO and IJWF from Minnich and Chou, 1997.

the argument that the chaparral productivity (i.e. fuel supply) dictates landscape-scale rates of burning, with a negative feedback between fire frequency and fire size.

The time-dependence in fire occurrence is related to the fact that fires can propagate through chaparral or forests only if the heat released in burning fuel exceeds the energy heat sink of water in vegetation. Factors contributing to increasing fire hazard during succession are fuel continuity (stand cover), total biomass, and lowering of stand fuel moisture from increasing dead-to-live stand fuel ratios (Rundel, 1983; Keeley and Keeley, 1989; Barro and Conard, 1991). Fire hazard in stands is low during the first decades of succession because chaparral canopy is initially discontinuous for around 10 years, and stand fuel moisture is high due to leaf stomatal controls that regulate transpiration under high evaporative demand to levels above combustion thresholds. The accumulation of flammable dead fuels gradually increases with time-since-fire, especially after 30 years spring (summary data in Rundel, 1983) due to the reduced ability of shrubs to meet concurrent demands of photosynthate storage and growth (Sparks et al., 1993). Another model is that the expanding foliage area of dominant shrubs in maturing stands advances seasonal soil drying, hastening the onset of seasonal drought stress (Riggan et al., 1988).

Self-organized turnover of patch mosaics also occurs in mixed conifer forests of the SSPM. It is hypothesized that fire hazard also increases gradually with cumulative buildup of needle litter, shrubs, and conifer recruitment (Minnich et al., 2000).

Individual fires, of course, each have different sizes, intensities, and severity in vegetation damage because each was associated with a unique combination of weather, terrain, and fuel conditions. However, the cumulative impact of all fires scaling at centuries or millennia results in spatial structures arising from time-averaged processes on the landscape that are equilibrated to ecosystem productivity (landscape fuel buildup) tied to climate. As long as fire occurrence is spatially and temporally random, regional burning properties will concentrate on the modal properties of fire factors.

Fire control has a significant effect on the weather of fires because the suppression of small fires nonrandomize the occurrence of large fires (Minnich and Chou, 1997; Minnich, 1983). Relatively small changes in relative humidity and wind spreads may produce large differences in energy release associated with spread rates of flame fronts (fuel energy consumed per time). On an area-weighted basis, fires in BCA establish by chance during prevailing onshore sea breezes and slope winds in summer (relative humidity 20-40%, winds 5-20 mph). In SCA, the efficient elimination of countless small fires is a selective process that nonrandomly encourages very large "escaped" burns to coincide with severe weather (fires starts are easily extinguished in "normal" weather), resulting in high average spread rates and flame line intensities. Most burning in SCA coincides with offshore Santa Ana winds in autumn (relative humidity 10-20%, winds 20-50 mph). The corresponding denudation of younger stands increases fire size and homogenization of the mosaic.

Historical roots to the U.S. and Mexican fire management systems

The United States and Mexico form one of the most profound political boundaries in the world, dividing respectively, an industrialized, urbanized economy on the U.S. side from a "third-world" developing economy on the Mexican side. Yet, the transborder region began with the same political and ecological baseline. BCA and SCA were first settled by Franciscan missionaries in response to directives by the Spanish crown to expand the Spanish sphere of influence in the Californias against Russian encroachment (Bolton, 1927). In 1769, the

Franciscans initiated an unbroken chain of missions that eventually developed an extensive open-range grazing economy and local agriculture in the coastal plains, a land-use system that persisted through the Hispanic period to the mid-nineteenth century. The mountains were avoided except for occasional harvest of timber and for use as summer pasture. The division of California from Baja California ultimately originates from an agreement made at the beginning of the mission period. Once established in Alta California, the Franciscans quickly realized that they had insufficient manpower to establish missions south of San Diego and, furthermore, Dominican leaders desired a share of California. In 1772, a "concordat" was signed between the viceroy of Mexico and the leaders of the Dominican and Franciscan orders. The Dominicans agreed to take charge of the old Jesuit mission system in Baja California and to develop missions in the mediterranean lands of the northern peninsula as far as San Diego. The Franciscans had jurisdiction of Alta California from the present international border northward (Meigs, 1935). Lands originally in Franciscan holdings came under control of the United States in 1850; Dominican lands remained in Mexico.

Until recently, most of Baja California's biological environment was not as intensively exploited as Alta California, nor were its wildlands under formal protection. Indeed, the vegetation, protected by isolation, has a pristine character rarely seen in Alta California. Until the end of World War II, northern Baja California remained largely politically and economically isolated and undeveloped, despite its proximity to the rapidly expanding economy of Alta California (Henderson, 1964). Within Mexico, Baja California was a distant outpost from Mexico City.

The region's isolation has been responsible for a centuries-long delay in the development of agriculture and ranching after the Spanish discovery of the peninsula (Henderson, 1964). In the late eighteenth century, the Dominican padres conducted many enterprises with indigenous farmers and ranchers, but these efforts resulted in localized subsistence agriculture and little immigration into northern Baja California.

Cattle grazing remained the most significant economic activity through most of the nineteenth century. As the mission system disappeared, Dominican landholdings were granted or sold to local citizens, usually Mexican government officials and military officers, who began subsistence cattle ranching in the sierra. The gold strikes in the Sierra Juárez and the west slope of the Sierra San Pedro Mártir between 1873 and 1890 resulted in increases of cattle and commercialization of cattle operations, but the ores played out within a few years and the miners dispersed (Henderson, 1964; Chaput et al., 1992). Except around the Dominican missions, agriculture did not exist in these semi-arid lands until the 1880s. The population increased with the expansion of agriculture during the dictatorship of Porfirio Díaz in 1877-1911 (Henderson, 1964). During this period, much of the best land for agriculture, mostly grassland in the coastal valleys and desertscrub on the Colorado Delta, was cleared for crops. Dry farming of wheat and barley was successful in Valle Ojos Negros, in Valle San Vicente, and in the basins southeast of Tijuana. The inaccessibility of the pine forests has prevented significant removal of timber during the past two centuries.

The total population of the entire peninsula of Baja California, which covers an area nearly equal to that of Alta California, was counted in the thousands into the early twentieth century (Henderson, 1964). Today Baja California is mostly an unfragmented, wild landscape, with scattered patches of agriculture, reminiscent of the California landscape in the nineteenth century. Most mountain lands are effectively unoccupied other than for a few scattered, small ranches. Wildland fires in the mountains are uncontrolled to this day, and deliberate burning is still practiced by *vaqueros* and farmers. Large parts of the landscape remain little altered from the late eighteenth century, when Europeans first described them (Minnich and Franco-Vizcaíno, 1998).

In contrast, Alta California's ecosystems underwent a cycle of intense human exploitation parallel to that in many other areas of the western United States (Lockmann, 1981). The Gold Rush in 1849 drew large numbers of Anglo-Americans to Alta California, and when the mines were exhausted, the well-watered lands permitted a transition to agriculture. Forests were logged for construction, fuelwood was culled for mining operations and domestic use, and rangelands were grazed by livestock. By the end of the century, after forests and rangelands had been exploited across the United States (Robinson, 1975), a growing awareness of the need to conserve those areas arose. Public concern for a variety of issues including watershed protection, wildfire control, and forest protection resulted in large areas of the public domain being placed into national parks and national forests. Logging and grazing were managed or prohibited; fire control was instituted.

A Mexican fire regime in California

Fire history evidence in California suggests that a BCA fire regime had evolved into the modern conflagration regime during the early twentieth century (Minnich, 1987; Minnich, 1988). These writings suggest that small fires and patchiness were characteristic of chaparral during the late nineteenth century. According to Mendenhall (1930), an early forest ranger in the San Gabriel Mountains north of Los Angeles, "Fires occurred every year...and were not extensive due to the fact that they ran into older burns and checked themselves." In the San Bernardino Mountains, the 1903-04 L.C. Miller Silvicultural Survey party saw evidence of fire at ten localities across an area of about 20,000 ha. During the U.S.-Mexican boundary survey of the 1890s, which encompassed the coast ranges between Mexico and the San Jacinto Reserve, boundary workers stated that "the signs of fire having gone through the brush are constantly evident." John Leiberg, who conducted the forest reserve surveys under the U.S. Geological Survey at the turn of the century, noted that in the San Gabriel Reserve, recent fires burned over 12,000 acres in four widely separated drainages (Leiberg, 1899, 1900). Leiberg made the most explicit account of patch mosaics in the San Jacinto Mountains, 100 km east of Los Angeles, describing the chaparral as "a growth which varies from extremely dense to thin or open, but rarely forms large uninterrupted patches. The dense portions are commonly separated by narrow lanes [burns], which are wholly free of brush...." He also stated that "recent fires...[were] scattered throughout the reserve in small tracts." Tree-ring fire-scar data reveal evidence of periodic fire in mixed conifer forests throughout California (McBride and Laven, 1976; Kilgore and Taylor, 1979; Swetnam, 1991, 1993). Newspaper accounts describe several extensive subcanopy fires in the logging belt of the western San Bernardino Mountains between 1860 and 1900 (Minnich, 1988). Ground photographs dating to the late nineteenth century reveal open park-like forests and basal fire injury to tree boles (Leiberg, 1899, 1900).

After 1900, most lands on the SCA side were placed into the Cleveland National Forest, and Cuyumaca and Anza-Borrego State Parks. Remaining lands were used for cattle grazing in herbaceous communities under fence. Suppression has been official policy since 1900 (Lockmann, 1981; Pyne, 1982; Minnich, 1987a). In California, organized fire suppression developed from a concern for watershed protection, flood cycles, erosion, and damage to property. This practice dates to around 1900 when a national consensus emerged toward conservation of forest resources. In 1900, Gifford Pinchot, Chief Forester, visited Pasadena to "press hard for the employment of 100 rangers [to be] employed seven months/year cutting [fuel] breaks on the ridges, clearing out undergrowth, and building trails through the mountains so that every section can be reached readily by fire fighters. The rangers could patrol their ranger district ... [to] keep a lookout for blazes" (Minnich, 1987). The fuel breaks were designed to break up chaparral into blocks in order to contain fires within individual stream drainages. The "10 o'clock policy" implemented at this time, i.e. that all fires be put out by 10 o'clock the next morning, has been practiced ever since with ever increasing technological assistance, primarily for the suppression of large fires. The most important change was the introduction of aerial drops of water or chemical retardants beginning around 1950. Also utilized are bulldozers and massive manpower, brought in from many areas outside California to build lines around the fire perimeter, utilizing the fuel break systems. The expansion of large cities in SCA since World War II has resulted in an ever increasing urban/wildland interface.

When did suppression begin altering chaparral fire regime?

Keeley et al. (1999) present data that fires in California "brushlands" have always been large since fire records began in the early twentieth century. They propose that (1) because the size of fires in SCA have remained unchanged since records began in 1910, and (2) because suppression became effective with technological advancements in 1950, then fires have always been large, even before suppression. This argument rests on an unsubstantiated *ad hoc* assumption that the effectiveness of suppression is coupled with technology. While small fires can be suppressed with relatively primitive means, suppression of very large fires has never been effective. The spatial extent of fires does not decrease with increased funding of suppression nor with improvements in technology. Despite vast differences in funding and technology, fires have been larger in California than in Baja California since the 1950s. Moreover, the discontinuity in patch density and size along the international border had already developed by the 1920s (Minnich and Chou, 1997). The most expensive aspect of suppression—encircling large fires—is futile because the energy release of flame lines exceeds the energy of suppression by orders of magnitude. Large fires easily skip over fuel breaks because passing embers in the wind initiate new flame lines kilometers in advance of the primary flame line. Suppression is effective only during low energy states, i.e. the extinguishing of small fire starts, a process that began in earnest by 1900 (Minnich, 1987). This can be done at little cost and with little technology.

Evidence that chaparral patch dynamics were altered soon after the initiation of suppression is illustrated in the San Gabriel Mountains where chaparral covers 150,000 ha (Minnich, 1987). Immediate suppression of small fires proved to be quite effective. After two successful seasons, the October 27, 1902 edition of the *Los Angeles Times* reported in an interview with T.P. Lukens: "The local rangers have been very fortunate in nipping blazes in the bud this season. No disastrous fires have occurred..." From 1905 to 1918 forest rangers combed the hills to extinguish small fires. A list of fires compiled by Mendenhall (1930) reveals remarkably little burning from 1905 to 1918 with the total burn area of only 8500 ha, or 5.6% of the chaparral which covers around 150,000 ha. For the 14-year period, the area of chaparral burned per year averaged 0.4% instead of long-term rates of 2.0%. These trends show that the mean age of chaparral stands increased throughout the mountains during this period. The hiatus was followed by three massive conflagrations totaling 80,000 ha in 1919 and 1924. The presuppression patch mosaic described in the late nineteenth century was already altered in 20 years.

The processes leading toward the enlargement of patch mosaics were understood even during this period. William Mulholland, better known for his efforts in importing Owens Valley water to Los Angeles, deduced a change in the pattern of fire at the turn of the century, and explained it in terms of pre-existing patch mosaics (Minnich, 1987). In an interview with the *Los Angeles Times* after a fire in 1908, he stated: "If the portion of watershed burns off each year, then there is always a large majority of watershed covered with a new green growth that will defy any fire. Experience has taught us that we cannot prevent fire. It is better to have a fire every year, which burns off a small area... than to have a big one denuding the whole watershed at once." Eleven years later, two simultaneous conflagrations denuded 110,000 acres in the San Gabriel Mountains, after which Mulholland stated to the *Los Angeles Times*: "The deplorable thing about the present fires is the vast extent of the territory burned over in a single season. Fires we have every year, but only small areas have been generally burned over at a time and very rarely does it occur that the growth on a watershed is of such maturity as to burn out with a single occurrence."

Changes in mixed conifer forest

As was the case with chaparral, an early onset of suppression is also recorded in mixed conifer forest. Tree-ring studies show a falloff in burning by 1900 in California (Swetnam, 1993). In contrast to chaparral where fire intervals and species composition have been stable from presuppression to suppression times, the large transnational divergence in fire intervals in mixed conifer forests had led to important differences in species composition and stand structure on both sides of the international boundary. In the SSPM (Minnich et al., 2000), forests consist of open stands of large mature trees dominated by pines, with overstory densities of 65-145 stems ha^{-1} and cover of 25-45%. Pole-size stems in the subcanopy average 15 ha^{-1}. It was hypothesized that the open stand structure resulted from vigorous selective elimination of subcanopy trees by intense understory fires. While chronosequence data show gradual recruitment of saplings to pole-size status over a fire cycle of 50 years, most subcanopy trees perish in landscape-scale fires, leaving only a few to join the canopy layer. The rate of entry into the overstory class is balanced by low overstory mortality rates. Present-day forest densities may reflect a long-term stable forest population structure. Time-series aerial photographs since 1956 reveal that local post-fire recruitment and stand-thickening are balanced by subcanopy mortality of young trees in other stands (Minnich et al., 2000). Estimates of stem densities, stem diameters, and species composition in a timber survey conducted in 1888 are remarkably similar to present stands (Minnich and Franco, 1998).

On the U.S. side, open park-like forests of old-growth trees, similar to present-day forests in BCA, were described and photographed in many areas of California in the late nineteenth century (SNEP, 1996; McKelvey and Johnston, 1992; Minnich, 1988; Vankat, 1977; Vankat and Major, 1978). Forest densities (trees with diameters greater than 10 cm) averaged 80 to 200 ha^{-1}, with most trees having diameters greater than 60-100 cm (Vankat, 1977; Vankat and Major, 1978; Minnich et al., 1995). The decline in burning on the U.S. side after 1900 has been paralleled by stand-densification, and regionwide buildup of subcanopy fuels. Most forests show an age-specific trend away from dominance by Ponderosa and Jeffrey pine, and toward dominance by sapling and mid-size classes of white fir and incense cedar (Weatherspoon et al., 1992; Minnich et al., 1995; SNEP Science Team, 1996; Roy and Vankat, 1999). Older trees show high levels of mortality from disease and insect attacks. The enormous fuel loads in the dense forests of California are encouraging a new pattern of "stand-replacement" or "crown" fires that destroy whole forests. Replicates of Vegetation Type Map Survey (VTM) field quadrats taken during

1929-34 in the SBM show stem density increases of 100-200 stems ha^{-1} (diameters greater than 10 cm) over the past 60 years, with thickening rates directly proportional to mean annual precipitation (Minnich et al., 1995). The density of young stems (diameters smaller than 30 cm) currently range from 50-100 ha^{-1} in the SBM compared to 15-40 ha^{-1} in the SSPM (Fig. 10). The total density of ponderosa pine stands regenerating from the nineteenth century logging in the SBM often exceeded 500 stems ha^{-1} (Albright, 1998). Stand-thickening has led to increasing densities of dead trees related to infestations of bark beetles and pathogens (Pronos et al., 1999). High subcanopy tree mortality in this range was ascribed to competition for light and soil moisture (McBride and Laven, 1999). Both California and SSPM forests experienced drought during 1987-1990, but recent mortality was an order of magnitude less in the SSPM than California, only 1-3 ha^{-1} (Minnich et al., 2000). It was concluded that the effect of the drought on forest mortality rates was offset by low tree densities, reducing competition for soil moisture and nutrients (Minnich et al., 1995, 2000). In the Sierra Nevada, tree densities (stems larger than 10 cm dbh) have climbed to 500 ha^{-1} on west slope ponderosa pine forest (Vankat, 1977; Vankat and Major, 1978; Roy and Vankat, 1999).

Fire Management

Both the large and intense fire represents the least desirable outcome in the management of fire-prone ecosystems because the size and energy release of fires is directly related to the threat of burning, erosion, sedimentation, and flooding of property and infrastructure. The cost of large fires can be enormous. In Los Angeles, California, intense brushfires with 30-50 m flame lines—pushed through thick mountain chaparral brushfields by strong, dry Santa Ana winds from the desert—spread into several suburbs at the urban-wildland interface during the autumn of 1993. These fires easily overwhelmed suppression forces and destroyed about 1,000 homes at a cost of one billion dollars. In 1991, the Oakland fire burned 3,500 homes at a cost of 3.5 billion dollars. Such disasters have occurred repeatedly in California, and each is followed by renewed debate as to whether fire suppression management practiced for nearly a century has contributed to large fires in the state.

The beginnings of fire suppression were a response to threats on land-use and to watersheds. However, this approach is futile if only catastrophic and indefensible wind-blown fires are carried through unmanaged fuels beyond the interface. Sooner or later under orthodox suppression, every house along the interface will be subject to a fire that cannot be fought. The concept that surrounding burns can prevent the destruction of infrastructure is illogical because suppression forces cannot control large fires. This was understood at the beginning of the fire suppression era. William Mulholland stated in 1908, "Experience has taught us that we cannot prevent fire [as]....it is almost impossible to combat mountain brushfires when once they have well started...." (Minnich, 1987).

Fire management is ultimately fuel management. The long-term spatial and temporal predictability of fire can be used as a central concept for effective management in chaparral. Large uncontrollable fires can be mitigated by reintroducing a fine-grained patch mosaic through proactive broadcast burns. Fire poses a cyclical threat in space and time due to the self-regulating property of fire and fuel dynamics, i.e. the removal of fuels in a burn precludes a recurrence for decades. Increasing the number of fires will produce smaller fires but not an increase in the area burned. Fire fighting personnel need only to check the progress of the fire relative to the patch mosaic. This strategy can be accomplished by recycling chaparral at intervals of 30-50 years, depending on local productivity rates. This requirement is actually modest. For example, the San

Gabriel Mountains of California are covered by approximately 150,000 hectares of chaparral. To completely recycle the entire ecosystem at 40-year fire return intervals requires the burning of approximately 4,000 ha each year. This is equivalent to only 2 or 3 burns.

Post-fire chronosequences on both sides of the U.S.-Mexico border show that chaparral is stable under both suppression and uncontrolled fire regimes. Chaparral is stable because sprouting habits and latent seed pools permit efficient stand establishment under short and long fire intervals (Keeley, 1989; Minnich and Bahre, 1995). Chaparral recovery is insensitive to the size of fires because recolonization of burns by long range seed dispersal is not required for any shrub species.

Hence, management strategies can assume that long-term primary productivity rates and fuel production are nearly constant, reflecting the broad-scale climate. Therefore, the spatial extent of burning will approach steady states averaged at the scale of the landscape. In addition, transborder fire history shows that the rates of burning in southern California and Mexico are very similar. Hence, suppression has not resulted in excessive regional fuel buildup, except in the size of patches. It is thus unnecessary to increase the rates of burning to prevent regional fuel buildup. In fact, chaparral cannot be burned at higher rates because the availability of fuels becomes more limiting (an increase in the area of nonflammable vegetation). Without fire control in BCA, high fire densities and fine-grained patch mosaics are a spontaneous outcome due to high natural ignition rates. Hence, broadcast mosaic burning will become a low-maintenance inexpensive management option once a fine-grained patch mosaic is reestablished. To design specific management plans, National Forests and other land management agencies already have fire history databases to reconstruct current patch structure.

Prescribed broadcast burns should be conducted during the summer, which is the primary fire season in BCA. During that time, the weather is fairly constant, being dominated by slope winds moving up the mountain in daylight and down slope at night. Most fires spread with prevailing winds from west to east. Unexpected weather conditions due to the jet stream (such as Santa Ana winds) are practically nonexistent, especially in July and August. Our observations of past fires in BCA have shown that flames normally spread slowly uphill during the afternoon, when daily temperature maxima and relative humidity minima occur. Flames generally stop during the night, with fires persisting in logs and snags.

Other advantages of planned broadcast mosaic burning include the proactive selection of appropriate weather and the forewarning of landholders weeks in advance. The fine grained fragmentation of denuded lands helps to attenuate post-fire sediment yields in watersheds. Fine-grained patch mosaics are also beneficial to biological diversity by enhancing local variability in vegetation successions.

The primary advantage of prescribed broadcast mosaic burning is that large units of vegetation can be burned economically, and over long timescales at rates equal to regional fuel production. However, the current funding system is not suited to planning. Fire management agencies are paid for fire fighting costs *a posteriori* from emergency funds. Little funding is provided up front in budgets for proactive fuel management of the landscape.

Fire management and Land Use

Emergency funding of suppression and FEMA funding of natural disasters encourage land development and rebuilding after fire disasters in dangerous environments at the urban-wildland interface (Davis, 1998). Regional fire management options have also become complicated and intractable with the growth of dispersed, small landholdings within wildlands.

Instead of encircling fires, an alternative policy is to treat settlement inholdings (ranchsteads, villages, camping facilities) as point features, around which fires can be allowed to pass through in a vast periodically flammable landscape. For this strategy to work, there must be intense fuel management around local inholdings. In BCA, local ranches use livestock to remove fuels around buildings. Agricultural zones and cities utilize livestock, or plow fields in contact with natural vegetation. Similar measures can be undertaken in California, including severe building codes that require the design of fireproof structures.

Some scientists and land managers advocate the focus of controlled burns at urban-wildland interface (Keeley, 1999). Clearly, the protection of structures near wildlands should have highest priority. However, this approach is futile if only catastrophic and indefensible wind-blown fires are carried through unmanaged fuels beyond the interface.

Mixed conifer forest

Because few forests have burned in the past 100 years, indefensible stand-replacement fires will be the wave of the future in mixed conifer forest (Albright, 1998). Urbanization within forests has created a fire management dilemma. Fire suppression combined has encouraged stand-thickening and risk of stand-replacement fires. Private lands, many in historic logging areas that have the densest forests, have become urbanized where construction practices utilize wood products for roofs, siding, and decks that add to fuel loads. The presence of people and structures leads to a feedback in which increased need for fire protection further contributes to stand-thickening and buildup of fuels.

Fire managers need to assess fire hazard conditions and develop fuel management strategies as a scale that promotes sustainable ecosystem management and meets fire protection needs. While the presence of structures precludes the use of prescribed fire, mechanical treatments can be used to mimic the effects of past unmanaged fire regimes. Fire hazard reduction includes logging operations that concentrate on the removal of saplings and pole-size trees and even some commercially valuable trees, but leave large mature trees. Stand densities should be reduced to levels observed before fire suppression. In undeveloped lands, stand-thinning can be accomplished with intense subcanopy broadcast burns, similar to those observed in the SSPM. If stands are too thick, slash removal of young and mid-size trees may be necessary before burning.

Fire management in Mexico

Until recently, a fundamental problem for fire management in Mexico has been the country's political centralization. Policy and budgetary decisions were made in Mexico City, with little flexibility for local and regional peculiarities or the development of unforeseen circumstances. The weather change in political administration brought about by the last presidential elections has opened the possibility for consideration of regional differences, and there are now several initiatives for the development of an integrated forest and fire management plan that would move away from the reactive policies of the past.

Nevertheless, a large proportion of Baja California's population immigrated recently from the tropics where the vegetation is not well adapted to fire. The immigrant's world view has not caught up with the reality of living in a mediterranean region. The public's negative perception of wildland fire that has been reinforced by the central communications media, and attitudes possibly appropriate for the tropics have been unquestioningly extended to Mexico's distant mediterranean corner.

Federal law requires that landowners be held responsible for wildland fires that start on their properties. All wildland fires detected by the authorities are reported to the Prosecutor for the Environment for possible prosecution. Determining responsibility is difficult since a large proportion of the territory is in common lands of *ejidos*, a communal form of landholding unique to Mexico. Prosecutors are reluctant to take on cases in which witnesses are lacking, where lightning was the likely cause of ignition, or where burning affected chaparral rather than riparian and mountain forests, which are viewed as inherently valuable. In actual practice, fewer than five percent of fires merit prosecution, most of these are cases that clearly involve malicious intent.

It has become evident that the fire suppression paradigm, which began to take effect in the 1960s in Baja California, is no longer accepted by the federal and state authorities, and most of the key managers agree that fire suppression is excessively dangerous and expensive for Mexican conditions. Few Baja California firefighters have sufficient training to understand the risks inherent in fighting wildland fire. When large fires do occur, only the military has sufficient manpower to mount a credible campaign, but putting untrained soldiers on the fire lines is potentially a prescription for disaster. Previous experience with wildland fire has shown that contracting aerial firefighting technology from the United States is a luxury that the treasury can ill afford. And it is widely recognized by the authorities that wildland fires go out naturally of their own accord, mostly due to factors beyond human control.

Forest resources, however, are almost universally seen as too valuable to allow to burn, and the public demands that “something” be done about forest fires. Thus, failure to “combat” forest fires is seen by the authorities as politically unacceptable. This dilemma has resulted in the persistence of the policy of fire suppression on the ground while at the same time there are official doubts as to its effectiveness. An operational compromise has developed which dictates mobilization against forest fires, but allows fires in shrublands to burn so long as there is little threat to lives or property. It is not generally recognized that this policy by default threatens the continued existence of Baja California’s small forests by repeating the mistakes made in the United States.

A complicating factor is that the detection and suppression of fires in the mountain forests of Baja California has long been a source of summer employment for several small brigades of firefighters whose job it is to detect and report fires in addition to “combating” them. Given the durability of this item in the Federal budget, it would be difficult now to wean the local population from this source of revenue. The role of the fire brigades should thus be amplified to include training and experience with prescribed fire. This would improve effectiveness by augmenting the firefighter’s experience and turn the brigades into a proactive force in reducing fuel loads in critical areas such as the environs of the National Astronomical Observatory.

Early indications are that the current presidential administration considers conservation of Baja California’s environment a priority, and it is likely that a nuanced approach to fire management will continue to be supported. An important opportunity for change may be provided by the initiative to reintroduce the California Condor to its former habitat in the Sierra San Pedro Mártir and its environs. This initiative, which is part of the effort to establish a biosphere reserve in the Sierra, would bring international attention to northern Baja California and require an extensive public relations campaign to acquaint the public with the importance of Baja California’s forest and shrubland habitat for the safe return of this emblematic bird. The reintroduction of the California Condor would present a good opportunity to educate Baja California’s public about the ecological realities of its environment while simultaneously developing the political credibility for a more realistic management of wildfire.

Conclusion

The very different dynamic in BCA stands in remarkable contrast with that on the California side. The BCA fire regime may serve as a model for SCA, prior to the establishment of modern suppression. Baja California's more natural fire regime and low labor costs provide an excellent opportunity for baseline research on fire and fuel management in Mediterranean-type regions. Given the public's reluctance to see valuable forest resources burn on public lands, reducing fuel loads manually, rather than allowing fire to do it, is widely seen as a viable option. Permitting the harvesting of fuels as an economic activity for local populations would be consistent with the "Mexican modality" for biosphere reserves. This would provide an opportunity to turn the Sierra San Pedro Mártir into a natural laboratory where different strategies of fire management could be tested side by side under nearly natural initial conditions.

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Whales and Shared Coastal and Marine Management of the Border Pacific

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Introduction

> International cooperation is essential to protection of the environment and biodiversity of the seas. The marine environment transcends national borders, most of it is beyond the reach of any national authority, and activities on land or at sea in one country can often have far-reaching effects in other countries at long distances from the site of the activity. (Thorne-Miller, 1999:135)

Even more than terrestrial environmental issues, there is a need for at least binational cooperation in dealing with migratory marine species. Pacific Gray Whales know no borders, cannot survive in a single nation's jurisdiction, are dependent on food sources during part of the year in US waters and on breeding and birthing lagoons in Mexico during the rest of the year. The nine threats (discussed below) to the health and survival of marine mammals are global in scope, or are impacting mammals that migrate among more than Mexico or the US. As such, they cannot be addressed unilaterally.

Whales are charismatic fauna that have demanded the attention of generations of people around the world. In the 1970s, they served as the focus of the rallying cry "save the whales;" a cry that eventually led to substantial international protections from the threat of whaling. Whales are high-end indicators of the health of the ecosystems in which they live. There is a direct correlation between their health and the health of the ocean's biodiversity for which they are both predator and prey and serve as significant food biomass after their dead bodies come to lie on the ocean floor.

Unfortunately, the whales are not yet "saved." A few species have begun to recover from whaling, but most whale species are in decline either in number or in health. As indicator species, the continued decline of many species of whales demonstrates the decline of the oceans generally and the large marine ecosystems (LMEs) in which most whales live. This decline is a threat to human health and to food resources which humans take from the ocean. As charismatic species, whales may serve as focal points to stimulate public opinion in favor of efforts to protect the health of LMEs and the ocean.

The chapter begins with an overview section regarding the apparent quality of our knowledge of the health and welfare of whales. A case study at the end of this section will review US and Mexico efforts to limit harassment of whales during whale watching tourism activities. The next part of the paper is a very brief description of six short- to medium-term and

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three long-term threats to marine mammals (see Table 1 below). The short to medium-term threats are direct fisheries interactions, overfishing by humans, marine debris, loss of habitat, ship collisions, and sound pollution. The long-term threats are whaling, climate change/ozone depletion, and bioaccumulation of toxins. The list of threats is intended to be a summary of the current literature regarding threats to whales. It is not, therefore, an independent assessment. An attempt was made to collect the most recent reports and texts on the threats to whales, to undertake some limited interviews with scientists and other experts and then list within a two level priority system the known threats to whales (a detailed listing of these comments is set forth in Appendix A). Given the current threats, a brief description of the legal and institutional factors contributing to possible strategies to protect the migratory whale populations between the US and Mexico is set forth. Appendix B is a listing of some relevant international agreements to which the Mexico and US are both parties. A habitat threat case study involving the proposed alteration of the Laguna San Ignacio calving grounds of the Pacific Gray Whale is described at the end of this section. The brief conclusion suggests the potential for binational cooperation to aid in the conservation of migratory whales in the shared coastal and marine environments of the border in the Pacific. At the end of the chapter a reference list is provided.

Overview

> Many of the causes for declines in marine wildlife persist: incidental capture in fishing gear, destruction of critical habitat, and health problems related to pollution, including immunosuppression and endocrine disruption. Efforts to help populations recover are hampered by lack of research or recovery actions to identify and help species at risk, and little or no government financial support for the programs that protect and restore marine wildlife. (CMC, 2000: 23)

There are short-, medium- and long-term threats to whales. As a result, certain species and/or populations within those species are endangered or vulnerable (per the International Union for the Conservation of Nature categories). Because whales are charismatic, they get a lot of attention from environmental non-governmental organizations (ENGOs). The ENGOs seem to be able to raise money to work on these issues precisely because of the charismatic nature of whales.

A large percentage of humans live along the coasts. Interestingly so do a large number of whales. Even the pelagic, or open ocean, whales come to the coasts to breed, birth their young, and to feed. Yet, we know very little about whales. Submerged in the water as is natural for them, they are hard for us to identify, much less count and estimate population sizes. They are hard to observe to learn about feeding and other important behaviors. We do not even know where a few great whale species go for half of each year. How do you lose track of the largest mammals to ever inhabit the planet? The answer is that we are terrestrial and they most certainly are not. As a result, much of our knowledge takes the form of speculation or inadequately confirmed theory. But there are some things we know about whales and other marine mammals that should make us very concerned about their long-term health and welfare.

Whales of the West Coast of North America

The list below sets forth by species category the common names of individual species of Cetacea which appear on the West Coast and which regularly fall under Mexico and US jurisdiction. However, it should be remembered that for many marine mammals “the species may not be the most significant unit of biodiversity. Populations may represent important genetic diversity that should not be ignored in measures to conserve biodiversity." (Thorne-Miller, 1999: 45)

<u>Cetacea</u>[2]

WHALES, PORPOISES & DOLPHINS

Toothed Whales	**Baleen Whales**
Orcas or Killer Whales	Gray Whale
Dolphins	Rorquals (includes Humpbacks, Minkes and Blues)
Porpoises	Right Whales (nearly extinct in the North Pacific)
Sperm Whales	
Beaked Whales	

As with all ecosystems, "an important indicator of the health of the ocean is the status of the species at the top of the web of sealife" including whales, dolphins and seals (CMC, 2000: 20). While we do not know exact numbers for many marine mammal species, we have observed a decline in their numbers as a result of reading whaling records, observing fisheries bycatch rates, or annually photographing seal rookeries. Thus the apparent declining numbers of a number of whale species indicates the ocean is not healthy. For example, "[w]hen the populations of whales were much greater, their bodies were likely a very important source of food on the sea floor; they and other mammals still provide food and habitat for a community of opportunistic creatures that move from one to the next as the bodies are consumed." (Thorne-Miller, 1999: 101) For many marine mammals . . . we don't even have sufficient scientific information to know if populations are increasing or decreasing, let alone why." (CMC, 2000: 21) According to at least one respected researcher, "the demise of marine mammals . . . is a *fait acompli.* Many species and populations have gone extinct, and others are impoverished or on the brink of extinction." (Thorne-Miller, 1999: 16)

It is hard to find a silver bullet for whale issues. Most are too large or too political for ENGOs to be effective. (Croll) Thus there needs to be a concerted effort to develop strategies which prioritize and seek to address key threats to whales.

Pacific Gray Whale Watching Management Case Study

This case study will highlight the current laws, regulations and guidelines governing whale watching in Mexico and the US. Such laws are primarily focused on the Pacific Gray Whale that migrate within coastal waters and spend most of their time within US or Mexican legal jurisdiction. The sustainable joint management of the whales as a natural resource is an economic benefit to Mexico and the US through earning generated by whale watching.

Whale "watching" probably began many centuries ago when coastal indigenous people observed the first whale. Research whale watching began in the mid-1940s when Professor Carl L. Hubbs of Scripps Institute of Oceanography began his daily Gray Whale migration counts on the Institute's rooftops in La Jolla, California.

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[2] Derived from even-toed ungulates such as cows or pigs.

Commercial whale watching began in 1955 when Chuch Chamberlin offered one-dollar trips to see Gray Whales as they passed southern California on their way to Baja California. Raymond M. Gilmore took over the trips, which became something of a legend in California. For three decades, Gilmore's incredibly popular whale watching tours were part science, part education, and part fun. During those three decades, whale watching grew as an industry, as did the public's interest in whales, spreading throughout California, the west coast of North America, and then around the world.

Whale watching has become a major industry around the world. Whale watching, as a non-consumptive practice, can be a model of sustainable development, which does not reduce the available natural resource for present or future generations. At present, whale watching plays a substantial economic role in several west coast US and Mexican communities. The main species watched are Humpback Whales, Gray Whales, Blue Whales, Minke Whales, Sperm Whales, Short-finned Pilot Whales, Killer Whales, and Bottlenose Dolphin (Hoyt, 1995 at 3).

Unfortunately, the human interest can be too much and some efforts to get close result in harassment of the whales. There are potential short-term (changes in behavior), medium-term (changes in distribution and migratory routes) and long-term (changes in reproductive success) effects which may result from this human attention (Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, 1997 at 4). Because of this, we have begun to see the development of regulations and guidelines related to whale watching which are intended to protect the whales that are being observed.

There is a clear need for caution to ensure that whales are not harassed and thus adversely affected by our desire to visit them up close in their natural habitat. Appropriate codes of behavior need to be developed for commercial and recreational whale watchers. Related to this need is the desire for consistency and coverage across jurisdictions for these codes. One jurisdiction's regulations may be inefficient to protect whales if an adjacent jurisdiction, which shares the migratory species, lacks similar regulations.

Our review of relevant popular reports (a Lexis/Nexis search for all US newspaper articles on whale watching from 1989 to the present), combined with a limited number of interviews of whale watch tour operators (from the US and Mexico) and whale watching regulators (from all three nations), indicates a near unanimous conclusion that commercial whale watching vessel operators voluntarily abide by guidelines, and comply with laws and regulations. Recreational boaters and aircraft, however, often fail to live up to similar standards. The perception is that recreational boaters are merely ignorant, rather than intentionally flouting the law (although there are reports of isolated instances of individual recreational boats which directly ignored the warnings of commercial platform operators)(Hierta, 1991 at 30). For example, a National Marine Fisheries Service (NMFS) representative indicated that commercial whale watching vessel operators generally comply with guidelines and regulations, and that most of the complaints NMFS received have been about private boat operators interfering with whales.

Prosecutions are few as a result of the scarcity of human and financial resources for enforcement agencies. In other words, regulators cannot be present on every boat and aircraft. In addition, regulators commented that prosecutions were made difficult because success would hinge on evidence that a whale watching boat or aircraft had caused a change in whale(s) behavior or had violated a proximity regulation. Producing solid evidence to prove up such harassment cases is often impossible.

The legal aspects of whale watching vary by species and by jurisdiction. Generally speaking all of the laws, regulations and guidelines seek to avoid instances of threatening orientations of approach, rapid approaches, disturbing noises, or any sudden changes in noise or direction of the whale watching platform. The ultimate goal is to make whale watching safe for whales for the long term so that whale watching may be enjoyed by present and future generations. If harassment occurs, feeding may be disrupted, anxiety may be caused, and if mating is disturbed, conception may not occur.

The United States of America

Whale watching in the US occurs on both the Atlantic and Pacific coasts and in the Gulf of Mexico. Whale watching is also frequent in the Hawaiian Islands. In other words, a number of different whale habitats and species are found within US waters. This has complicated the quest for a unified statute relating to whale watching.

The two key federal statutes that apply to whale watching activity are: the Marine Mammal Protection Act of 1972 (MMPA) and the Endangered Species Act (ESA), both of which prohibit the "taking" of certain species (marine mammals, including all whales, in the case of the MMPA, and designated species of whales in the case of the ESA). "Take" is defined under the MMPA to include harass, hunt, capture or kill, or any attempt to do so; "take" is further defined by regulation to include "the restraint or detention of a marine mammal, no matter how temporary"; and "the negligent or intentional operation of an aircraft or vessel, or the doing of any other negligent or intentional act which results in the disturbing or molesting of a marine mammal." While exemptions to the prohibition exist under the MMPA, the NMFS asserts that whale watching is not an exempt activity. Under the ESA, "take" is defined to include harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or any attempt to do so. Prohibitions on harassment and pursuit should limit the activity of whale watching vessels.

Several years ago, the NMFS attempted to promulgate standardized regulations governing whale watching on a national level; however it met with such opposition that it withdrew the proposed regulations and is now dealing with the issue regionally. This opposition asserted that a single regulation would be overbroad given different conditions, and different species' responses to whale watch approaches. The remarkable observation, however, is that the regional guidelines and regulations are all very similar, indicating that a general national standard might have been possible after all.

NMFS has promulgated regulations specifically to protect Humpbacks in Hawaii and North Atlantic Right Whales along the coast of New England. Regulations, rather than guidelines, have been implemented for these specific areas because the Right Whales in the North Atlantic are still an extremely endangered species, and because of numerous reports regarding vessels interfering with Humpback mothers and their calves around the Hawaiian Islands. NMFS otherwise deals with whale watching through guidelines.

NMFS has drawn up specific guidelines for Gray Whale watching off the California coast. These include boat and aircraft avoidance suggestions, as well as a definition of harassment as any action that “substantially disrupt[s] the normal behavior pattern of a Gray Whale” such as “a rapid change in direction or speed; escape tactics such as prolonged diving, underwater course changes, underwater exhalation; or evasive swimming patterns such as swimming away rapidly at the surface; attempts by a female to shield a calf from a vessel or a human observer by tail swishing or by other movements to protect her calf.” (Hoyt, 1984 at 150).

Other than these geographic location and species specific regulations and guidelines, NMFS recommends a 100-yard approach limit for whale watching vessels and a 1000-foot limit for aircraft. These guidelines address only the conduct of vessels and aircraft approaching whales and do not address the situation where a whale unexpectedly appears within the limit.

The US regulatory enforcement and guidelines compliance experience is limited. NMFS is not capable of watching each and every vessel at all times, and thus must rely on self-regulation and reporting. It places its greatest efforts on education and making sure all would-be whale watchers know about the laws, regulations or guidelines.

Mexico

Mexico regulates whale watching through a number of programs, laws and regulations that fall under the jurisdiction of its environmental and tourism secretariats. Mexico rightly takes great pride in its whale protection measures. The nation was one of the first to call for protections of cetaceans in the 1930s. It also created the world’s first whale sanctuary for the Pacific Gray Whale in the lagoons of the Baja California Peninsula where the Grays winter, procreate and give birth to their young. Whale watching in Mexico occurs on both the Atlantic and Pacific coasts and in the Gulf of Mexico. In addition, whale watching is becoming more common in the Sea of Cortez. The greatest concentration, however, involves the congregation of hundreds of whales in the Baja California Peninsula lagoons, which provide a tremendous opportunity to observe the whales close to the coast. However, the concentration of so many whales in so little space also means that even a single boat could harass a large quantity of whales (Sánchez Pacheco).

Mexico’s whale watching legislation is derived from its 1988 General Law of Ecological Equilibrium and Environment. In addition, its Fisheries Law establishes the methods necessary for the protection of marine mammals (Ley de Pesca, artículo 3, fracción V), and Mexico's penal code prohibits any harm to marine mammals (Código Penal Mexicano, artículo 254 bis) (Sánchez Pacheco).

In addition, Official Mexican Standards (NOMs) establish regulations governing whale-watching activity. The most important of these is NOM-EM-074-ECOL-1996, which revised a 1994 law on the same subject.[3] While the new NOM covers a number of different issues, it establishes the rules regarding Gray Whale observation in the whale lagoons of Baja California Sur, including Ojo de Liebre, San Ignacio, and Magdalena Bay, as well as the protection and conservation of Gray Whale habitat.

In Baja California Sur, whale watching is limited to those companies which have applied for and been given permits. The permitees are required to comply with a set of regulations enforced by inspectors from Mexico's office of the Attorney General for the Environment (PROFEPA). These regulations are based on historical studies conducted by SEMARNAP's National Institute of Ecology (INE) on whale distribution, relative abundance, and behavior, as well as the experiences of whale watching operations in these lagoons, which are part of SEMARNAP's ongoing Vizcaíno Biosphere Reserve Gray Whale Program (Sánchez Pacheco). The whale watch regulations include the following:

- Designated whale-watching areas, which include only those portions of the lagoon in which the percentage of solitary whales (generally the males and some juveniles) exceeds the percentage of mother-calf pairs.
- A limitation on the number of boats that can be on the water at one time, and regardless of the number of the boats, a prohibition against noise which causes changes in the normal behavior of the whales.
- Defined areas of transit to reach the whale watch areas.
- A maximum speed of 10km/h in the areas of permitted whale watching to avoid harassment and collisions with whales.
- A requirement that whale watch permitees are also expected to obey protections set for the islands and lagoon environment generally.
- A requirement that operators ensure the safety of passengers. (Sánchez Pacheco)

What are the most serious problems affecting whales?

In Table 1 below we describe the specific threats to whales identified in our research (see Appendix A). They are divided into two levels: short- to medium-term threats, and long-term threats. These levels relate not only to the length of time before impact from the threat, but also a first attempt at prioritization of where effort should be placed. The short- to medium-term threats should respond to a short- to medium-term concerted effort, while the long-term problems are more intractable and need to be addressed within the context of much more comprehensive efforts.

[3] The law has recently been revised again.

Table 1: Summary of Threats

Short to Medium Term Threats	Impacts
Direct Fisheries Interactions (Operational Interactions)	Accidental entanglement in gillnets and other fishing gear causing injury and death. The mortality rate for some species is so high there is a risk of extinction.
Overfishing by Humans (Biological Interactions)	Overfishing by humans of resources relied upon by whales is contributing to their decline. Marine mammals are also wrongly blamed for fisheries depletion and thus exterminated like pests.
Marine Debris	Whales are injured and killed by ingestion of or entanglement in marine debris. There may also be a link between pollution and lowered immunity levels.
Loss of Habitat	The physical destruction of important expanses of natural habitat is a significant contributor to the decline of whales.
Ship Collisions	For some species of Whales collisions with ships is a major cause of mortality.
Sound Pollution	Ocean noise is causing acoustic disturbance, injury and even death to whales.
Long Term Threats	**Impacts**
Whaling	There is a resurgent effort to undertake whaling operations.
Climate Change and Ozone Depletion	These atmospheric changes will impact the ocean's productivity and are expected therefore to have an indirect negative impact on whales.
Bioaccumulation of Toxins	Direct mortality, reproductive impairment, and increased susceptibility to disease.

Mexico-US binational solutions

This section of the paper is intended to be a description of the legal and institutional factors contributing to possible strategies to protect the migratory whale population between the US and Mexico given some current threats of harvesting, alteration of habitat through development and commercial activities.

The contrast between how marine issues are handled must first be highlighted. Mexico and the US address most border environmental issues bilaterally. However, in the ocean where the political boundary is gone most environmental issues are handled multilaterally. Part of this is just that environmental issues are best handled at the relevant level. However, governments – which are obviously concerned about protecting their sovereign interests – are more able to approach marine issues "without borders" as they are environmental problems that are more often international in their nature.

Agreements regarding marine environmental protection and species conservation have generally taken a back seat to those regarding shared use of the seas for commerce or on sovereign rights to exploit natural resources in the sea. However, this is changing. There has been some international institutional development: the United Nations Environment Programme now deals with marine conservation, the UN Food and Agricultural Organization oversees world fisheries, the International Whaling Commission governs whaling, the International Maritime Organization oversees ships and shipping.

There are also numerous international efforts relating to migratory marine species or the threats to them. However these are not necessarily "border region" oriented. Appendix B is a list of bilateral and multilateral agreements to which the Mexico and US are parties. Many of these agreements relate to responsibilities and obligations which the US and Mexico have toward their shared migratory whale population. For instance:

- Habitat Protection – the 1940 Convention on Nature Protection and Wild Life Preservation in the Western Hemisphere focuses on the protection and preservation of all species and genera of their native flora and fauna in their natural habitat.
- Pollution Prevention – the 1973 International Convention for the Prevention of Pollution from Ships was intended to protect the marine environment from pollution from ships.
- Control of commercial exploitation – the 1975 Convention on International Trade in Endangered Species of Wild Fauna and Flora specifically lists the Pacific gray whale as an Appendix I endangered species, trade in which is to be tightly controlled.

However, for this purposes of this chapter I will briefly review the marine conservation efforts[4] which relate directly to the waters near the border or within the shared California Current Large Marine Ecosystem, specifically the Bight of the Californias project, the Ocean Wilderness Network, the Baja California to Bering Sea Marine Conservation Initiative, and the North American Commission for Environmental Cooperation (CEC)[5] whale watching ecotourism studies/pilot projects. This LME together with the Gulf of Alaska LME were recently identified by a CEC biodiversity workshop on "Strategic Directions for the Conservation of Biodiversity" as one of 14 regions of conservation priority to focus CEC's biodiversity program. The region reflects ecosystems that are continuous across national boundaries or are vital to shared species or critical ecological processes. While recognizing the extreme importance of many national priority areas, the experts felt that these international corridors and linked ecosystems require a new approach based on continental-scale cooperation and planning initiatives.

Bight of the Californias Global Programme of Action

Ocean pollution is a worldwide problem. Eighty percent of all ocean pollution starts on land. Point source pollution originates from a single location. Scientists call non-point source pollution that which is caused by millions of individual actions. The Bight of the Californias, also known as the Southern California Bight, is a marine ecosystem that extends from Point Conception, California (US) to Cabo Colonett and Bahia de San Quintin, Baja California (Mexico). The Bight of the Californias pilot project deals with both point and non-point sources of land-based ocean pollution. Mexico and the United States each have marine conservation

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[4] Omitting for now, though relevant, efforts by the International Boundary and Water Commission, the Border Environment Cooperation Commission and the North American Development Bank to address reduction of sewage flows into the ocean near the border region (which on the other hand are noted and subsumed within the Bight of the Californias pilot project).

[5] The CEC is a trinational organization whose members are Canada, Mexico and the United States, created under the North American Agreement for Environmental Cooperation (NAAEC) to address regional environmental concerns, help prevent potential trade and environmental conflicts and to promote the effective enforcement of environmental law.

programs. This project integrates the efforts of both countries, allowing people in Mexico and in the United States to work together across the border to reduce the sources of pollution that affect the Pacific Ocean waters they share.

In 1995 more than 100 nations, including Canada, Mexico and the United States, agreed to a plan of action to tackle ocean pollution. This plan was developed under the auspices of the United Nations Environment Programme. The plan, The Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities (GPA), is a practical, step-by-step guide to helping people working at regional, national and international levels to determine what actions are needed to deal with sources of ocean pollution that start on land. The CEC is helping Canada, Mexico and the United States to develop the cooperative partnerships needed to implement the GPA. Two pilot projects, the Bight of the Californias and a second in the Gulf of Maine are multinational efforts designed to put into effect the GPA. These projects seek to reduce ocean pollution by inviting the people who understand the problems best to devise solutions.

Ocean Wilderness Network

One of the most important movements regarding marine protection today involves the creation of marine parks. Such reserves or protected areas only exist in less than 1% of the waters of the US. This can be compared to roughly 5% of US land that has been dedicated to wilderness protection. There is now a strong scientific consensus that marine reserves are good for conservation and for fisheries outside the reserve boundaries.[6] Further, the ENGO SeaWeb is about to embark on a nation-wide communications campaign to convince the American public to support the creation of marine protected areas. Coincident with this, a coalition of ENGOs from Canada, Mexico and the US has formed around supporting a network of marine protected areas on the West Coast of the North America (beginning with the US coast). The coalition, which has named itself the Ocean Wilderness Network (OWN) has prepared a detailed strategic plan for the next three years, and has joint funding to hire two staff to undertake coordination of the coalition. The Packard Foundation approved an approximately $1 million grant for OWN on March 15, 2001 in response to the coalition's application for support for its strategic plan. Such protected areas, if created, will be extremely beneficial habitat for marine mammals and/or for their food resources.

Baja California to Bering Sea Marine Conservation Initiative

Over the past two years, the Canadian Parks and Wilderness Society has been collaborating with government agencies and non-governmental organizations in Mexico, the United States and Canada in developing the Baja California to Bering Sea Marine Conservation Initiative (B2B). The goal of this initiative is to establish a linked network of MPAs, together with other conservation strategies, on the West Coast of North America. More than 60 individuals have expressed interest in this initiative. In May 2000, the first meeting was convened to discuss the scope, goals and objectives for B2B.

The advantages of linking the CEC MPA project with the B2B initiative include:

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[6] There is now compelling scientific evidence that marine reserves conserve both biodiversity and fisheries, and could help to replenish the seas, says a scientific consensus statement signed by 161 of the world's leading marine scientists. The statement was released in February 2001 at the annual American Association for the Advancement of Science (AAAS) meeting.

- Existing trilateral connections have been established within both the government and non-governmental communities;
- Existing broad network of interest, especially in the government and NGO community in B2B;
- New funding has been secured from the Goldman Fund in San Francisco (US$50,000 over the next two years), and other funding requests are pending that could leverage any support from the CEC;
- The overall objectives and goals between the CEC and the B2B initiatives are very similar and quite compatible;
- It is early enough in the development of the B2B initiative to incorporate the CEC action plan elements;
- Excitement and interest in Baja to Bering is growing.[7]

CEC whale watching Ecotourism studies/pilot projects

The CEC started an initiative on Sustainable Tourism in Natural Areas in 1998. This project began by exploring ways to promote the 'greening' of the tourism industry as it related to natural areas in North America. The project was designed to take place in three phases between 1998 and 2002.

The first phase, from 1998 to 1999, consisted of a scoping exercise comprised of two main activities. The first was the preparation of a background paper that outlined the state of sustainable tourism in North America and underscored the major issues. *The Development of Sustainable Tourism in Natural Areas in North America: Background, Issues and Opportunities* was prepared in large part as a discussion paper for the participants of a multistakeholder workshop held 27–28 May 1999 in Playa del Carmen, Quintana Roo, México. This background document covers the definition and context of sustainable tourism in terms of demand, natural and cultural resources to meet this demand in North America, the actors involved in sustainable tourism, and the policy/regulatory framework surrounding sustainable tourism. The workshop "A Dialogue on Sustainable Tourism in Natural Areas in North America" comprised the second activity in the scoping phase of the project. Geoffrey Wall, president of the International Academy for the Study of Tourism, chaired it, and the invited speakers and participants included government, NGOs, and academia.

To begin the third phase, in March 2001 the CEC sponsored a forum on "Sustainable Tourism and Whale Watching in North America: A Baja to Bering Case Study" in La Paz, Baja California. According to planeta.com, "Discussions focused on (1) the benefits and drawbacks of nature-based tourism in North America using whale watching as a pilot study, (2) how whale watching can contribute to conservation of biodiversity, (3) the opportunities and challenges of developing a plan for sustainable whale watching in the area in conjunction with regulations, certification and guidelines, (4) how local communities can participate, and (5) identifying economic barriers and financing issues." Recommendations in each of these areas were made together with two general recommendations from the final plenary session. The group recommended a comprehensive effort be made toward communications related to this area of CEC effort and that the CEC should foster the development of three or more pilot projects to

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[7] Personal communication with Hans Herrmann, Head of Conservation Biodiversity program of the Commission for Environmental Cooperation (February 2001).

develop and/or highlight best practices in the whale watching industry sector. These pilot projects will thus be the third and last phase of this project.

Habitat Threat Case Study: the binational effort to stop the Laguna San Ignacio saltworks

The habitat case study involving Laguna San Ignacio is a clear example of a multinational corporation, seeking to build an industrial facility in an internationally designated Biosphere Reserve and World Heritage Site, frequented by the Pacific Gray Whale which passes through three nations' waters in its annual migration, and drew the attention of the world and certainly inspired the binational cooperation among US and Mexican ENGOs to fight against the project. There was nothing solely domestic about this.

The following is a brief factual summary regarding the recently rejected solar saltworks, which a joint venture had hoped to build along side of Laguna San Ignacio, Baja California Sur, Mexico. Specifically, as proposed by ESSA *(Exportadora de Sal),* a joint venture of Mitsubishi Corporation (49%) and the Mexican government (51%), the new saltworks would create a massive 116-square-mile industrial landscape of evaporation ponds, a million-ton salt stockpile, fuel and water tanks, a 1.25-mile long pier with a shipping dock and conveyor belts running from crystallization ponds to the pier's end, workshops, headquarters buildings, and the facilities necessary to support 200 employees while onsite. Seventeen pumps operating 24 hours a day to draw 6,600 gallons of saltwater per second from the lagoon into the evaporation ponds. The new saltworks project was initially proposed by ESSA in 1994, seeking a building permit authorization supported by a Mexican government required Environmental Impact Assessment (EIA). Because the proposed project site was within a federally designated protected area, it was the responsibility of Mexico's National Institute of Ecology (INE) (part of SEMARNAP [the Mexican Secretariat for the Environment, Natural Resources and Fisheries]) to decide whether the proposal could be approved.

In 1994, a Coalition, then made up primarily by Mexican environmental groups, mobilized against the saltworks project using various legal remedies, and asserted significant and substantive legal and scientific arguments. As a result, the first EIA regarding the Laguna San Ignacio saltworks was rejected in 1995 by INE primarily because the project was not appropriate for a buffer zone of a Biosphere Reserve.

ESSA first appealed the rejection, then decided to prepare a new EIA document. In response to allegations that Mexico as the project proponent and reviewer of the EIA had a conflict of interest, SEMARNAP created an International Scientific Committee to advise INE and ESSA on what to include in the environmental assessment.

In July 1996, the International Scientific Committee issued scientific terms of reference (TORs) for the new EIA. Concurrently, INE issued socioeconomic TORs that also had to be addressed by the EIA. Obviously, the project, in addition, had to be consistent with Mexico's environmental laws and regulations.

The proposed Laguna San Ignacio saltworks would disturb and degrade a unique and irreplaceable natural area and pose risks -- direct and indirect, including those associated with the expected influx over time of additional people and commercial activities -- to whales and numerous other species, as well as to the very fragile surrounding desert environment. The principle reason to work in opposition to the saltworks was almost entirely on legal grounds. The proposed saltworks could not be designed to overcome the legal reasons for which it was rejected in 1995. The lagoon had (and continues to have) the four levels of legal protection it has been given over the years. Even if there were no endangered species involved, these legal principles should not be ignored. Further, there is a substantial worldwide history of harm to fisheries from saltworks of this type, which thus threatened the livelihood of the few locals who live around Laguna San Ignacio. This said, the Biosphere Reserve and other designations for this lagoon were established to protect: “14 plant species (4 rare, 2 threatened, 2 under special protection and 6 endemic) and 72 animal species (15 rare, 39 threatened, 6 in danger of extinction, 7 under special protection and 5 endemic). These species could be directly or indirectly harmed by habitat alteration and construction and operation of the project in question.”[8]

The endangered Pacific Gray Whale[9] is only one of the species under protection. However, it captured the attention of the media and environmental groups and became symbolic of this campaign. This Eastern Pacific stock of the gray whales is the last one (in the late 1950s, there were fewer than 1,000 gray whales left; today there are over 22,000.). The Atlantic and Western Pacific stocks are, respectively, extinct and nearly so. The proposed saltworks is just one of many threats to gray whales and as such must be viewed in context. Habitat degradation and aboriginal whaling constitute cumulative threats to the Pacific Gray Whale. The gray whale is a shared migratory species which is the subject of an extensive whale watching industry which yearly brings in US$10s of millions of dollars for Canada and the US, and an estimated US$5 million in Mexico. How well is this industry regulated? What is the current status and potential impact on the gray whale of development in Baja California Sur’s Magdalena Bay, Laguna San Ignacio, and Ojo de Liebre (the three remaining nursery lagoons)? What would be the impact of further development in these lagoons? What is the impact of Russian whaling, Makah Indian whaling and Inuit Indian whaling? What would be the impact if the Chul na Tuth First Nation of Vancouver Island also receives permission go whaling? Add to this, bioaccumulation of toxics and changes in habitat from climate change and it becomes clear that we must be extremely careful in doing anything that might impact this species.

As for the effect of the proposed salt plant on the gray whales, it should be noted that after ESSA began operations at Guerrero Negro, whales abandoned a small lagoon there for over a decade. Their disappearance has been attributed to ESSA’s dredging of the lagoon’ mouth aimed to accommodate salt barge traffic. The whales returned only after

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[8] Environmental impact assessment rejection letter from Gabriel Quadri de la Torre to Juan Bremer Gonzalez. (27 February 1995).
[9] Appendix I of CITES.

ESSA moved its barge operations to the larger Laguna Ojo de Liebre (Sánchez Pacheco, and Hoyt, 1984: 177-8).[10]

More specifically, building the saltworks at Laguna San Ignacio would risk introducing three of the four major threats to whales, other than whaling: loss of habitat, accidents involving collision with ships, and the slow but inexorable bioaccumulation of toxics (For more information of these major threats, see Payne, 1998). New human population will be attracted, crowding the whales in the lagoon with more boats, noise and waste. Large ocean going vessels will be introduced into the area. Large quantities of toxic substances such as oil, diesel fuel, and brine wastes will be present. Brine wastes contain toxic concentrations of magnesium sulfate, potassium chloride, bromine, iodine, and boron, which, as proposed by ESSA, will be dumped into the adjacent Bahía de las Ballenas (the aptly named "Whale Bay").

Sometime during the first quarter of 2000, ESSA submitted its EIA to INE. This submission should have triggered a review process that would include an initial assessment by the International Scientific Committee, followed by a "public consultation" opportunity. Finally, INE's Director General for Environmental Impact and Ecological Zoning, taking into account the following results:

- the assessment made by the International Scientific Committee,
- the public consultation, and
- its own assessment as the competent authority,

was to propose a finding to the Secretary of the Environment, Julia Carabias, as to whether or not to authorize the project.

On Thursday March 2, 2000, however, Mexico's President Ernesto Zedillo announced that he had decided to cancel, and Mitsubishi Corporation had agreed not to pursue, the Laguna San Ignacio saltworks. While many were rightly thankful that Mitsubishi's plans to put an industrial saltworks in a whale sanctuary had been rejected, we must remember that the project was not rejected on legal or environmental grounds, as it should have been. Mexico has a process for reviewing EIAs, but apparently President Zedillo had no qualms about derailing the "process." Zedillo's exercise of *presidentialismo* avoided transparency of decision-making. It placed the extreme power of the president over the rule of law. Because the project was not derailed on its merits, this same presidential power could be used to resuscitate the project during a future administration. This is a bad precedent for Mexico, even if most believe that not building the facility was the right decision, because once again the legal process for project review was subverted and the competent authority sidelined.

Conclusion

There are short-, medium- and long-term threats to whales. As a result, certain species and/or populations within those species are endangered or vulnerable. Because whales are charismatic, they get a lot of attention. However, we do not know exact population size for many

[10] This was also noted by the IUCN during its evaluation of the site following its nomination as a UNESCO Biosphere Reserve.

whale species, However, the declining health and size of a number of whale species or populations indicates the ocean is not healthy.

Whales are high-end indicators of the health of the ocean habitat and biodiversity. As such there is a need for binational cooperation in dealing with migratory marine species because threats to Pacific Gray Whales occur primarily in Mexican and US waters. Because of these threats a group of ENGOs recently petitioned to have the Gray Whale re-listed as an endangered species under the US Endangered Species Act. If it is re-listed, and if a species recovery plan is drawn up, it must be remembered that only part of the migratory corridor and therefor the threats to habitat fall under US jurisdiction. Regardless one can hope that the Pacific Gray Whale will serve as a focal point to stimulate public opinion in favor of efforts to protect the health of the Gulf of Alaska and California Current LMEs.

While we have highlighted the contrast in which marine issues are handled multilaterally, Mexico and the US address most border environmental issues bilaterally. Recently some binational efforts on marine conservation have been begun. For good or bad even these efforts often have to do with joint implementation of obligations created by multilateral agreements. Regardless, the binational solutions, including some trinational ones fostered by the North American Commission for Environmental Cooperation are a significant step in the right direction. It is clear that the cooperation is leveraging the resources of Mexico and US toward common goals. But there is still more that can be done. A future area for North America cooperation is the consistent enforcement of laws over time and across nations related to Natural World Heritage Sites, and UNESCO Biosphere Reserves.

It is the wildness, beauty and simplicity of nature that attracts us to it. These same qualities should encourage us to value it enough to change our habits. Many have discussed the resilience of nature. If we give it a chance, it can recover from the indignities we have made it suffer. For example, in the late 1800s and the mid-1900s humans nearly exterminated the Eastern Stock of the Pacific Gray Whale to reduce its blubber to oil for foodstuffs and to make corsets from its baleen. By 1946 there were less than 2,500 Gray Whales left. Since then, merely by virtue of a moratorium on hunting them, the Gray Whale has recovered to what some believe to be its pre-exploitation population level of over 25,000. A ten-fold population increase in about 50 years! Given that the Gray Whale lives primarily within the national waters of Mexico and the US, this recovery of Eastern Pacific Gray Whale is transborder cooperation at its best.

Appendix A: The Threats

Short- to Medium- Term

Direct Fisheries Interactions (Operational Interactions)

Marine mammal interactions with fisheries fall into two broad categories: operational interactions and biological interactions. Operational or direct interactions primarily refer to accidental entanglement in gillnets and other fishing gear which results in injury and death. The mortality rate for some marine mammal species is so high there is a risk of extinction. The following are excerpts from the current literature and interviews:

- This is a key short-term threat. For example, it is responsible for the serious decline in the Harbor Porpoise on the California coast and the Vaquita in the Sea of Cortez (Croll)
- Within the environmentalist community the "need" for zero dolphin mortality from tuna fisheries interactions has almost become a litmus test regarding a group's level of commitment to marine mammal protection. (Bedolfe, Croll)
- Salmon aquaculture in British Columbia and in Chile has an indirect impact on marine mammals. (Bedolfe)
- Trawling harms some marine mammals. (Bedolfe)
- Several marine mammal species "are in danger of extinction, in large part from entanglements in fishing gear." "Currently, 39 out of 144 U.S. populations of whales, dolphins and seals suffer such high levels of human-caused mortality that the populations cannot grow and recover." (CMC, 2000: 10 and 20)
- "Operational interactions include accidental entanglement of marine mammals in gillnets and other types of fishing gear . . ." (Twiss, 1999: 3)
- "Deaths of marine mammals caused by fishery operations also involve a wide range of mammal species and types of fisheries." (Twiss, 1999: 102)
- "Not all marine mammal mortalities due to interactions with fishing gear are immediate. Injuries to the animal, or gear fragments that remain attached to the animal, may make the animal more susceptible to death at a later time from infection, starvation, or some other cause." (Twiss, 1999: 102-3)
- Vaquita are threatened by incidental catch in gillnets and shrimp trawls. "The only measure that would completely protect the Vaquita and possibly allow it to recover would be an enforced total ban on gillnetting and trawling activities in the northern Gulf of California." (Twiss, 1999: 297)
- Other than whaling, a top cause of premature death for cetaceans is their accidental death in fishing gear including purse seine nets for dolphin and drift nets for other species (Payne, 1995: 302-304).
- "Incidental catches in fishing nets of large numbers of dolphins have recently caused heavy mortality." (MacDonald, 1993: 175)
- "Gill-nets, laid to catch salmon or capelin, also catch and drown dolphin. Inshore species of porpoises such as Dall's and Harbor porpoises are most at risk" (MacDonald, 1993: 185)
- "Because porpoises prefer to prey on open-sea fish, they are vulnerable to "incidental" capture by certain types of fishing gear set for those fish." For example, salmon gill nets, herring weirs etc. (MacDonald, 1993: 198)

Overfishing by humans (Biological Interactions)

Overfishing by humans of resources relied upon by marine mammals is contributing to their decline. Marine mammals are also wrongly blamed for fisheries depletion and are thus considered competitors to be exterminated like pests. The following are excerpts from the current literature and interviews:

- Fisheries management on a species-by-species basis is a threat to whales, thus ENGOs working on fisheries issues may be indirectly benefiting whales (Thorne-Miller interview)
- "1. Overfishing by humans, not whales, has been identified as a major problem for the worlds' ocean resources. 2. Many whales feed on krill and fish species not used by humans. 3. In most cases, predatory and cannibalistic fishes are greater predators of fish than are whales and other marine mammals. 4. Hunting whales is unlikely to provide increased catch of fish species, because of the complexity of ecosystem interactions." (NOAA, undated: 3)
- "Fisheries have also reached a level of incomprehensible destruction . . . Commercial fishers farther offshore in international waters are not subject to national regulations and only recently have come under scrutiny." (Thorne-Miller, 1999: 17)
- There are "Too many boats and too much high-tech gear" focused on "maximum sustainable yield" of fish resources. (Thorne-Miller, 1999: 18)
- "The bycatch may be even more devastating to pelagic (open-ocean) ecosystems than the catch." (Thorne-Miller, 1999: 19)
- "[Marine mammal] populations are now so small that they consume less than 8 percent of the fish production. Many marine mammals are no longer counted as major parts of the ecosystem – they are treated more as lovable or not-so-lovable tourist attractions, depending on the beholder; when they eat fish, they do so at the risk of wrath from commercial fishers. Even when we love them and protect them from harassment, we do little to protect their food supply." (Thorne-Miller, 1999: 78-9)
- Human demand is removing organisms from the ocean, which are the foods of whales. (MacDonald, 1993: 174)
- "The future of the rorquals depends on the success of the . . . conservation of their food-base, krill." (MacDonald, 1993: 225)
- "Finally, one factor which for whales and dolphins may represent the greatest threat is the increasing need for man to exploit the sea for food . . . man is beginning to harvest a variety of food organisms (for example krill in the Southern Ocean, capelin, sand eels and sprats in the North Atlantic), which form important links in the marine food chains for cetaceans, seals and seabirds alike." (MacDonald, 1993: 175)
- "Finally, direct competition for particular fish species may be an important potential threat [to Dolphins] as man turns increasingly to the marine environment for food." (MacDonald, 1993: 185)

Marine Debris

Marine mammals are injured and killed by ingestion or entanglement in marine debris. There may also be a link between pollution and lowered immunity levels. This is a growing problem due to increased use of non-degradable synthetic items. The following are excerpts from the current literature and interviews:

- There may be a link between pollution and lowered immunity for marine mammals. Clearly, we know that disease is increasing (Thorne-Miller interview)

- The "oceans are finite and destructible. Wastes dumped and drained into the ocean do not disappear; they are neither economic nor ecological externalities." (Woodard, 2000: 227)
- "Oil pollution is a serious problem for marine and coastal fauna." (Goudie, 2000:125)
- "Every year [marine debris] injures and kills thousands of marine animals that ingest or become entangled in the trash" among them are "large whales, Northern fur seals, Hawaiian monk seals and other threatened or endangered whales." (CMC, 2000: 13 and Russel)
- "About 20 percent of all ocean pollution is due to activities at sea – vessel traffic, waste disposal, oil and gas exploration, and mining on the deep-sea bed. Most of the remaining 80 percent comes from activities on land." (Thorne-Miller, 1999: 22)
- Marine mammals "are injured or killed when they become entangled in marine debris or when they ingest it." (Twiss, 1999: 342)
- "At least three factors account for the recent increase in marine debris: (1) disposal practices rooted in the outdated notion that the ocean's enormous size enables it to absorb all kinds of human waste without harm; (2) proliferation of synthetic materials resistant to degradation in the marine environment; and (3) increasing numbers of mariners and coastal residents using and discarding more and more synthetic items." (Twiss, 1999: 342)
- "Because of their buoyancy and persistence, plastic items contribute disproportionately to the overall impact of marine debris. Most of the debris that either entangles animals or is found in their stomachs is made of plastic." (Twiss, 1999: 344)
- Marine debris is estimated to impact 15% of the world's cetaceans. (Twiss, 1999: 347)
- Marine debris may be creating harmful biological impacts on entire populations of marine mammals. (Twiss, 1999: 349)

Loss of habitat

The physical destruction of important expanses of natural habitat is a significant contributor to the decline of marine mammals. The following are excerpts from the current literature and interviews:

- Ecosystem set asides, advocacy for creating marine mammal sanctuaries is becoming more and more important. (Bedolfe) [Also see Thorne-Miller, 1999: 117 et. seq.]
- "The only way to understand and conserve marine ecosystems is to study, manage, and regulate them *as* ecosystems." (Woodard, 2000: 229) [for example, Woodard identifies in his Appendix A that there are two such ecosystems on west coast of North America: Gulf of Alaska and the Californian]
- "We must concentrate our attention on the parts of the ocean that are within national jurisdictions. Not because the high seas are unimportant but because both ocean life and the threats to it are concentrated near land." (Woodard, 2000: 230)
- Loss of important habitat is the cause of endangered status for several species of marine mammals. (CMC, 2000: 20)
- "As of June 2000, less than one-half of one percent of our ocean waters receive [wilderness] protection, and only one-half of one percent of that area, or less than 50 square miles, prohibits extractive use, such as fishing and mining." (CMC, 2000: 11)
- Marine mammals are united by habitat requirements "all are dependent on an aquatic ecosystem for survival. This dependency makes them visible indicators of habitat degradation." (Reynolds, 1999: 1)

- "Management of marine mammals (and indeed of all living resources) involves maintenance of the habitat on which a species depends, not simply maintaining the species itself; therefore, managers may tend to consider marine mammals as a group that has some common habitat requirements and perhaps common vulnerabilities." (Reynolds, 1999: 1)
- "One of the most obvious sources of biodiversity loss is the physical destruction of significant expanses of natural habitat." (Thorne-Miller, 1999: 20) [examples at page 21]
- There are three issues: (a) "The world's coastal areas are being overwhelmed with people and pollution"; (b) "critical coastal resources . . . are being plundered in the name of development and lost through inertia and neglect"; and (c) "the inability of governments . . . to craft and implement rational coastal management plans is having far-reaching consequences" (Hinrichsen, 1998: 4)
- "Because they fire our imaginations so effectively, we can often marshal the political clout needed to set aside area of the earth to protect whales . . . Such sanctuaries also become havens for lesser-known species of animals and plants that are so necessary for life but that because they have not inspired us have no friends and therefore die alone. The principle seems to be this: if you want to save an area, save its most inspiring inhabitant. The rest will be maintained along with it." (Payne, 1995: 340-1)
- The most important habitat for whales are "the ocean areas with the highest primary productivity." (MacDonald, 1993: 169)
- "Cetaceans are not randomly distributed over any region but instead appear to be associated with oceanographic features such as upwellings (where food concentrations tend to occur), or undersea topographical features such as continental shelf slopes (which may serve as cues for navigation between areas). Breeding areas for most cetacean species (particularly small toothed whales) are very poorly known, but are better know for some of the large whales." (MacDonald, 1993: 171)
- "Modification of the marine environment is occurring in many parts of the world." (MacDonald, 1993: 174)
- "Actual removal of suitable habitat by the building of coastal hotel resorts, breakwaters which change local current patterns and encourage silting, and dams which regulate water flow in rivers, all impose threats." (MacDonald, 1993: 175)

Ship collisions

For some species of Whales, collisions with ships are a major cause of mortality. The following are excerpts from the current literature and interviews:

- This is an East Coast problem. It is not a problem on the West Coast, except in very urbanized ports because we have few surface feeders. (Croll)
- Collisions with boats are the cause of endangered status for several species of marine mammals. (CMC, 2000: 20)
- "Half of the right whales' known mortality is caused by collisions with ships and entanglement in fishing gear." (CMC, 2000: 24)

Sound Pollution

Ocean noise is causing acoustic disturbance, injury and even death to marine mammals. The following are excerpts from the current literature and interviews:

- Sound pollution in the ocean is a key long-term issue. Not just Low Frequency Active Sonar (known as LFA), but also cumulative effects of all ship traffic and other noise. We need to understand how is it affecting whales. (Croll)
- We know we can cause physical trauma to marine mammals with loud noise. We also believe that recurrent sound can cause permanent harm over time. (Potter)
- Since 1974 there have been seven documented instances of mixed species strandings (mixed species is very rare) that were associated with Navy activity involving active sonar systems. (Weilgert)
- Ocean noise is comprehensive, worldwide and ubiquitous. Some is from classified sources; much is from regular ship traffic. (Jasny)
- Loud anthropogenic sound can mask over biological/natural sounds that may be crucial for marine mammals to hear. (Jasny)
- Noise may cause marine mammals to abandon traditional habitats. (Jasny)
- LFA and other active (as opposed to passive) sonar are a key emerging threat to marine mammals. (Bedolfe)
- The only likely candidate for communication among whales is sound. “Large whales have well-developed inner ears and exceptionally well-developed acoustic areas in their brains. This suggests that sound is important to them.” (Payne, 1995: 171)
- “Acoustic disturbance comes from sonic testing (for example during oil exploration), military depth charge practice and particularly from motor boat traffic.” (MacDonald, 1993: 175)
- Dolphins are impacted by acoustic disturbance from boats. (MacDonald, 1993: 185)

Long-Term

Whaling
The future of whales depends on the success of the protection they have received in recent years. But this seems to be falling apart. There is a resurgent effort by Japan and Norway to undertake whaling operations. In addition, they have supported active attempts to expand indigenous whaling. The following are excerpts from the current literature and interviews:

- Whaling conducted under the “scientific research” exception to the moratorium on international whaling is really commercial whaling. (Palumbi)
- Scientific whaling allows protected species to slip into the market. (Palumbi)
- Several species of whales have been brought back from the brink of extinction by international protection, which ended whaling by the vast majority of nations and in effect restricted it for those nations that refuse to stop: Norway, Japan, and Iceland. (Steuer)
- Whaling for Sperm whales was halted in 1985, but continues by some native tribes, and Japan now asserts the right to hunt Sperm whales. (Steuer)
- Japan plans to continue the expansion of whaling operations. (Steuer)
- Exploitation of marine mammals will increasingly become a threat. (Bedolfe)
- “Whale stocks have been reduced by at least half through uncontrolled hunting during the past half-century. Populations of the large varieties, those that have been most heavily exploited, have been cut to a tiny fraction of their former sizes, and the hunting, especially by the Russians and the Japanese, still goes on.” (Goudie, 2000:140)
- “Marine mammals have been hunted relentlessly until they are on the brink of extinction or at the very least play a far less significant role in the ecosystem.” (Thorne-Miller, 1999: 106)

- "Dolphins, porpoises, and small whales are highly vulnerable to hunting because of their small size and, in some species, their habit of riding the bow waves of vessels." (Twiss, 1999: 303)

Climate Change and Ozone Depletion

These atmospheric changes will impact the ocean's productivity and are expected therefore to have an indirect negative impact on marine mammals. The following are excerpts from the current literature and interviews:

- Climate change will result in impacts that will vary according to species and population. Fortunately we know how to reverse human impact on climate change. (Würsig)
- The reduction of Arctic ice reduces the ocean's production of copepods, a key food source for whales. (Würsig)
- Warmer water may be lethal to, or impact reproduction by, some marine mammal species. (Würsig)
- Warmer water may be lethal to some food species important to marine mammals. It may also force some predators that currently consume fish and other ocean resources to turn to marine mammals if food source availability changes. (Würsig)
- Reduction of ice and sea level rise may result in dramatic change/loss of habitat including birthing lagoons for cetaceans. It will be especially hard on species with narrow habitats such as gray whales. It may also cause changes in availability and location of food sources. (Würsig)
- This is a very key long-term issue. How will marine mammals deal with global climate change? Use of whales for advocacy might be instrumental in seeking support for a campaign against climate change. (Croll)
- Climate change will impact the ocean's productivity. Based on experience with El Niño, the production of krill will be key, which will have a direct negative impact on whales. See the experience of the die-off of gray whales in 1999 and 2000. (Croll)
- John McGowan of Scripps Institution of Oceanography found that there has been a 70 percent decline in zooplankton as ocean temperatures have risen. "McGowan has documented an ecological crisis extending across a third of the North Pacific, from the Gulf of Alaska to the southern California coast." Warm water marine mammals are increasing; cold-water marine mammals are dwindling. (Woodard, 2000: 51)
- Declines in krill populations have been measured as a result of ozone depletion. (Thorne-Miller, 1999: 35)
- Climate change and global warming will impact whales. (Payne, 1995: 318-21)

Bioaccumulation of toxins

The bioaccumulation of toxins in the tissue of marine mammals (as a separate category from ingestion of marine debris discussed above) causes direct mortality, reproductive impairment, and increased susceptibility to disease. The following are excerpts from the current literature and interviews:

- This is a key long-term issue. It is less problematic on the west coast because of the offshore transport from California (Croll)
- Northern killer whales are the most contaminated with biotoxins. PCBs are serious problems. Dioxins and other persistent toxins are also being found. Males are retaining the PCBs; females rid themselves of it by passing it to their young during lactation. (Ross)

- PCBs cause reproductive failure, increased susceptibility to disease, malformations and other birth defects, and neurological deficits. (Ross)
- Killer whale contamination is an indicator of ocean contamination. (Ross)
- We are most concerned with organochlorine compounds and toxic elements, but our current state of knowledge about their impact is incomplete. Organochlorines are highly fat-soluble and accumulate in the lipids of animals. “Because the ultimate sinks for many of these persistent compounds are the oceans of the world, where organochlorines are rapidly absorbed to organic matter and taken up by plankton, marine mammals have been an end point in the food web accumulation of these compounds.” (Reynolds, 1999: 485-6)
- “Mounting evidence suggests that organochlorines may be detrimental to marine mammal populations” through direct mortality, reproductive impairment, and increased susceptibility to disease. (Reynolds, 1999: 499)
- “In marine mammals, blubber is the major repository for organochlorines” . . . “very few studies have attempted to estimate the absolute body load of organochlorines in marine mammals” (Reynolds, 1999: 492-3)
- Extremely high concentrations of DDT and PCBs have been reported in cetaceans from the eastern North Pacific off southern California. Also high concentrations in seals and sea lions in coastal southern California. (Reynolds, 1999: 498)
- “Marine mammal populations with high exposure to organochlorines are also likely to have been subjected to numerous other forms of human-induced stress, such as other contaminants, noise pollution and disturbance, habitat deterioration, or changes in food quantity and quality.” (Reynolds, 1999: 503)
- Whales face death from “the slow but inexorable accumulation of toxic substances in their bodies.” (Payne, 1995: 305)
- Humans are releasing toxic waste products into the ocean. (MacDonald, 1993: 174)
- “Toxic chemical pollution (particularly from heavy metals, oils and persistent chemicals) from urban, industrial and agricultural effluents may also have serious harmful effects . . .” species in enclosed seas or in coastal waters are most “vulnerable and presently showing decline.” (MacDonald, 1993: 175 and 185)

Appendix B – Relevant International Agreements

	Conventions relating to management or conservation of shared migratory species in the marine environment and/or shared management and conservation of coastal and marine ecosystems.	Entered into force		Signed	
		Mexico	US	Mexico	US
1	Convention for the Regulation of Whaling	1/16/35	1/16/35	-	
2	International Convention for the Regulation of Whaling, 1946 (TIAS 1849). http://sedac.ciesin.org/pidb/texts/intl.regulation.of.whaling.1946.html	6/30/49	11/10/48	-	12/02/46
3	Convention on Nature Protection and Wild Life Preservation in the Western Hemisphere http://djl04.djl.co.uk/iucn/elipac/treaties/tre-0030.txt	6/27/42	5/01/42	11/20/40	10/12/40
4	International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto, as amended (MARPOL 73/78). http://djl04.djl.co.uk/iucn/elipac/treaties/tre-0720.txt	7/23/92	10/2/83	6/1/78	6/27/78
5	Convention on Fishing and Conservation of the Living Resources of the High Seas. Done at Geneva Apr. 29, 1958. Entered into force Mar. 20, 1966. TIAS 5969. http://sedac.ciesin.org/pidb/texts/high.seas.fishing.living.resources.1958.html	9/1/66	-	3/20/66	9/15/58
6	Convention on the Territorial Sea and the Contiguous Zone. Done at Geneva Apr. 29, 1958. Entered into force Sept. 10, 1964. TIAS 5639. http://sedac.ciesin.org/pidb/texts/territorial.contiguous.zone.1958.html	9/1/66	-	9/10/64	9/15/58
7	Convention on the High Seas. Done at Geneva Apr. 29, 1958. Entered into force Sept. 20, 1962. TIAS 5200. http://sedac.ciesin.org/pidb/texts/high.seas.1958.html	9/1/66	-	9/30/62	9/15/58
8	Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter. Adopted at London, November 13, 1972, appears at 11 I.L.M. 1294 (1972). http://sedac.ciesin.org/pidb/texts/marine.pollution.dumping.of.wastes.1972.html	8/30/75	8/30/75	12/29/72	12/29/72
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21	Convention on the Continental Shelf http://www.unesco.org/webworld/com/compendium/2602.html	9/1/66	6/10/64	9/15/58	-

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Sea Turtle Conservation across the Shared Marine Border

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1. Introduction

Declining sea turtle populations have been the focus of international concern for a number of years. The Kemp's ridley, the hawksbill, and the leatherback are considered Critically Endangered; loggerheads, green turtles, and olive ridleys are listed as Endangered; and flatbacks are considered Vulnerable (Meylan and Meylan, 1999; IUCN Red List, 2000).[1] In the United States, all species of sea turtles that live in U.S. waters are listed as endangered or threatened under the Endangered Species Act of 1973.[2] The Convention on International Trade in Endangered Species of Flora and Fauna (CITES) lists all sea turtles in its Appendix I, so that they are prohibited from international trade from or to signatory countries (Pritchard, 1996).

The decline in population numbers is due to human interactions. Sea turtles and their eggs are prized worldwide for human consumption. Furthermore, their oils are used for lubricants and ingredients in cosmetics, and their shells for jewelry and eyeglass frames. Nonetheless, mass slaughter of turtles and plunder of their nests have been and remain a prime cause of population declines (National Research Council, 1990). Encroachment of human populations into coastal habitats further contributes to population declines by degrading nesting beaches. Harvesting of sea turtles for subsistence or commercial purposes and incidental mortality in commercial fishing and other such activities further diminish sea turtle populations.

Mexico contains critical nesting habitat for six out of the seven species of sea turtles that exist in the world today. These are: the green turtle, *Chelonia mydas,* which includes the eastern Pacific populations considered by some to be a separate species *Chelonia agassizii*; loggerhead, *Caretta caretta;* Kemp's ridley, *Lepidochelys kempi*; olive ridley, *Lepidochelys olivacea*; hawksbill, *Eretmochelys imbricata*; and leatherback, *Dermochelys coriacea.* All are listed as endangered or threatened, and as populations that were the largest on our planet as recently as 40 years ago, but have since collapsed.

Kemp's ridley nesting populations have declined to about 1% of their abundance in 1947, when an estimated 40,000 females nested in one day at their only important nesting beach,

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Kemp's ridley nesting populations have declined to about 1% of their abundance in 1947, when an estimated 40,000 females nested in one day at their only important nesting beach, Rancho Nuevo, on the Mexican coast of the Gulf of Mexico (National Research Council, 1990). This spectacular mass nesting of female turtles, known as *arribazón* (Spanish for "arrival" of animals), seemed to be a thing of the past by the 1970s, with barely 200 turtles nesting during a given season. More recently, Pacific nesting populations of leatherback turtles *(Dermochelys coriacea)* have also declined to less than 10% of their abundance in the late 1970s and early 1980s. The leatherback population nesting along the Pacific coast of Mexico, in the states of Michoacan, Guerrero, and Oaxaca, had declined from an estimated 30,000 females nesting annually in the early 1980s (Pritchard, 1982) to less than 5,000 in 1995 (Sarti et al., 1996). For the Kemp's ridley, this dramatic decline was undoubtedly the result of sustained and well-documented overharvest of the eggs during the 1940s, 1950s, and 1960s, combined with harvest of adults and juveniles in U.S. and Mexican fisheries in the Gulf of Mexico. Harvest of eggs at nesting beaches combined with mortality resulting from incidental capture in high seas and coastal fisheries is also believed to have precipitated the collapse of the Pacific leatherback populations.

The endangered or threatened status of sea turtles and the difficulties in their conservation and management stem from a number of factors, but most importantly are due to: a unique life history that makes their populations vulnerable to several sources of mortality at critical stages in their life, which is aggravated by the fact that many species require decades to reach maturity; their generally migratory nature, where their migrations may extend across national jurisdictions and the high seas, creating a transboundary resource and jurisdictional problems; degradation of nesting sites; incidental mortality in harvesting of shrimp, swordfish, and other fisheries; and the open-access nature of extended economic zones and the high seas. Conservation and management strategies thus need to focus on the implications of different conservation measures on different stages of sea turtle lives for overall population growth and on strategies that tackle the transboundary issue requiring cooperative conservation and management by many different nations.

Sea turtles are migratory species with a unique life history whose migrations can span entire ocean basins in tropical and temperate waters. These migrations bring them through the waters of extended economic zones of different nations and the high seas, thereby ranging across overlapping national jurisdictional zones and even on the high seas, where there is little or no governance. These transboundary resource stocks are thus not subject to a governance regime for conservation and management on the global commons and benefit little from enforceable arrangements for multilateral cooperative management. Moreover, the open-access nature of this resource and the waters in which they migrate lead to the well-known "Tragedy of the Commons" in which there are little or no incentives for conservation.

The transboundary and migratory nature of sea turtles, as well as associated jurisdictional issues, means that conservation and management measures need to be cooperative, joint efforts by two or more nations, depending on the species involved. The orientation of these bilateral or multilateral arrangements will vary, in part, depending upon the stage of the life cycle and species involved. A recent example of a multilateral conservation treaty is the Inter-American Convention for the Protection and Conservation of Sea Turtles. The objective of this Convention is to promote the protection, conservation, and recovery of sea turtle populations and the habitats on which they depend, based on the best available scientific evidence, taking into account the environmental, socio-economic, and cultural characteristics of the Parties. The area of application of this Convention (the Convention Area) comprises the land territory in the Americas of each of the Parties, as well as the maritime areas of the Atlantic Ocean, the Caribbean Sea, and the Pacific Ocean, with respect to which each of the Parties exercises sovereignty, sovereign rights, or jurisdiction over living marine resources in accordance with international law, as reflected in the United Nations Convention on the Law of the Sea. Another multilateral initiative is the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), which prohibits trade in turtle products, striving to protect them from slaughter for jewelry, accessories, and decorative items.

To date, one of the most sustained, vigorous, and successful conservation efforts among nations has been the bilateral, joint program between the governments of Mexico and the United States for the Kemp's ridley sea turtle. Mexico initiated conservation efforts in 1966 at Rancho Nuevo, Tamaulipas, the species' only nesting area; however, the population continued to decline for the next two decades. The bilateral program was established in 1978 and by the late-1980s the decline stabilized, and since then this species appears to be on the road to recovery. It now appears that this early intervention pioneered by scientists at the Instituto Nacional de Investigaciones Biologicos Pesqueras was important in preventing the imminent extinction of the Kemp's ridley; however, the recent signs of recovery are generally acknowledged to be the result of the expanded bilateral effort that provided additional resources and a forum to craft and implement a broader recovery strategy. This bilateral program has involved both formal and informal collaboration between government agencies, including the Instituto Nacional de la Pesca (INP), U.S. Fish & Wildlife Service (USFWS), the U.S. National Marine Fisheries Service (NMFS), and the U.S. National Park Service, and private institutions, which include the Gadys Porter Zoo, HEART (Help Endangered Animals Ridley Turtle). Bilateral conservation programs have focused on the nesting process and have included beach and nest protection, establishment of additional nesting areas to extend the range and reduce risks, headstarting programs, and implementation of measures to reduce fishing mortality. Much of this collaborative work has been done under a formal bilateral Cooperative Agreement between the NMFS and INP, known as MEXUS-Golfo. The Kemp's ridley program is a success story that has served as a model for sea turtle conservation, providing the framework for a similar approach currently underway with the Pacific leatherback under the MEXUS-Pacifico Cooperative Agreement between NMFS and INP.

This chapter examines these two shared, cooperative conservation efforts and the way in which the two formal bilateral Cooperative Agreements, MEXUS-Golfo for Kemp's ridleys and the MEXUS-Pacifico Cooperative Agreement for leatherbacks, between Mexico and the United States have helped facilitate conservation of sea turtles across the shared marine border. The next section examines the evolution and general life history of sea turtles, Section 3 provides background on the Kemp's ridley turtle, Section 4 covers background on the leatherback, Section 5 examines conservation measures for sea turtles, Section 6 considers conservation measures specific to the Kemp's ridley, Section 7 considers conservation measures specific to the leatherback, and Section 8 offers concluding remarks.

2. Evolution and General Life History of Sea Turtles

Sea turtles are ocean-going reptiles that have lived since the Triassic period, 245 to 208 million years ago. The earliest known sea turtles appear in the fossil record in the Late Jurassic period, 208 to 144 million years ago. Scientists believe that modern sea turtles are derived from marsh-inhabiting ancestors that lived during the Late Triassic period.

When turtles first entered the sea is unknown, although probably in the early Mesozoic, and for the next 100 million years – during the rise and reign of the dinosaurs – the sea turtles shared the ocean with other air-breathing reptiles, including the ichthyosaurs and plesiosaurs. At the end of the Cretaceous period, the dominant large reptiles went extinct, but sea turtles continued to flourish (Pritchard, 1996). The modern sea turtles are monophyletic, that is they share a common ancestor tracing back to approximately 100 million years ago. The hardshell turtle (*Cheloniidae*) lineages appear to be approximately 35 million years old, while the leatherback is the only surviving species of an older lineage (*Dermochelyidae*) tracing back approximately 75 million years. Recent genetic studies suggest that leatherbacks, despite their ancient ancestry, went through a population "bottleneck" less than 1 million years ago, most likely as a result of regional population extinctions during the last ice age (Dutton et al., 1999a).

Seven species of sea turtles in two families are recognized: (1) loggerhead (*Caretta caretta*); (2) Kemp's ridley (*Lepidochelys kempii*); (3) olive ridley (*Lepidochdys olivacea*); (4) hawksbill (*Eretmochelys imbricata*); (5) flatback (*Natator depressus*); (6) leatherback (*Dermochelys coriacea*), and (7) the green turtle (*Chelonia mydas*). In addition, there is controversy over the status of the distinctive eastern Pacific populations of green turtle considered by some to be a separate species, *Chelonia agassizii.* [3]

Sea turtles inhabit every ocean basin, with representatives of some species found from the Arctic Circle to Tasmania (Meylan and Meylan, 1990). Hawksbills are perhaps the most tropical of the sea turtles, whereas leatherbacks are known to make forays into colder, sometimes polar, waters (Meylan and Meylan, 1990). The majority of sea turtles are cosmpolitan in distribution, but two species have relatively restricted distributions: flatback in northern Australia, Kemp's ridley in the Gulf of Mexico and the North Atlantic (Pritchard, 1996; Meylan and Meylan, 1990).

Migration habits differ among sea turtle species. Migrations may range from a few to thousands of kilometers. Migration habits differ not only among species but also among different populations of the same species. Some sea turtle populations nest and feed in the same general areas; others migrate great distances. While each species has specialized dietary and habitat requirements that reflect adaptations to different ecological niches (Hendrickson, 1980), all generally have the same basic life history cycle (Figure 1).

Females come ashore to lay their eggs, which develop and hatch in the sand on tropical or sub-tropical beaches, seasonally laying 4-12 clutches of 50-150 eggs over a 3-to 6-month period. Incubation time varies with species, clutch size, and temperature and humidity in the nest. The incubation period for most species is 45 to 70 days. The sex of an embryo is determined by the incubation temperature during a critical period spanning the middle third of incubation. Lower nest temperatures produce more males; higher temperatures produce more females. Before this was known, the early conservation practices consisted of digging up newly laid eggs and incubating them in styrofoam boxes in sheds on the beach. This protected nests from destruction and increased the production of hatchlings. However, this practice inadvertently masculinized the population by producing, in the case of leatherbacks, only male hatchlings (Dutton et al., 1984), and is now avoided where possible. Instead, eggs are now reburied in the beach in enclosures under natural conditions.

In sea turtles, the tremendous egg production is offset by mortality of eggs and hatchlings due to predation and natural cycles of beach erosion. Eggs hatch after 50-75 days, producing

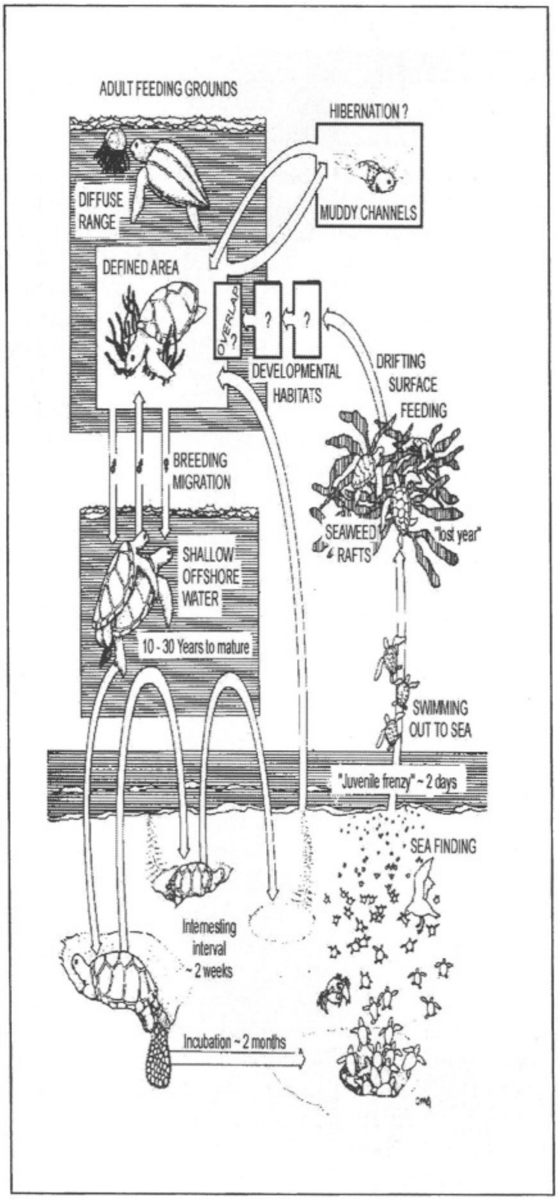

Figure 1. General life history stages and habitat stages in sea turtles (from Mrosovsky, 1983)

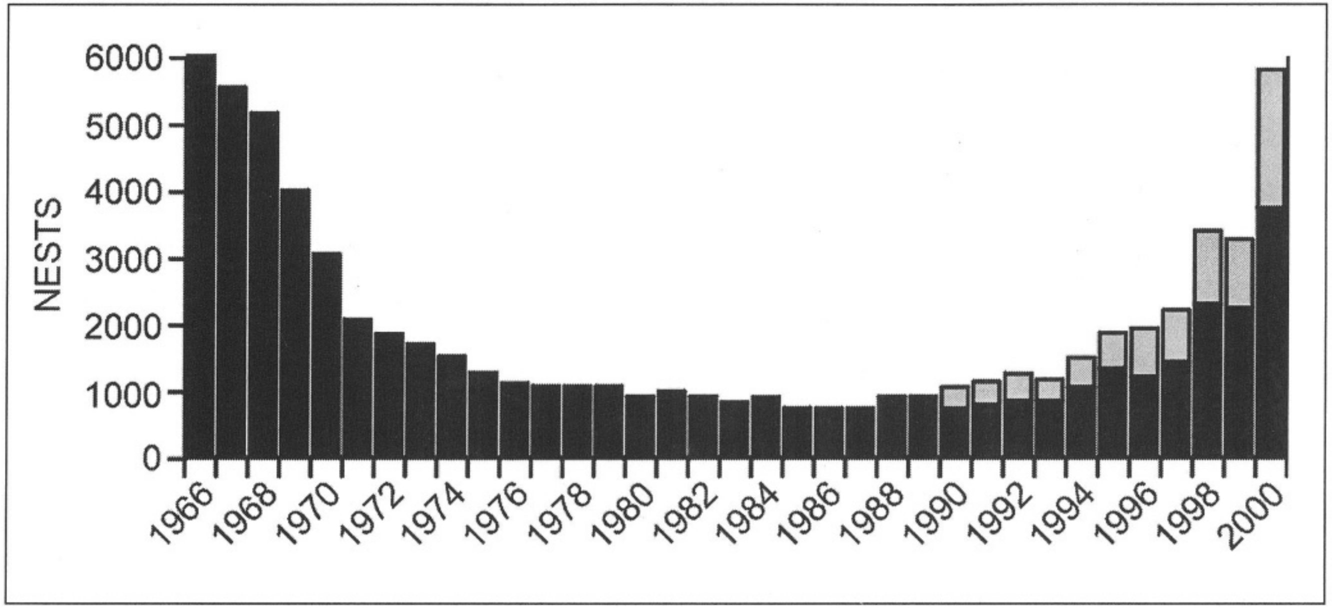

Figure 2. Kemp's ridley sea turtle nesting at beaches in Rancho Nuevo (1966-2000). Recent expansion of nesting at Tepehuajes and Barra del Tordo is indicated by grey portions of the bar columns of figure 2 (Marquez et al., 2001).

hatchlings that emerge from the sand, immediately scurry to the ocean and swim out through the surf and offshore. Post-hatchlings enter a pelagic phase during which it is thought that they are carried by currents until they settle into developmental habitats (see Figure 1) (Musick and Limpus, 1996). The duration of this pelagic phase is unknown, but has become known as the "lost year" (Carr, 1963) because juveniles of this stage are rarely seen and little is known about it. The duration of this phase is most likely several years. Although the migratory patterns of the young turtles during the first year have long been a puzzle, most researchers believe that they ride prevailing surface currents, situating themselves in floating seaweed or oceanic convergence zones where they are camouflaged and where they can find food. Juveniles "settle" into developmental habitats, which for some species like Kemp's ridley and green turtles consist of coastal and inshore waters. Some, like the leatherback and loggerhead most likely remain pelagic through much of their life history. Sea turtles may take anywhere from 6 to over 30 years to mature, depending on the species and location.

Once mature, the females undertake reproductive migrations from forage/developmental areas to the nesting beaches. These migrations may take them thousands of kilometers, and tagging studies have shown that females tend to return to the same beach in subsequent years. This observed nesting beach fidelity was the basis for the Natal Homing hypothesis (Carr, 1963), stating that females return to their natal beaches to nest once they mature. This assumption has profound conservation implications, and many programs involving beach hatchery enhancement of hatchling production have proceeded with the expectation of a future payoff in the form of increasing nesting populations as females mature and return to natal beaches. Although it has not been possible to directly test this theory, sufficient evidence has accumulated from genetic studies that indirectly support natal homing, and this model is now generally accepted, although the precision of this homing, which in turn define stock boundaries, appear to vary between species and geographic regions (Bowen, 1994).

The mechanisms that allow natal homing to occur are not fully understood. However, olfaction plays an important role; hatchlings are able to imprint on chemical cues and presumably can distinguish chemical "signal" of particular beach or region (Owens et al., 1986). It is thought that important olfactory, magnetic, or celestial cues are imprinted during an early critical period that spans the first few weeks of life when hatchlings emerge from their nests, scurry down the beach and swim out to sea. This was exploited with the Kemp's ridley in an experiment that attempted to establish a new nesting population in Texas by incubating eggs collected in Mexico at Padre Island, and "imprinting" the hatchlings on this new natal beach. This is discussed in more detail below.

3. Kemp's Ridley[4]

The Kemp's ridley is a small and largely benthic species. Adult males and females are equal in size and reach about 55 to 75 cm (22-30 in.) and 30 to 50 kg (66-110 lb.). Growth rates of wild hatchlings are unknown. Minimum adult size may be reached in 6 or 7 years; however, many turtles may take longer to mature. Age, size structure, and sex ratios of the population are not well known.

Kemp's ridleys are mostly found in the Gulf of Mexico, although they also occur along the Atlantic coast as far north as Long Island and Vineyard Sound, Massachusetts. Drifting hatchlings and young juveniles from the western gulf gyres apparently enter the eastern gulf loop current and are carried via the Florida current into the Gulf Stream and up the east coast. Kemp's ridley turtles follow two major routes in the Gulf of Mexico: one northward to the Mississippi area, the other southward to the Campeche Bank, near the Yucatan Peninsula. Adults are found almost entirely in the Gulf of Mexico (Marquez, 1990).

Hatchlings spend many months as surface pelagic drifters, although little is known about how long they remain in this habitat, about their eating habits, and about how they get back to coastal waters. During the post-pelagic stages, the smallest juveniles may be found in shallow waters of bays or lagoons, such as those on the Texas border (Shaver, 1995). Larger juveniles and adults probably forage in open but shallow gulf waters, occupying shallow foraging areas over extensive seagrass beds. They take the relatively fast blue and spotted crabs and other species of crabs and invertebrates.

Apart from a few isolated cases, Rancho Nuevo, Tamaulipas, Mexico (about 161 kilometers, or 100 miles, south of the Texas border) is the only known nesting site of the Kemp's ridley (Pritchard, 1996; Marquez, 1996). During the nesting season (April-July), females gather in the sea near the nesting beach and then emerge *en masse* to nest over several hours in an *arribazón.* Unlike other sea turtles, Kemp's ridleys nest during the daytime, whereas the other species nest during the night. In addition, almost all nesting occurs near Rancho Nuevo along a 50-km stretch of beach (Marquez et al., 2001). Nesting has only rarely been observed at any other beach, such as the irregular nesting area near Tecolutla, Veracruz, and occasional nests in Texas. Thus, nesting on the beach at Rancho Nuevo is crucial to the survival of the species.

Based on an amateur film by Andrés Herrera in 1947, Hildebrand (1963) and Carr (1963) guessed that 40,000 turtles nested at Rancho Nuevo (Márquez, 1999). No data were available until 1965, at which point the biggest *arribazón* numbered less than 5,000 turtles. In 1973, the largest *arribazón* contained only 200 individuals. Despite beach protection, this number continued to drop for the next 20 years, by which time total nestings for the season were only numbered in the hundredsSurveys conducted between 1978 and 1988 indicated an average of about 800 nests per year, declining at about 14 nests per year, to an all time low in the late 1980s (Marquez et al., 1999). The total number of nesting females may have been as low as 350 on beaches where tens of thousands of Kemp's ridley used to nest

This initial failure to respond to protection indicates that recruitment was jeopardized by prolonged near-total harvest of eggs and shrimp trawling in the Gulf of Mexico, the primary juvenile and sub-adult habitat and the only habitat of adults (Pritchard). In 1990, the mortality from shrimp trawling was estimated to lie between 500 and 5,000. Collectively, other trawl fisheries, passive gear fisheries, and entanglement fisheries were estimated in 1990 to yield between 50-500 deaths a year. Deaths due to dredging and collisions with boats were estimated in 1990 to lead to a further 5-50 deaths every year. Additional sources of anthropogenic mortality were estimated in 1990 to come from oil-rig removal, intentional harvests, entrainment by electric power plants, ingestion of plastics and debris, and from accumulation of toxic substances, especially from ingested petroleum residues. Mortality also occurs from human and non-human predation of eggs in nests, predation of hatchlings and juveniles by crabs, birds, fish, and mammals. The nesting population reached a low in the mid-1980s and in the last few years has begun to modestly but steadily increase (Marquez et al., 2001). A detailed description of the biology of the Kemp's ridley is given in Marquez, 1994.

4. The Leatherback

The leatherback is the largest of all living sea turtles. Mature leatherbacks reach about 1.2 to 1.9 m (4-6 ft) and 200 to 506 kg (441-1,116 lb.), with the smaller individuals occurring in eastern Pacific nesting populations. The largest leatherback recorded was 916 kg (2,019 lb.). Unlike the hardshell tutles, the leatherback's carapace is covered with skin and an insulating layer of blubber around the neck and shoulders, which, along with several other remarkable adaptations, allow this species to thrive in colder waters, ranging circumglobally from 71°N to 42°S latitude in the Pacific Ocean and in all other major oceans (NMFS and USFWS, 1998). Leatherback turtles tend to dive, often to great depths, in a cycle that follows the daily rising and sinking of the dense layer of plankton and jellyfish on which they feed (Eckert et al., 1989).

Leatherbacks can be found in coastal waters, but are essentially pelagic. They forage widely in temperate waters except during the nesting season, when females return to tropical beaches to lay eggs. They are highly migratory, exploiting convergence zones and upwelling areas in the open ocean, along continental margins, and in archipelagic waters. Leatherbacks have some of the longest migration of all sea turtles and can travel great distances between feeding and nesting areas. Although leatherbacks do not nest on the U.S. Pacific coast or territories, they forage in U.S. waters. Animals that are found at these forage areas are mainly from nesting beaches in the western Pacific and would undertake extraordinary migrations across the Pacific to return to nest in Indonesia, Solomon Islands, or Papua New Guinea (Dutton et al., 1999b). This migratory behavior exposes them to several U.S. and international high seas fisheries, where they are taken as bycatch. While some eastern Pacific leatherbacks are found in the north Pacific, most animals that originate in Mexico and Costa Rica migrate south to feed in waters off Peru and Chile and further out in the southeastern Pacific (Dutton et al., 1999b; Eckert, 1999; Morreale et al., 1994). The juvenile developmental areas remain unknown.

There are several sources of mortality. The products of leatherback turtles rarely, if ever, enter international commerce. There is some local consumption of nesting turtles in some areas in Indonesia and elsewhere; however, it is primarily the eggs that are harvested. Asiatic nesting colonies (such as that in Terengganu, Malaysia) were generally exploited for eggs rather than meat, and this prolonged total egg harvest was primarily responsible for the demise of their population (Chan and Liew, 1996).

On the Pacific coast of Mexico, three primary nesting areas are found in the states of Michoacan, Guerrero, and Oaxaca, where female leatherbacks each lay up to 11 clutches seasonally between October and March. Females are believed to migrate long distances between foraging and breeding grounds, at intervals of typically 2 or 3 years (NMFS, 2000). Mean age at sexual maturity is estimated around 13 to 14 years (Zug and Parham, 1996). The natural longevity of leatherbacks is still unknown (NMFS and USFWS, 1998), although some nesters tagged as adults over 20 years ago continue to nest regularly, suggesting that leatherbacks remain reproductively active for many years.

Although Atlantic populations appear to be stable or even increasing, leatherback populations are declining at all major Pacific basin nesting beaches, especially in the past two decades (NMFS and USFWS, 1998; Spotila et al., 2000). The major decline of these nesting populations was most likely brought about by a severe over-harvest of eggs coupled with incidental mortality from fishing (Eckert, 1997), especially the high seas driftnet fishery in the 1980s (Sarti et al., 1996).

5. Conservation Measures for Sea Turtles

While Recovery Plans recognize a wide array of threats (to recovery) in both the marine and terrestrial life stages (USFWS and NMFS), in reality, most conservation effort has focused on the nesting beaches, where the problems are more surmountable. Generally this involves protection of nesting habitat, protection of nesting females, protection of nests and measures taken to enhance hatch success of clutches and survival of hatchlings. The main threats on nesting beaches are over-harvest of eggs and killing of adult females; protective measures aimed at mitigating both activities are easy to carry out and cost-effective. This conservation strategy has great potential as long as mortality at sea during various life history stages does not negate protection measures on nesting beaches. Thus, once again, the transboundary and migratory nature of this global public good means that conservation and management measures need to consider the whole range of the life cycle and migration, and that coordinated, multilateral measures are required. Even in the absence of egg harvest by humans, up to 60% of nests may be destroyed by high tides and natural cycles of beach erosion at some of the largest nesting populations such as Suriname (Dutton and Whitmore, 1983); those nests that aren't washed away are vulnerable to predation or harvest by humans.

The simple practice of collecting eggs as soon as they are laid, and incubating them in hatcheries increases hatchling production by orders of magnitude and may provide a buffer for marine impacts. This has been standard management practice for some of the first sea turtle conservation programs that were initiated in the Atlantic, almost 30 years ago, and may in part explain why in the Caribbean and South Africa, leatherback populations have been increasing steadily in recent years, despite extensive fishing mortality, while Pacific populations, that have really only recently been subjected to effective beach protection measures, have experienced catastrophic declines. In simple terms, without beach protection measures designed to at least ensure some hatchling production, any conservation measures aimed at reducing juvenile and adult mortality at sea are moot. However, simply protecting eggs and hatchlings will be ineffective at preventing extinction, if excessive mortality of older juveniles and adults persists.

Conservation of sea turtles depends, in part, upon critical life stages in which reduced mortality can have the greatest influence on the maintenance or recovery of endangered or threatened sea turtle populations (National Research Council). Sea turtles have high levels of fecundity, so that they lay great quantities of eggs throughout their life, and particularly if mortality is low for adults. High fecundity of sea turtles compensates for high mortality during the egg and hatchling stages of life, delayed sexual maturity, and mortality during juvenile stages (Spotila et al., 1996). The reproductive value of a turtle egg is low and as a consequence, the sensitivity of population growth to the loss of an egg is also low. Hence, sea turtle populations under normal conditions appear to be able to withstand substantial egg loss. The reproductive value of a large juvenile, sub-adult, or adult is higher than that of an egg. Population growth is most sensitive to changes in survivorship of large juveniles and sub-adults, so that reduction of human-induced mortality in these life stages can have a significantly greater effect on population growth than reduction of anthropogenic mortality of eggs and hatchlings. Adult females are more important than turtles at any other life stage with regard to potential immediate contributions toward recovery of the species (Heppell et al., 1996; TEWG, 1998).

Many sea turtle populations cannot sustain high rates of mortality among adults, but low levels of fishing mortality can be compensated by improving survival of eggs and hatchlings by protecting nesting beaches and enhancing survival of nests and hatchlings until they enter the ocean (Spotila et al., 1996). Protection of nesting beaches may be essential given the inevitable mortality due to incidental catch by even the best operated fisheries. The alternative is to close any fishery that causes even a very small mortality of leatherbacks. Such action can possibly be avoided by the relatively inexpensive action of protecting eggs and hatchlings on natural nesting beaches and by changing fishing practices to reduce mortality from incidental capture.

Anthropogenic sources of mortality can be more susceptible to conservation and management measures than many sources of natural mortality, especially those at sea.

Balancing the comparatively high benefit of reduced mortality in large juveniles, sub-adults, and even adults is the comparative cost of reducing mortality in eggs and hatchlings due to greater ease of access, monitoring, and protection on beaches. The laying of eggs at specific times of the year reinforces this cost-savings. When a species such as the Kemp's ridley lays most or all of its eggs along a 50-km stretch of one beach, then protection of this critical choke point becomes crucial, and the costs drop and the benefits rise.

Habitat protection may be achieved through forming limited-access or protected areas (Miller, 1996). This includes protection of nesting beaches, but also foraging areas and other habitats such as mating areas, inter-nesting areas, and migration routes.

The relatively late sexual maturity of sea turtles has several implications for conservation and management. Population declines in the face of heavy adult mortality can take some time to ascertain, since the existing comparatively large pool of juveniles and sub-adults continue to sexually mature and reproduce, but eventually, the reduced numbers of offspring from the smaller population of breeding adults in turn leads to a smaller number of offspring. Along similar lines, once a reduced adult population is established and even in the face of complete protection, the smaller number of offspring spend many years as juveniles and sub-adults before they reach sexual maturity. Moreover, this smaller pool of juveniles and sub-adults recruited to the adult population have a limited number of offspring. In short, population declines can take time to notice, thereby potentially delaying conservation measures, and once conservation measures are established, many years may be required for the population to rebound even with complete protection and very low anthropogenic-induced mortality.

Bilateral or even multilateral, cooperative conservation and management is required. The dispersal and migration of sea turtles from their nesting sites across extended economic zones of more than one nation and the high seas means no single nation, acting alone, can ensure adequate conservation, management, and protection measures to maintain viable populations of these transboundary sea turtles. The bilateral conservation measures between Mexico and the United States described for the Kemp's ridley and leatherback turtles in the next two sections represent a good start in this direction.

6. Conservation Measures for Kemp's Ridley Sea Turtles

Conservation measures for Kemp's ridley sea turtles have focused on the nesting area around Rancho Nuevo (from La Pesca to Tampico), Mexico, essentially the only primary area this species nests. The initial unilateral measures taken by Mexico to monitor and protect Kemp's ridleys (detailed below), although essential, may alone not have been sufficient to reverse the dramatic population decline. This is because mortality of larger juveniles and adults continued as a result of the U.S. shrimp fisheries at the forage grounds in the Gulf of Mexico, until Turtle Excluder Devices (TEDs) were required to be used by U.S. shrimp trawlers in the early 1990s to prevent turtles from drowning. The recognition in the U.S. NMFS/FWS Recovery Plan that the scope of the recovery effort needed to go beyond elimination of this incidental mortality within territorial U.S. boundaries to include allocation of resources toward bilateral efforts both on nesting beaches in Mexico and in both nation's fisheries has been key to the success of recovery efforts for this shared resource.

The U.S. Recovery Plan for the Kemp's ridley includes the following as recovery criteria: continued, complete, and active protection of the known nesting habitat and the waters adjacent to the nesting beach (concentrating on the Rancho Nuevo area) and enhanced production/survival of hatchling turtles; essential elimination of mortality from incidental catch in commercial shrimping in the United States and Mexico through use of TEDs and to achieve full compliance with the regulations requiring TED use; attainment of a population of at least 10,000 females nesting in a season, and successful implementation of all priority recovery tasks. Sea turtle eggs of all kinds, including Kemp's ridleys, receive legal protection in Mexico, where they first received legal protection in the Table General de Vedas (General Schedule of Closed Seasons), which has been strengthened and extended several times by laws that protect turtles or establish closed seasons for them (National Research Council), culminating with the total ban for all sea turtle species on the decree of 1st of June of 1990 (Diario Oficial, 1990). Mexico has also established a no-trawling zone in the area critical for Kemp's ridleys in southern Tamaulipas.

As a result of concerns over the status of the Kemp's ridley, intensive monitoring of nesting and associated conservation efforts on Mexican beaches started in 1966 with the installation of the first camp in Barra de Calabazas, Rancho Nuevo, Tamaulipas, Mexico (Márquez et al., 1999). This site was central to the beaches most densely nested by Kemp's ridley turtles. A portion of this beach was designated a "Natural Reserve" in 1977 (Diario Oficial, 1977). This reserve incorporated 15 kilometers of coastline and a 4-km offshore zone closed to commercial fisheries during the breeding season of Kemp's ridleys.

Before 1978, monitoring activities were limited to 25 kilometers of beach (Márquez et al., 1999), and resources were relatively limited. In 1977 the joint MEXUS-Gulf Program was initiated between INP and NMFS, and as part of a broad bilateral collaboration, additional resources contributed by NMFS, USFWS, and Private Institutions allowed a considerable expansion of conservation effort on the nesting beaches the following years. Between 1978 and 1989, after obtaining All-Terrain Vehicles through this bilateral program, the area patrolled was extended and the proportion of nests recorded and protected correspondingly increased. In 1990, the project expanded further bringing the total beach surveyed to 45 kilometers. Between 1992 and 1996, the area patrolled was expanded to 120 kilometers by establishing several new camps. Since 1997, other minor nesting beaches in the State of Veracruz have been included, increasing the protected area to over 200 kilometers. In 1998, the Mexican National Fisheries Institute constructed a new monitoring camp for the turtles at Tepehuajes, a nesting beach about 50 miles north of Rancho Nuevo. The National Marine Fisheries Service has committed funding since 1996 to support enhanced monitoring of nesting activities in Mexico, improvements to a research compound at Rancho Nuevo, and expanded educational programs.

Between 1985 and 1987, the annual number of nests recorded along 30 kilometers at Rancho Nuevo reached the lowest on record, 740 in 1985, 752 in 1986, and 742 in 1987

(Márquez et al., 1999). This low number occurred even after two decades of nesting site protection, reflecting the slow rebound of comparatively long-lived populations.

Soon after 1987, the annual number of nests slowly started to increase to 2,409 in 1998, and continues to increase, with 3,788 clutches laid in 2000 (Márquez et al., 1999, 2001). A similar trend was also observed in the same season at Barra del Tordo (434 nests) and Barra de Tepehuajes (1,622 nests). The mean annual increase in nesting at Rancho Nuevo between 1988 and 1998 is 8 percent (Márquez et al., 1999). The annual increase in nesting for Rancho Nuevo, Barra del Tordo, and Barra de Tepehuajes combined is 12 percent (see Figure 2 for turtle nesting changes over time).

This gradual increase in nesting numbers beginning in the early 1990s is likely to be the result of a combination of conservation measures (Márquez et al., 1999). These conservation measures include an increase in recruitment to the population due to beach and nest protection and Rancho Nuevo and neighboring camps, establishment of a marine reserve offshore, and the introduction of Turtle Excluder Devices.

The Kemp's ridley population had reached a critically low number when efforts began to establish a second nesting beach in Texas. In 1976, the U. S. National Park Service proposed discussions with the U. S. Fish and Wildlife Service for a project to establish a nesting population of at Padre Island National Seashore near Corpus Christi, Texas (Shaver et al., 1998). In 1977, these two organizations convinced Mexico's Departamento de Pesca, Texas Parks and Wildlife Department, and the U. S. National Marine Fisheries Service to join them in a Kemp's Ridley Recovery Program, part of which was the feasibility study called "head-start" (Eckert et al., 1994). Florida Audubon Society and the Gladys Porter Zoo (Brownsville, Texas) also participated.

As part of the bilateral program, the government of Mexico sent 2,000 Kemp's ridley eggs each year to the United States and continued the practice until it was terminated in 1993. The eggs were collected and placed in Styrofoam boxes containing sand from the Padre Island National Seashore, where they were taken and carefully incubated and hatched. The hatchlings were allowed to scurry down the beach and enter the water briefly for imprinting before being scooped up for transport to the National Marine Fisheries Service Laboratory in Galveston, Texas, for head-starting.

Under the head-starting program, hatchlings are retained in captivity and raised for several months to increase the juvenile population by reducing hatchling mortality. The U.S.-Mexico Cooperative Headstart Project has been the responsibility of the National Marine Fisheries Service laboratory Galveston, Texas, since 1978 (National Research Council). Hatchlings were also taken directly from the nesting beach at Rancho Nuevo, Mexico, to the Galveston, Texas, facility for head starting. The tiny turtles lived in individual buckets and were fed turtle feed. Until 1992, a total of 21,634 juvenile Kemp's ridleys had been released as part of the Head-start program (Marquez, 1994). From 1979-1994, seven confirmed Kemp's ridley sea turtle nests were documented on the Texas coast (Shaver, 1994), virtually all at Padre Island National Seashore. In contrast, four nests laid in late May and mid-June 1995 were found on south Texas beaches: one at Mustang Island on 29 May, two at Padre Island National Seashore on 30 May, and one at Mustang Island on 16 June. In 1996, two headstarted Kemp's ridleys nested at the Padre Island National Seashore, and in April 1998 one more has been recorded nesting on Mustang Island to the north of Padre Island.

Between 12th of April and 15th of June 1998, thirteen confirmed Kemp's ridley turtle nests were found on the coast of southern Texas, USA (Shaver et al., 1998). Of the thirteen nests, nine were found on North Padre Island at Padre Island National Seashore, two on Mustang Island, and two on South Padre Island.

Kemp's ridleys that nest in south Texas today are likely a mixture of returnees from the experimental imprinting and head-starting project and others from the wild stock. They could also include survivors (or their offspring) from hatchlings released in a project started at South Padre Island in 1967 (Francis, 1978). The nesting by turtles released as part of this project and production of hatchlings from their nests support the primary working hypothesis of the binational project; *viz.* that experimentally imprinted and head-started Kemp's ridleys are able to join the natural, wild population, find their way to nesting beaches, copulate successfully, and produce viable offspring (Eckert et al., 1994; Caillouet, 1998). Kemp’s ridleys, as benthic, coastal feeders, are very susceptible to shrimp trawler mortality as juveniles as well as adults. Hence, the creation of near-shore reserve by the Mexican government has contributed to the increases in population. A comparable reserve off of South Padre Island, to limit fishing mortality from shrimp trawlers, would also be desirable but has yet to be established.

Mexican biologists employ a method for relocating turtle eggs into hand-dug nest that reproduce natural dimensions and conditions as closely as possible. All nests are reburied in a protected enclosure and guarded from poachers, predators, or accidental crushing on the open beach. The enclosure fence is buried a few feet in the sand to keep out natural predators, such as coyotes, skunks, and dogs. Guards constantly present at the corral protect the eggs from human activities that could harm the clutch. This low-tech approach is a cost-effective management measure that has been applied on sea turtle beaches around the world. In the United States, the Lower Rio Grande Valley NWR is essentially modeling its egg protection program on the Mexican Kemp's ridley project.

7. Conservation Measures for Leatherback Sea Turtles

Leatherback nesting populations are declining along the Pacific coast of Mexico and Costa Rica (Sarti et al., 1999; Spotila et al., 2000; NMFS, 2000). Comparatively few leatherbacks are returning to nest on east Pacific nesting beaches and are likely facing abnormally high mortalities during years in which they do not nest. Since 1993, environmental education and conservation efforts through law enforcement have greatly reduced egg poaching in Costa Rica (Chaves et al., 1996).

Leatherback population decline is especially severe in Mexico. Three reports from the late 1970s and early 1980s indicate that three beaches located on the Pacific coast of Mexico sustained a large portion of all global nesting of leatherbacks, perhaps as much as one-half. Since the early 1980s, the eastern Pacific Mexican population of adult female leatherbacks has decline from approximately 30,000 in 1980 (Pritchard, 1982) to less than 1,000 in 1999-2000 (Sarti et al., 2000). Sarti et al. (1996) report that nesting declined at Mexiquillo, Mexico, at an annual rate of over 22 percent over the past 12 years. The causes of this decline are not entirely clear, but may include intensive egg harvest in the nesting areas, incidental capture of adults or juveniles in high seas fisheries, and natural fluctuations due to changing environmental conditions (Sarti et al., 1998). Although leatherbacks are not captured for meat or their skin in Mexico, their eggs are eaten. Sarti et al. (1998) estimate that there may have been almost total harvest of clutches laid on some Mexican beaches in the past. Entanglement of juveniles and adults in longlines and driftnets may also account for some mortality. Eckert et al. (1997) suggest that swordfish gillnet fisheries in Peru and Chile have contributed to the decline of leatherbacks in the eastern Pacific; the decline in Mexiquillo, Mexico, nesting populations occurred at the same time that fishing effort doubled in the Chilean driftnet fishery.

Most conservation programs protecting nesting beaches in Mexico have continued since the early 1980s (NMFS, 2000). By the mid-1980s, field camps (staffed by biologists and often assisted by the Mexican military) protected nearly all of Mexico's most important nesting grounds. Protective measures, especially emergency ones recommended by a joint U.S.-Mexico leatherback working group meeting in 1999, have led to greater nest protection and nest success. Mexican marines were present during the 1999-2000 season at three primary nesting beaches in Mexico (Llano Grande in Oaxaca, Mexiquillo in Michoacán, and Tierra Colorada in Guerrero) responsible for about 34 percent of all Mexican nesting activity (Sarti et al., 1997). During that period, 736 (57 percent) of 1,294 documented nests were protected, resulting in 25,802 hatchlings (Leatherback Working Group, 2000). This represents an improvement over previous years, where only 10-34 percent of clutches laid were protected. Monitoring and protection measures at the secondary nesting sites of Barra de la Cruz and Playa Ventura resulted in 67 percent (296 nests) and 10 percent (243 nests) protection, respectively. The current primary management objective aims to protect over 95 percent of nests laid at the three primary beaches and to maximize protection of all the secondary nesting beaches over the next three years. Preliminary data from the 2000-2001 nesting season suggests that this goal was nearly achieved at at least one of the primary sites (Sarti et al., Unpublished)

Table 1
Leatherback Nest Protection at three Primary Beaches on the Pacific Coast of Mexico: Mexiquillo, Tierra Colorada and Llano Grande

Season	Number of clutches laid	Number of clutches protected	Percentage of clutches protected
1996-97	445	86	19.3%
1997-98	508	101	19.9%
1998-99	442	150	33.9%
1999-2000	1590	943	58.7%

Source: Sarti et al., 2000.

In addition, a total of 256 nests were recorded at Agua Blanca (Baja California), but sand temperatures too low for normal embryonic development led to none of the nests producing hatchlings (Leatherback Working Group, 2000). Although artificial incubation at raised temperatures is a possibility, limited resources will instead be focused on improving hatch success and protection of nests at the three primary beaches and other mainland secondary beaches, since the Baja California nesting environment is not naturally conducive to successful incubation.

The primary beach program includes protecting nesting females, eliminating illegal egg harvest, and relocating nests to protected hatcheries (Leatherback Working Group, 2000). Continued presence of marines and increasing personnel and efficiency of beach coverage will enhance ability to save more nests from poachers. The National Marine Fisheries Service will continue to provide financial assistance to support research, monitoring, and protection at the three primary beaches, including an annual aerial survey. Conservation International (Mexico) will administer the funds. The National Marine Fisheries Service and Instituto Nacional de la Pesca and the U.S. Fish and Wildlife Service will implement a 3-year plan to construct permanent facilities at the three primary beaches and seek funding for a permanent expanded program, with an objective to protect over 95 percent of nests laid at the three beaches. In order to involve local communities in beach protection programs to save more nests from poachers, negotiations have been underway with the communities in Llano Grande, particularly a partnership with the Community of Cahuitan (which has donated a plot of land where the new field station will be located). Local villagers were hired and trained as field technicians in the 2000/2001 nesting season, and a year-round grassroots environmental education program is being developed.

The Mexico-U.S. bilateral program, called the Mexus-Pacific Cooperation Agreement, is between Instituto Nacional de la Pesca and the Southwest Fisheries Science Center of the National Marine Fisheries Service. All joint scientific research on shared Pacific marine resources of interest to both institutions in the Pacific is conducted under this cooperative agreement. Activities are proposed and progress reviewed annually at a meeting that brings scientists and managers together in working groups. In 1996 the plight of the leatherback was given highest priority, and a bilateral Leatherback Working Group was formed to design and implement an emergency Action Plan to prevent extinction of the Pacific Mexican leatherbacks. This Action Plan, and its official recognition under an agreement endorsed by the higher levels of government, allowed the necessary resources to be allocated relatively rapidly to implement measures that were deemed critical on the nesting beaches with the minimum amount of bureaucratic and political hindrance. The success of this program rests with the good working relationship that scientists and managers have established on both sides of the border over the years through the MEXUS-Golfo agreement under which much of the collaborative work was done in the latter years of the Kemp's ridley program, and perhaps with the fact that the Program is driven largely by a scientific rather than political agenda.

The success story of the Kemp's ridley has yet to come to fruition for Pacific leatherbacks, although it appears that the important issues of nesting beach protection are, for now, being adequately addressed. A new international forum will be needed to go beyond the nesting beach and tackle the seemingly insurmountable challenge of reducing threats at sea to eastern Pacific stocks of leatherbacks, which primarily involve fishing activities of many countries around the world.

8. Concluding Remarks

Sea turtles are common-pool, transboundary resources, which are global public goods.[5] As such, turtles have global public-good benefits and external or transboundary benefits for many nations. Sea turtles also contribute to biodiversity and, in at least the case of green sea turtles and coral reefs, are keystone species. Markets or economic incentives for conservation are absent and ineffective in the absence of property rights or cooperative, multilateral agreements to publicly conserve and manage these global public goods.

As global public goods and transboundary, common-pool resources, unilateral or bilateral conservation investments that increase the supply of adult turtles through onshore nesting projects, such as those bilateral programs discussed in this chapter, or reduce or eliminate their mortality through rigorous at-sea conservation measures, thereby maintaining supply (especially through future reproduction), often inadvertently allow other nations' fisheries to take these adults. In short, unilateral or bilateral conservation and management may simply allow the increased or preserved supply of adult turtles to be taken elsewhere for no or little net gain in population numbers.

Since seafood consumers do not pay their share of the full user cost of the sea turtle and seafood resources, and other consumer benefits from sea turtles – such as sea turtle existence – are not captured by markets, consumer demand for seafood for which sea turtles are jointly taken remains higher than would be expected, contributing to maintaining fishing pressures and turtle takes. Reduced local supply of seafood (for which sea turtles are jointly taken) from local unilateral conservation measures may simply be filled by imports of seafood harvested elsewhere with its own joint takes of turtles – there is no "excludability" possible for the unilateral or bilateral providers of global public goods.[6] Thus both consumers and fisheries harvesting the population elsewhere can be free riders to unilateral or bilateral conservation measures, and the social benefits provided by this public good exceed the private.[7] This free rider problem among both individuals and nations leads to substantial under-investment in conservation and management measures, and an increase in the investment needed to augment the supply of turtles will have to be accompanied by, or under the auspices of, multilateral agreements.[8]

In sum, conservation measures need to not only be global (or ocean basin-wide) and multilateral throughout the migratory range of turtles, but need to recognize the implicitly subsidized role of the direct consumer of seafood and seafood producer, non-market benefits to the public, transboundary nature of turtles and associated jurisdictional problems, and the joint production of seafood as a desirable private output – as a private "good" – and the joint production of sea turtle mortality as an undesirable external output – as a public "bad." Conservation and management measures also need to consider the different stages of the life cycle of the turtle, as discussed in considerable detail in this chapter, and in general the dynamics of Pareto-improving conservation policies.

In the absence of comprehensive multilateral agreements to cooperatively conserve and manage sea turtle populations, conservation strategies are left with unilateral or bilateral approaches such as those discussed in this chapter. Unilateral at-sea conservation and management measures may simply allow increased takes elsewhere over the migratory range and reduced local seafood supply to be filled by imports in which sea turtles were taken.[9] Without beach protection measures designed to at least ensure some hatchling production, any conservation measures aimed at reducing juvenile and adult mortality at sea are problematic. Beach protection measures also help provide for a safe minimum standard of population to preserve the population at a safe minimum level (Ciracy-Wantrup, 1968; Bishop, 1978), which is important given the considerable uncertainty over population numbers, life history, and other elements of sea turtle biology, delayed sexual maturity, and the irreversibility when a species becomes extinct.

In the absence of cooperative, multilateral management, bilateral approaches aimed at beach protection measures such as those for the Kemp's ridley through MEXUS-Golfo, and leatherbacks through the MEXUS-Pacifico Cooperative Agreement, are effective places to start sea turtle conservation and management. These bilateral efforts appear to have been effective for the Kemp's ridley, mainly because the sources of mortality were primarily limited to the Gulf of Mexico and territories under either U.S. or Mexican jurisdiction. The scope of the fisheries impact is far wider for the Pacific leatherback and will require a multilateral approach. In the meantime, the bilateral program that is underway may prove to have been crucial to at least halting the extinction of the Mexican nesting populations. Whether these populations will begin to recover remains to be seen.

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Endnotes

[1] An endangered species is one that is in danger of extinction throughout all or a significant portion of its range. A threatened species is one that is likely to become endangered throughout all or a significant portion of its range within the foreseeable future. The Endangered Species Act in the United States requires protection of both categories.

[2] As noted by the National Research Council, the leatherback *(Dermochelys coriacea)* and hawksbill *(Eretmochelys imbricata)* were listed as endangered throughout their ranges on June 2, 1970. The Kemp's ridley *(Lepidochelys kempi)* was listed as endangered on December 2, 1970. The green turtle *(Chelonia mydas)* was listed as threatened on July 28, 1978, except for the breeding populations of Florida and the Pacific coast of Mexico, which were listed as endangered. On July 28, 1978, the loggerhead (*Caretta caretta*) was listed as threatened throughout its range.

[3] Some scientists recognize eight species (Meylan and Meylan 1999, Pritchard, 1976). The black turtle or East Pacific green turtle *(Chelonia agassizii)* is recognized by some biologists as a distinct species, but some scientists contend that morphologtical, biochemical, and genetic data published to date are conflicting, and that the black turtle should be treated as belonging to green turtle *(Chelonia mydas).* In addition, the seven species of hard-shelled turtles are found in the family *Cheloniidae,* and the leatherback is found in the family *Dermochelyidae.*

[4] This section closely draws from the National Research Council unless otherwise noted.

[5] Sea turtles have many of the characteristics of a pure public good; if they are conserved for one, they are conserved for all. Sea turtles also have some of the characteristics of private goods in that turtles are harvested for eggs, meat, oil, and other products. Sea turtles are also not fully excludable in consumption; consumer benefits from existence, options for the future, and indirect consumption such as passive viewing and eco-tourism are non-excludable, but direct consumption for eggs, etc. is excludable since others cannot consume. In this regard, sea turtles are mixed, impure public, or intermediate goods (Heal, 2000; Sandler, 1999; Tisdell, 1991). The issue with mixed goods is to obtain the proper mix of uses, where factoring in the full social costs and benefits may preclude any private direct consumption such as for eggs, meat, and oil (Tisdell).

[6] A start in this direction of excludability and closing the import "loophole" to local, unilateral conservation and management measures is the banning of imports of shrimp caught in a way that harms endangered sea turtles (Section 609 of Public Law 101-162). The World Trade Organization (WTO) recently determined that the U.S. implementation of its law to protect sea turtles is consistent with earlier WTO Appellate Body recommendations (Lazaroff, 2001).

[7] Unilateral management of atmospheric public goods and associated problems, such as ozone depletion and emissions of greenhouse gases and global warming, is not attempted since it simply adversely affects the initiating nation's industries and well-being. Instead, atmospheric public goods are conserved and managed through multilateral environmental agreements –

protocols. This recognition is more uneven with oceanic public goods; dolphins in the Eastern Tropical Pacific are multilaterally managed by the Inter-American Tropical Tuna Commission and whales are globally managed by the International Whaling Commission. In addition, eco-tourism, either at sea or beach viewing, could help increase the indirect consumption private good aspect of sea turtles and thereby provide economic incentives for conservation.

[8] Unless a limited number of nations agree to provide the public good even without capturing the full benefits for themselves. Heal (p. 32) observes, "The problem with public goods is that the market provides inadequate incentives for their provision. The main reason is their non-excludability – the fact that the seller cannot prevent non-payers from benefiting from them." In addition, gear improvements for fisheries that incidentally take turtles may reduce local takes allowing increased takes elsewhere. Moreover, even under a multilateral agreement for turtles, gear improvements are a necessary but not sufficient condition in that these improvements would allow an increased number of fishers and supply of seafood for a given number of turtle takes.

[9] In addition, eco-labeling of seafood caught consistent with approved conservation standards, such as the Endangered Species Act, would provide a price premium. This higher price would provide economic incentives to fishers to harvest fish while minimizing the incidental takes of turtles, transfer some consumer surplus to producer surplus, and help maintain or even expand consumer surplus from non-market economic values and also indirect consumption. This price premium would represent a willingness to pay for sea turtle conservation. A voluntary sea turtle stamp or tax on consumption through the price premium or on production would be split between producers and consumers depending on their relative elasticities of supply and demand. The proceeds could be used for beach protection or other mitigation projects. For example, beaches and critical habitat could be purchased, seasonal offshore marine reserves during mating and nesting could be financed, local populations (who might otherwise harvest eggs or meat) could be paid to protect nesting sites, and so forth.

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Migration of Exotic Pests: Phytosanitary Regulations and Cooperative Policies to Protect U.S. Ecosystems and Agricultural Interests

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Introduction

In Executive Order 13112, President Clinton emphasized the need to prevent the introduction and to minimize the impact of invasive species to the U.S. ecosystems and agricultural industry. Exotic plants and insects can dramatically alter an ecosystem's balance and result in increased pesticide use which may negatively impact beneficial insects, water quality and human health. GAO (1997) estimates that the lost production, and prevention and control expenses from introduced plant pests is $41 billion annually. The Office of Technology Assessment (OTA 1993) reports that the potential cumulative economic loss caused by just 6 non-indigenous insects is $74 billion.[1] The establishment of the Mediterranean Fruit Fly *(Ceratitis capitata)* in the United States is estimated to cost $1.5 billion annually (Nichols, 2001). If the Mexican Fruit Fly *(Anastrepha ludens)* becomes established, the estimated 5-year loss would be $1.44 billion (Grimes, 1992). Historically, the projected losses from the establishment of exotic species have resulted in import bans or quarantine measures on all commodities from countries known to harbor the exotic insect. Bans and quarantine measures enacted to protect plants from other plants (weeds), insects, and other pathogens are called phytosanitary regulations. Because tariff levels in the world have decreased since the first agreement of the General Agreement of Tarriffs and Trade (GATT), these phytosanitary regulations (also called non-tariff or technical trade barriers) are more likely to be binding. In addition, as countries attempt to protect domestic producers competing with foreign counterparts without tariffs, domestic governments may use these types of trade barriers when little scientific basis for these regulations exists. Roberts (1998) suggests that technical trade barriers can be used as a non-transparent means of providing protection for domestic producers from foreign competitors.

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[1]Insects include the African honey bee, Asian gypsy moth, Boll weevil, Mediterranean Fruit Fly, Nun moth, and Spruce bark beetle. For comparison purposes, the expected losses from the establishment of foot and mouth disease was estimated to be $25.6 billion.

L. Fernandez and R.T. Carson (eds.), Both Sides of the Border, 455–484.

Domestic farmers support using import bans, arguing that the presence of exotic pests in production regions increases their costs, results in additional chemical applications, and may limit the movement of their agricultural products into export markets (including domestic markets in other states, such as Texas selling to California markets). Consumers may find that the exotic pests' damage results in higher prices for agricultural products and additional pesticide use, which may have environmental and human health impacts. Ecologists suggest that "when the outrageous economic and ecological costs of the wanton spread of existing exotics and continued entry of new ones becomes common knowledge, there will be a public outcry to mitigate the potentially dire consequences" (Niemela & Mattson, 1996). Exotic pests can be seen as a "public bad" like other forms of pollution. A standard economic conclusion is that under-abatement of this "public bad" will occur under perfect competition because individual producers and infested countries do not have to bear the full social cost of the pests' proliferation. Government intervention may be justified if regulators conclude that market mechanisms alone will fail to prevent or correct the negative externality since the resulting pest population in the domestic country may actually reduce domestic output and/or increase production costs (Roberts, 1999).

Even with import bans and quarantine regulations to inhibit direct migration on host commodities, exotic pests can act like trans-boundary pollution and not respect the border. Pests migrate through both natural and artificial pathways. They move great distances with wind currents and in water and soil. Basic artificial pathways are direct migration on the host commodity as well as on other items in aircraft, buses, ships, trains, trucks and automobiles. The proliferation of international trade and travel has increased exotic pests' opportunities to migrate into new countries. The industrial development and population growth along the U.S. and Mexico border is hypothesized to have resulted in increased numbers of the Mexican fruit fly in California and Texas. Smuggling of agricultural products has increased and may present an important pathway for exotic pests to enter the U.S. (GAO, 1997).

This paper examines theoretically and graphically whether the U.S. should use an import ban to decrease the threat of exotic pest migration from Mexico or work with Mexico to decrease the pest population and thus the probability of pest migration. In the strategic trade literature, if a government acts first and uses a continuous instrument,[2] it can improve the country's welfare (Brander and Spencer, 1985) in an imperfect market setting. This paper uses a competitive market model where the continuous instrument (tax, tariff, subsidy) is the level of pest control where the domestic government (U.S.) decides its own level and whether to subsidize the foreign country's (Mexico) pest control. The U.S. can also use a discrete instrument[3] (import ban) to affect domestic welfare. U.S. producers may benefit from the imposition of bans or quarantine provisions that exclude potential competitors and raise domestic prices. However, if Mexican growers cannot ship to the U.S. market, they may have less incentive to control the pest population; as the pest population increases, so does the likelihood of pest migration. As the U.S. price increases, the incentive to smuggle the commodities over the border also increases. If

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[2]A continuous instrument could be a tax or a subsidy that would vary with the quantity or quality of imports.

[3]A discrete instrument could be an import ban. Regulators enact this type of policy or they do not, but it is not affected by the level of imports or the quantity of pests as a continuous instrument would be.

the exotic pests do migrate, the producer welfare decreases as pest control costs increase and other countries place bans on the domestic commodities. The Mexican Fruit Fly (MFF) and Mediterranean Fruit Fly (Medfly) will be used as examples.

The following section includes the model development and discussion of comparative static results. A graphical analysis follows. A description of the current exotic pest protocol and cooperative techniques precedes the conclusions.

Theoretical Model

In the model, governments have perfect information about the underlying market structure and probability of pest migration. The domestic government has two continuous instruments: level of domestic pest control and level of subsidization of foreign pest control, and one discrete instrument: an import ban. The foreign government has one instrument: foreign pest control. Pest migration is assumed to occur only from the foreign to the domestic country, so no retaliation is included.[4] The model examines the provision of pest control (pollution abatement) and trade regulation selection in an open economy. The convention of the domestic country's variable appearing in lowercase letters and the foreign country's variables in uppercase letters is followed.

The model is a two-stage subgame perfect Nash equilibrium with each government committing itself to a level of pest control and/or a domestically imposed import ban. Once each government has determined the desired level of pest control and the domestic government has chosen whether or not to impose an import ban, the producers decide how much to produce of the homogenous product. Consumers choose their consumption level. The domestic growers sell to the domestic market and the foreign firms sell in both the domestic and the foreign market. Welfare of each country is a function of the levels of pest control and of the subsidy and whether an import ban is imposed. The reaction functions are determined by the game between the governments. The model is a static partial equilibrium two-country trade model with competitive market conditions. The market equilibrium quantities and prices are found and used to solve the game.

Competitive Market Model

Total cost function for the domestic industry is $c(q, n)$, where q is the domestic output and n is the number of pests domestically. The number of pests domestically, n, depends on the initial number of insects in the foreign country, N_0, the level of domestic control, x, and the level of foreign control, X. The percent of pests entering the domestic country through direct pest transfer on the foreign commodity, αQ_e, and through other pathways such as travelers, smuggling, and wind, γ, contributes to the final level of pests being equal to $n = N_0G(X)(\gamma + \alpha Q_e)g(x)$. Foreign pest level, N, is a function of the N_0 and X, such that $N = N_0G(X)$. $G(X)$ is the percent of pests left living in the foreign country after foreign control X, i.e., the inverse of a kill function. $g(x)$ is the percent of pests left living after domestic control, x. Both of these inverse kill functions are assumed to be negative and increasing ($G'(x)<0$, $G''(x)>0$; $g'(x)<0$, $g''(x)>0$). The marginal costs of producing both foreign output, Q, and domestic output, q, are assumed

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[4]Realistically, the foreign government could retaliate by using a ban on another commodity the domestic country exports to them.

positive and increasing ($C_Q > 0$, $C_{QQ} > 0$; $c_q > 0$, $c_{qq} > 0$), and the marginal costs of the pest level are positive ($C_N > 0$; $c_n > 0$). The marginal impact of more pests on marginal production costs is assumed to be non-decreasing with the level of operation ($C_{NQ} \geq 0$; $c_{nq} \geq 0$).

Domestic consumer preferences are represented by an additively separable utility function $U(q + Q_e) + Z$ where $q + Q_e$ is domestic consumption of the homogenous agricultural good under consideration and is composed of both domestic production q and imports Q_e, and Z is the *numeraire* good. The marginal utility of consuming $q + Q_e$ is positive and declining ($U_q > 0$, $U_{qq} < 0$). Consumers have a budget constraint, $y=p(q+Q_e)+Z$, where p is domestic price and y is disposable income. An identical structure is used for the foreign consumers.

Individual consumers and producers consider n and N as given when determining their consumption and production choices. Domestic consumers choose $q + Q_e$ to maximize their utility, $u(q + Q_e) + y-p(q+Q_e) - \beta(rx+sX)$. The variable, β, is the proportion of the control expenditure the consumers pay.[5] rx is the total expenditure on domestic control. The domestic government provides sX as a subsidy for foreign control. Foreign consumers choose Q_d to maximize their utility $U(Q_d) + Y-PQ_d- B((R-s)X)$. P is the foreign market price; Y *is* foreign income; and B is the proportion of the control expenditure the foreign consumers pay. Domestic producers choose q to maximize profits, $pq - c(q,n) -(1-\beta)(rx+sX)$, taking the number of pests as given. To sell in the domestic market, foreign growers pay for a quarantine treatment with a per unit cost of t.[6] Foreign producers choose Q_e and Q_d to maximize their profits: $(p-t)Q_e + PQ_d - C(Q_e + Q_d, N) - (1-B)(R-s)X$. The total foreign expenditure on pest control is $(R-s)X$.

The market clearing conditions, the First Order Necessary Conditions (FONC), are:

$$\begin{aligned} p&=u'(q+Q_e)\\ P&=U'(Q_d)\\ p&=c_q(q,n(N_0,X,x,\alpha,Q_e,\gamma))\\ p-t&=C_Q(Q_e+Q_d,N)\\ P&=C_Q(Q_e+Q_d,N) \end{aligned} \tag{1}$$

Solving the equations in (1) simultaneously results in the equilibrium prices and quantities. The competitive equilibrium is denoted as $q^*(\Theta)$, $Q_e^*(\Theta)$, $Q_d^*(\Theta)$, $p^*(\Theta)$, and $P^*(\Theta)$ where $\Theta = (N_0, X, x, \alpha, \gamma, t)$. Using the implicit function theorem, the comparative statics of the market equilibrium are computed and presented in Table 1. For detailed derivations, see Lynch (1996).

As the direct (α) and other migration (γ) of pests increases, the domestic quantity decreases and domestic price increases. With more pests domestically, q decreases as domestic growers' costs increase. The foreign country increases exports. As Q_e increases, Q_d falls, thus

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[5]If the pest control is financed by the government, tax revenues must be collected. In some circumstances, agricultural organizations contribute to these exotic pest exclusion and eradication programs.

[6]Under current regulations, quarantine treatments must satisfy a Probit 9 criterion, i.e., the treatment must eliminate 99.9986 percent of the insects. Thus, if a product has undergone an acceptable quarantine treatment, α should equal 0, i.e., there will be no or little pest migration directly on the foreign quantity, Q_e. If this is the case, $n = N_0G(X)(\gamma)g(x)$.

Table 1. Competitive Equilibrium Comparative Statics

Equation variable	q^* domestic production	Q_e^* foreign exports	Q_d^* foreign consumption	p^* domestic price	P^* foreign price
Parameters					
Direct migration (α)	-	+	-	+	+
Other migration (γ)	-	+	-	+	+
Initial pest level (N_0)	?	?	?	?	?
Foreign pest control (X)	?	?	?	?	?
Domestic pest control (x)	+	-	+	-	-
Quarantine treatment (t)	+	-	+	?	-

foreign price increases. Consumers in both countries are worse off while foreign producers are better off. Similarly, as domestic pest control increases, q increases, Q_e falls, and domestic and foreign prices decrease. Domestic pest control benefits domestic growers and provides no benefit to the foreign country, shifting the comparative advantage in favor of the domestic growers. As foreign pest control increases, no prediction can be made about domestic and foreign quantities and prices. The foreign pest control benefits both the foreign and domestic producers. Fewer foreign pests decreases the likelihood of migration to the domestic country. However, since both growers benefit from fewer pests, either country's producers may benefit more. For example, if X decreases the foreign growers' costs more than the domestic growers', foreign producers will export more to the domestic country. As foreign commodities enter the domestic market, domestic price will decrease and domestic growers will produce less. Alternatively, the domestic growers benefit more therefore domestic production increases relative to foreign exports. Interestingly, as the initial level of pests increases, no inferences can be made about market quantities and prices. An increase in the level of initial pests results in an increase in the effectiveness of the pest control measures initially. However, although pest control is more effective, there finally may still be more pests. Therefore, exports may increase or decrease and may result in more or less pest migration. Again the relative change in the costs of the foreign and domestic producers determines the impact on domestic quantity and thus the domestic and foreign prices. If the quarantine treatment cost increases, the domestic quantity will increase as the exports fall. The foreign price will decrease as the quantity sold in the foreign market increases. The effect on the domestic price is ambiguous as it is affected by both the increased domestic quantity and decreased exports. The relative changes in quantities will determine the overall effect on domestic price.

Free-Trade Solution

Under the free-trade scenario, growers act with no government intervention. Growers determine the level of pest control and pay for it. In each country, the growers select what is optimal for their own production costs, disregarding the fact that the foreign control level affects the domestic level of pests. Since a competitive market situation is assumed, the growers take price as given and do not behave strategically to keep the price high. New growers could enter the market or foreign growers could increase their exports. In addition, growers in both countries ignore that pest control may have negative environmental effects. Environmental effects are a function of pest control level, $h(x)$, with increased levels increasing environment damage ($h'(x)>0$).[7] These environmental effects can be seen as another market failure and are not included in the free trade solution of pest control. For simplicity, the *'s that indicate the optimal function values are omitted. Domestic and foreign growers solve:

$$Max \quad \pi = p(\theta)q(\theta) - c(q(\theta), n(N_0, X, x, Q_e(\theta), \alpha, \gamma)) - rx - sX \tag{2}$$

$$Max \quad \Pi = P(\theta)Q_d(\theta) + (p(\theta) - t)Q_e(\theta) - C(Q_e(\theta) + Q_d(\theta), N) + RX \tag{3}$$

Under this scenario, the equilibrium control and subsidy levels are determined by the FONCs:

$$-\frac{\partial c}{\partial n}[N_0 G(X)(\gamma + \alpha Q_e)g'(x) + N_0 G(X)\alpha \frac{\partial Q_e}{\partial x} g(x)] = r$$

$$-\frac{\partial C}{\partial N}[N_0 G'(X)] = R$$

The domestic and foreign growers will conduct pest control until the reduction in marginal cost using one more unit of pest control is equal to the per unit cost of pest control. The domestic marginal cost has two components: how the level of pest control directly affects the level of the domestic pests and thus the marginal costs, and how the level of pest control affects the import level and thus the potential pest migration. As mentioned above, the growers do not consider any negative externalities ($h(x)$ and $H(X)$) that may result from using the control mechanisms. Thus, growers may use more pest control than is socially optimal. However, in the scenarios examined below, the governments pay part of the pest control cost. In this case, the growers are paying the full cost of the control; therefore they may use less pest control than with government intervention.

The domestic growers cannot impose an import ban to stop direct migration with the commodity, i.e., domestic growers cannot set Q_e (thus αQ_e) equal to zero. If they could, domestic price would increase as imports decreased to zero, domestic quantity would rise, and foreign consumption would increase and foreign price would decrease. In the domestic country, the direct migration of the pests would fall to zero. The FONC becomes

$$\frac{\partial c}{\partial n}[N_0 G(X)\gamma g'(x)] = r.$$

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[7]If exotic species were not controlled, disruptions to the ecosystem that have negative impacts on societal welfare may result. In this paper, however, the externalities are assumed to be directly connected to the control measures. Some control measures such as sterile insect release have no negative environmental or health effects (USDA- APHIS, 1999a). More details on the environmental effects are provided in the description of the program, provided later in the paper.

Under a free trade scenario, the domestic growers would have to pay for the subsidy. However, subsidizing the foreign growers may lower foreign costs and improve their comparative advantage vis-a-vis the domestic growers. This would make foreign products more competitive. Therefore, no subsidy is given.

The free trade solution may be sub-optimal. Less foreign control may be conducted and more pests may migrate to the domestic production areas than is optimal from a domestic welfare viewpoint. The introduction of exotic pests would increase the level of domestic pest control, which has environmental externalities. Foreign growers do not consider the impact of their pest control on domestic pest levels, thus may not conduct enough pest control.

Government Problem

Given the public good aspect of the exotic pest problem and the environmental externalities, governments often intervene to maximize their country's welfare. In this model, the domestic government takes the market clearing conditions in (1) as given and chooses the pest control level, x, and the subsidy levels to give the foreign government,[8] s, and whether to impose an import ban to maximize the country's welfare. The government pre-commits to a specific policy intervention that cannot be altered even if it is sub-optimal ex-post, i.e., once the farmers choose their output levels and consumers their consumption levels. The decision of whether to impose the import ban is determined by comparing the welfare with a ban $(\sigma = 0)$ to the welfare without a ban $(\sigma=1)$. The ban will have three discrete effects: it alters the level of controls used and thus the level of pests and the environmental effects, it changes the price of the commodity and therefore consumer surplus, and it impacts the domestic production of the commodity. These changes may move in opposite directions to affect domestic welfare. As above, environmental effects are a function of pest control level, $h(x)$, with increased levels increasing environment damage $(h'(x)>0)$, but are now considered explicitly. For simplicity, the *'s that indicate the optimal function values are omitted.

Under a Cournot behavior assumption, the domestic government conjectures that when it changes domestic pest control, the foreign government will hold its level fixed. Thus the government maximizes society's welfare by choosing x, s and σ as given by equation (5)

$$\begin{aligned} Max \quad w = {} & \sigma[p(\theta)q(\theta) - c(q(\theta), n(N_0, X, x, Q_e(\theta), \alpha, \gamma)) + \\ & u(q(\theta) + Q_e(\theta)) + y - p(\theta)q(\theta) - p(\theta)Q_e(\theta) - sX - rx - h(x)] + \\ & (1-\sigma)[p(\theta)q(\theta) - c(q(\theta), n(N_0, X, x, \gamma)) + u(q(\theta)) + \\ & y - p(\theta)q(\theta) - sX - rx - h(x)] \end{aligned} \tag{5}$$

The government is maximizing consumer and producer welfare minus the cost of conducting domestic pest control (rx) and subsidizing foreign pest control (sX). It also has a choice of imposing an import ban on the foreign country $(\sigma=1)$ or permitting imports $(\sigma=0)$. If the government weighs consumers, producers and the environmental effects equally, the welfare maximization problem (5) can be reduced to (6):

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[8] A subsidy can be viewed as any type of assistance to control pests. Although governments do provide monetary assistance to other governments, they also provide management, technical and equipment assistance. Governments have also cooperated on joint research projects.

$$\begin{aligned}Max\ w &= \sigma[-c(q(\theta),n(N_0,X,x,Q_e(\theta),\alpha,\gamma))\\ &+ u(q(\theta)+Q_e(\theta))+y-p(\theta)Q_e(\theta)-sX-rx-h(x)]\\ &+(1-\sigma)[-c(q(\theta),n(N_0,X,x,\gamma))+ u(q(\theta))+y-sX-rx-h(x)]\end{aligned} \tag{6}$$

The FONC with respect to x of (6) is:

$$\begin{aligned}&\sigma[u'[\frac{\partial q}{\partial x}+\frac{\partial Q_e}{\partial x}]-p\frac{\partial Q_e}{\partial x}-Q_e\frac{\partial p}{\partial x}-c_q\frac{\partial q}{\partial x}-\\ &c_n[\frac{\partial n}{\partial x}+\frac{\partial n}{\partial Q_e}\frac{\partial Q_e}{\partial x}]-r-h'(x)]\\ &+(1-\sigma)[u'\frac{\partial q}{\partial x}-c_q\frac{\partial q}{\partial x}-c_n\frac{\partial n}{\partial x}-r-h'(x)]=0\end{aligned} \tag{7}$$

By (1), several elements in (7) cancel each other out and the FONC is:

$$\sigma(-Q_e\frac{\partial p}{\partial x}-c_n\frac{\partial n}{\partial Q_e}\frac{\partial Q_e}{\partial x})-c_n\frac{\partial n}{\partial x}-h'(x)-r=0 \tag{8}$$

If $\sigma=1$ and imports are permitted, the domestic government considers the import-weighted price effect of increased pest control, the marginal cost effect, the marginal effect on the environment, and the direct cost to the taxpayers when deciding the level of pest control to apply. The government takes into account how the level of pest control will change the price and how the price change affects welfare. The marginal cost has two parts: the direct effects of pest control on the domestic pest population and the indirect effects through the change in the level of imports (as x increases, Q_e decreases) and thus the change in the number of migrating pests. As the government is playing Cournot and thinks it cannot influence the foreign control decisions, it picks a subsidy level of $s = 0$. The FONC for s is $-X = 0$. If the government chooses to use an import ban and sets $\sigma=0$, the optimal level of pest control is chosen such that

$$-c_n\frac{\partial n}{\partial x}-h'(x)-r=0 \tag{9}$$

From (9), one sees that a marginal increase in pest control will reduce producers' costs. The government will conduct pest control until the per unit costs and marginal environmental effects equals the reduction in producer costs. It will use less pest control than the free market solution under an import ban because it considers the marginal negative impact on the environment. This will increase the welfare of society relative to the free market solution which disregards the externality. To compare the level of the pest control between the two discrete situations, the domestic government picks the optimal level of Q_e in (6) and then compares it to the import ban level of $Q_e=0$. The optimal level of the imports from (6) will solve the FONC:

$$-c_n\frac{\partial n}{\partial Q_e}-\frac{\partial p}{\partial Q_e}Q_e=0 \tag{10}$$

Imports have two effects on domestic welfare. First, if the foreign country has no pests, i.e., $N_0 = 0$, $N_0G(X)=0$, or $\alpha=0$,[9] permitting imports increases domestic welfare by decreasing the price (weighted by the level of imports). However, if $\alpha>0$, allowing imports to enter the domestic market could decrease welfare by increasing the pest population and domestic marginal costs. The overall change in welfare of permitting imports depends on the magnitudes of these two effects. If the marginal change in production costs of more pests is always greater than the price change, the domestic country will set Q_e to zero, i.e., impose an import ban. If the effect on costs is less than the effect on price, imports are permitted until the change in costs equals the change in price. The level of pest control with and without a ban can be compared. Substituting equation (10) into (8), the optimal level of control with imports depends on the magnitudes of the change in domestic price due to the increase in pest

control and change in price due to the change in import quantity. If $\frac{\partial p}{\partial x}>\frac{\partial p}{\partial Q_e}\frac{\partial Q_e}{\partial x}$, more pest control will be conducted with imports than in the case without imports. If $\frac{\partial p}{\partial x}<\frac{\partial p}{\partial Q_e}\frac{\partial Q_e}{\partial x}$, less pest control will be conducted than without imports. The substitution of the market clearing conditions into the welfare equation provides $x = \hat{x}(X,N_0,\alpha,\gamma,t,r,\sigma)$, the domestic country's reaction function.

The foreign country maximizes its welfare given the market equilibrium condition and the domestic country's choice of σ by choosing X:

$$\begin{aligned} Max \quad W =\sigma[\, & P(\theta)Q_d(\theta)+(p(\theta)-t)Q_e(\theta)-C(Q_e(\theta)+Q_d(\theta),N)\\ & +U(Q_d(\theta))+Y-P(\theta)Q_d(\theta)-(R-s)X-H(X)]\\ & +(1-\sigma)[P(\theta)Q_d(\theta)-C(Q_d(\theta),N)+\\ & U(Q_d(\theta))+Y-P(\theta)Q_d(\theta)-(R-s)X-H(X)] \end{aligned} \tag{11}$$

or as simplified

$$\begin{aligned} Max \quad W = \sigma[& (p(\theta)-t)Q_e(\theta)-C(Q_e(\theta)+Q_d(\theta),N)+\\ & U(Q_d(\theta))+Y-(R-s)X-H(X)]+\\ & (1-\sigma)[-C(Q_d(\theta),N)+U(Q_d(\theta))+Y-(R-s)X-H(X)] \end{aligned} \tag{12}$$

The simplified FONC with respect to foreign control level, X, is:

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[9]If $\alpha=0$, no pest will enter with the commodity. This assumes that all quantities of the commodity follow the quarantine procedure and the quarantine treatment is 100 percent effective.

$$\sigma Q_e \frac{\partial p}{\partial X} - C_N \frac{\partial N}{\partial X} - (R-s) - H'(X) = 0. \tag{13}$$

If $\sigma=1$, the equilibrium X is determined by an export-weighted domestic price effect, the decrease in marginal cost to foreign producers of fewer pests, the marginal effect on the foreign environment, and the per unit cost of the pest control minus any subsidy given to the foreign government. Given that foreign pest control decreases potential pest migration, an increase in X may raise the production in the domestic country. As q increases, the domestic price will decrease, which makes the export market less desirable to foreign producers. This effect is included in $Q_e \frac{\partial p}{\partial X}$, which has an ambiguous sign.[10] Alternatively, if there are more exports, there could be a higher pest migration, which causes domestic costs to increase. If the domestic country institutes an import ban, $\sigma=0$, then the FONC becomes:

$$-C_N \frac{\partial N}{\partial X} - (R-s) - H'(X) = 0 \tag{14}$$

The foreign control effect on the domestic pest population is not considered. The foreign government determines pest control level by equating the decrease in the marginal cost for foreign producers to the marginal environmental effects and the per unit cost minus the per unit subsidy for pest control. The solution to (14) is the foreign country's reaction function, $X = \hat{X}(x\ N_0, \alpha, \gamma, t, R, s, \sigma)$. The level of foreign pest control can increase or decrease when the price effect is not considered. The incentive to control pests may decrease when the export market is closed due to an ban.

The comparative statics of the equilibrium of this non-cooperative game for the two choice variables, x and X, are derived. All the comparative statics have ambiguous signs.[11] One cannot tell how domestic pest control will change as foreign pest control changes, as the initial level of the pests increases, or as the direct or other migration of the pest population alters. Even for parameters like the cost of the control measures or the imposition of an import ban, one finds the pest control can change in either direction due to the interdependence of the two markets and the migration of the pests. Therefore, if countries act independently, policymakers need to evaluate whether a certain policy such as an import ban will increase their country's welfare in each exotic pest situation. No one policy will increase welfare in all cases of exotic pest threat.

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[10]

$$\frac{\partial p}{\partial X} = \frac{u''(q)U''(Q)[C_{QN}N_0 G'(X)(c_{qq} - c_{qn}\frac{\partial n}{\partial Q_e}) + c_{qn}\frac{\partial n}{\partial X}C_{QQ}]}{(-)}$$

[11]For detailed derivations, see Lynch (1996).

Cooperative Solution

If each of two countries recognizes that the other's pest control level affects its welfare, they might agree to cooperate. Equation (15) depicts the joint welfare-maximization equation

$$
\begin{aligned}
Max\ w + W = \sigma[&-c(q(\theta),n(N_0,X,x,Q_e(\theta),\alpha,\gamma))+u(q(0)+Q_e(\theta)) \\
&+y-rx-h(x)-tQ_e(\theta)-C(Q_e(\theta)+Q_d(\theta),N)+U(Q_d(\theta))+Y-RX-H(X)] \\
&+(1-\sigma)[-c(q,n)+u(q)+y-rx-h(x)-C(Q_d,N) \\
&+U(Q_d)+Y-RX-H(X)]
\end{aligned}
\tag{15}
$$

where the countries jointly choose x and X:
The two countries will set their joint pest control quantities given the following two FONCs:

$$
\begin{aligned}
&-\sigma c_n \frac{\partial n}{\partial Q_e}\frac{\partial Q_e}{\partial x}-c_n\frac{\partial n}{\partial x}-r-h'(x)=0 \\
&-C_N\frac{\partial N}{\partial X}-\sigma c_n\frac{\partial n}{\partial Q_e}\frac{\partial Q_e}{\partial X}-c_n\frac{\partial n}{\partial X}-R-H'(X)=0
\end{aligned}
\tag{16}
$$

Under cooperative welfare maximization, domestic pest control decreases relative to the non-cooperative Nash equilibrium. The cooperative foreign pest control can be greater or smaller than the non-cooperative level, as a marginal increase in foreign control expenditure has a cost-reducing effect in both countries. If the two governments choose to implement an import ban, the FONCs revert to (9) and (14) with the addition of the direct effect of foreign control on domestic marginal costs ($-c_n\frac{\partial n}{\partial X}$). While it seems counterintuitive to impose an import ban, if the joint welfare is maximized without permitting trade, it may be the policy decision. Operationally, in this case, the governments would determine how to share the joint costs $(rx+RX)$. If the domestic government is willing to bear a large percentage of the cost of foreign control, the foreign government may agree to the import ban.

Purchasing Foreign Pest Abatement

To influence the foreign control level without joint welfare maximization, the domestic country can act as a Stackleberg leader. The domestic country takes the foreign country's reaction to the domestic level of control and the subsidy, $\hat{X}(x,s)$, and determines the level of subsidy it must give the foreign country to maximize domestic welfare. In this case, the FONCs for the optimal levels of pest control and subsidy are :

$$-\sigma Q_e[p_n(\frac{\partial n}{\partial x}+\frac{\partial n}{\partial X}\frac{\partial X}{\partial x})+p_N(\frac{\partial N}{\partial x}+\frac{\partial N}{\partial X}\frac{\partial X}{\partial x})]$$
$$-\sigma c_n[Q_{en}(\frac{\partial n}{\partial x}+\frac{\partial n}{\partial X}\frac{\partial X}{\partial x})+Q_{eN}(\frac{\partial N}{\partial x}+\frac{\partial N}{\partial X}\frac{\partial X}{\partial x})] \tag{17}$$
$$-c_n(\frac{\partial n}{\partial x}+\frac{\partial n}{\partial X}\frac{\partial X}{\partial x})-r-s\frac{\partial X}{\partial x}-h'(x)=0$$

$$-\sigma Q_e[p_n\frac{\partial n}{\partial X}\frac{\partial X}{\partial s}+p_N\frac{\partial N}{\partial X}\frac{\partial X}{\partial s}]-\sigma c_n[Q_{en}\frac{\partial n}{\partial X}\frac{\partial X}{\partial s}+Q_{eN}\frac{\partial N}{\partial X}\frac{\partial X}{\partial s}]$$
$$-c_n(\frac{\partial n}{\partial X}\frac{\partial X}{\partial s})-X(s)-s\frac{\partial X}{\partial s}=0 \tag{18}$$

The government chooses a level of domestic pest control so that the import-weighted price effect, the marginal cost effect, and the negative environmental effect equals the per unit cost of pest control and the marginal impact on the subsidy for foreign pest control of more (less) domestic pest control. Acting as a Stackelberg leader, the domestic government considers how domestic control affects the level of the foreign control when maximizing welfare. The optimal subsidy level for foreign pest control is the level at which the benefits to domestic producers of reduced pest migration (through lower marginal costs) equals the cost of the subsidy. If the domestic government decided to ban imports, then it chooses the optimal level of pest control and subsidization to satisfy the following FONCs:

$$-c_n(\frac{\partial n}{\partial x}+\frac{\partial n}{\partial X}\frac{\partial X}{\partial x})-r-s\frac{\partial X}{\partial x}-h'(x)=0 \tag{19}$$

$$-c_n(\frac{\partial n}{\partial X}\frac{\partial X}{\partial s})-X(x,s)-s\frac{\partial X}{\partial s}=0 \tag{20}$$

Given an import ban, the domestic government sets the optimal level of pest control where the change in marginal costs and the change in the cost of the subsidy equals the per unit cost of the domestic control and the marginal environmental effects. While a price increase or decrease will have distributional impact, i.e., it will be gained either by domestic producers or consumers, the government does not consider the price effect, as it does not change domestic welfare if no trade is permitted. When deciding the subsidy, the domestic government considers how a marginal increase in foreign pest control affects domestic producers' marginal costs, the actual level of foreign control and how an additional unit of subsidy increases the cost of the subsidy.

Graphical Analysis

Some of the results of the theoretical model can be seen graphically. A graphical analysis depicts how domestic and foreign welfare changes if an import ban is imposed. These changes depend on how the production costs change due to the pest population, thus how the domestic supply curve shifts. In Figure 1, the domestic (importing country) and foreign (exporting

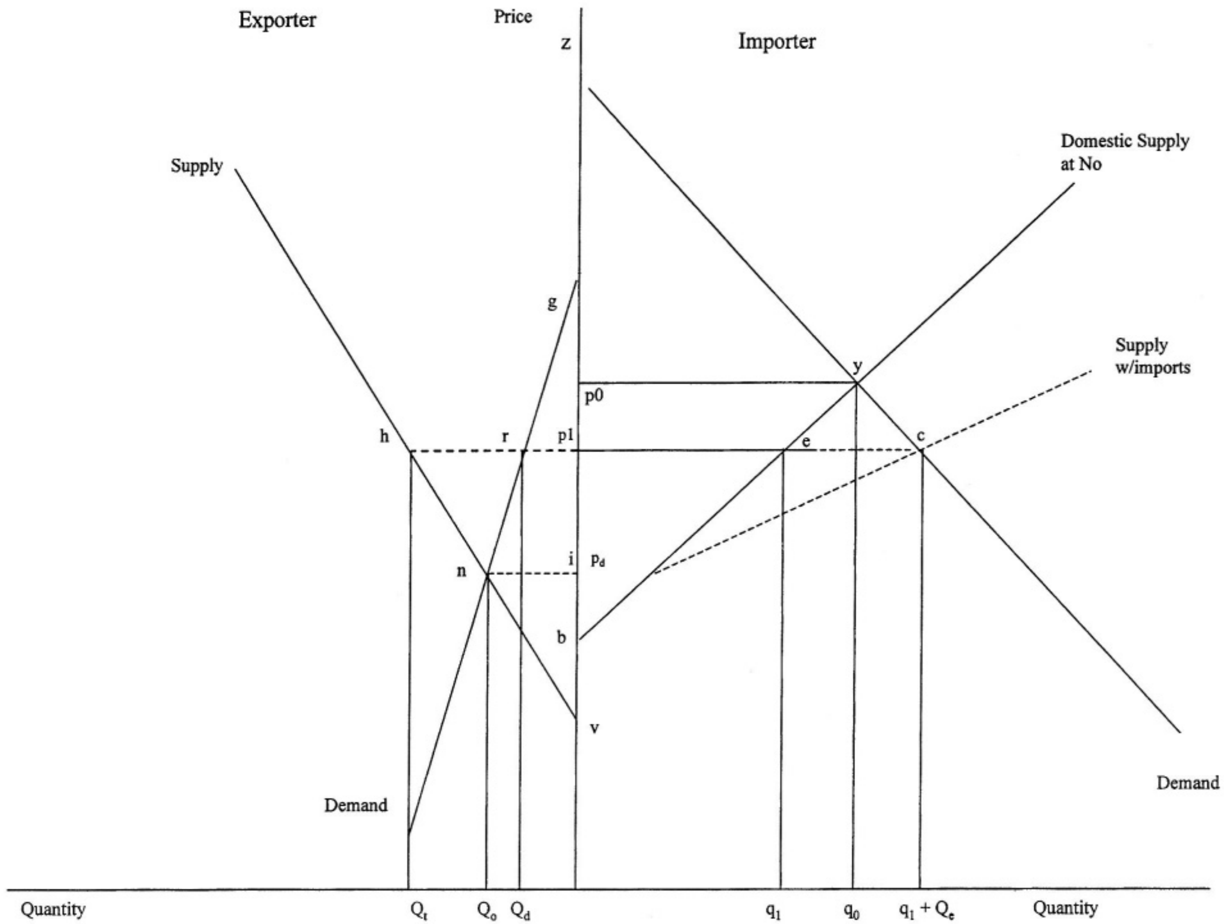

Figure 1. Domestic Welfare Changes with an Open Economy

country) demand and supply curves are given. The domestic country is assumed to have an initial pest level of zero, n_0. The domestic market is larger than the foreign market. Foreign producers have lower costs of production but have positive levels of the pest. If the domestic government imposes an import ban to exclude the exotic pest, domestic welfare is *zyb*. The domestic price is p_0 and domestic quantity is q_0. Consumer surplus is zyp_0 and producer surplus is byp_0. The foreign market price, P_d, is lower than p_0 at point *i*. Foreign consumer surplus is *gni* and producer surplus is *niv*. Under an import ban, foreign production and consumption equals Q_o. If the import ban is lifted and few or no pests migrate to the domestic country, the domestic consumer surplus increases to zcp_1 as the quantity consumed increases to $q+Q_e$ and price falls to p_1. Domestic producer surplus decreases to bep_1 and domestic quantity decreases from q_0 to q_1. Foreign consumer surplus decreases to grp_1 as price increases to p_1 and quantity consumed decreases from Q_o to Q_d. Foreign producer surplus increases to hvp_1 as quantity produced increases from Q_o to Q_r. Q_r-Q_d is the amount exported, Q_e. This depicts the standard trade result when no externalities exist of free trade benefitting domestic consumers due to the higher quantity and lower price. Domestic producers, on the other hand, prefer the import ban because they produce more and receive a higher price. This standard result changes if pests migrate into the domestic country's production regions through this trade.

Figures 2 and 3 present two situations where pests do migrate to the domestic country with the foreign imports. The two figures present different outcomes from the exotic pest migration. In Figure 2, where imports are permitted, the total supply available in the domestic market increases. Price decreases from p_o to p_1. However, the pest population also increases with imports causing domestic costs to increase. The increased cost causes the domestic supply curve to shift left from *DS* at $n=0$ to *DS* n_1. Thus the final supply in the domestic market with the imports is represented by *Supply*(n_1). The final price is p_1'. In Figure 2, the welfare change for domestic consumers by removing the import ban is still positive, and surplus increases from zyp_0 to zcp_1'. The domestic producer surplus falls from byp_0 to sep_1' for two reasons: they now have competition from imports, so domestic quantity decreases from q_o to q_1, and they have increased costs due to the pest population, which decreases quantity further from q_1 to q_1'. Foreign consumers lose as their price increases from P_d to p_1' and quantity sold decreases from Q_0 to Q_d. Foreign producers increase production from Q_0 to Q_t and receive a higher price p_1' instead of P_d. Foreign producer welfare increases from vnP_d to vhp_1'.

However, Figure 3 demonstrates how both domestic producers and consumers can lose by permitting imports. Imports are permitted and increase the domestic pest level. As the pest population increases, the cost of production increases for the domestic producers, thus the domestic supply curve shifts from *DS* $n=0$ to *DS* n_1. Domestic production decreases q_0 to q_1 and price rises to p_1', which is higher than p_0, the price when there was no trade. Since domestic producers were the major suppliers, their decreased production causes consumer welfare to fall under free trade from zyp_0 to zcp_1. The exotic pests increase costs and decrease quantities to the point that the quantity available post-trade (q_1+Q_e) is less than q_0. Domestic producer surplus decreases from byp_0 to sep_1. In Figure 3, the producers have larger losses from the increased per unit production costs (due to the increased pest population) than from the import competition. If the pests migrate only on the imports ($\alpha>0$ and $\gamma=0$), an import ban would be the optimal policy to maximize domestic producer and consumer surplus. On the other hand, if pest migration occurs regardless of import restrictions ($\gamma>0$), the domestic producers may prefer decreasing foreign pest populations to decrease the probability of migrating. If the higher price in the

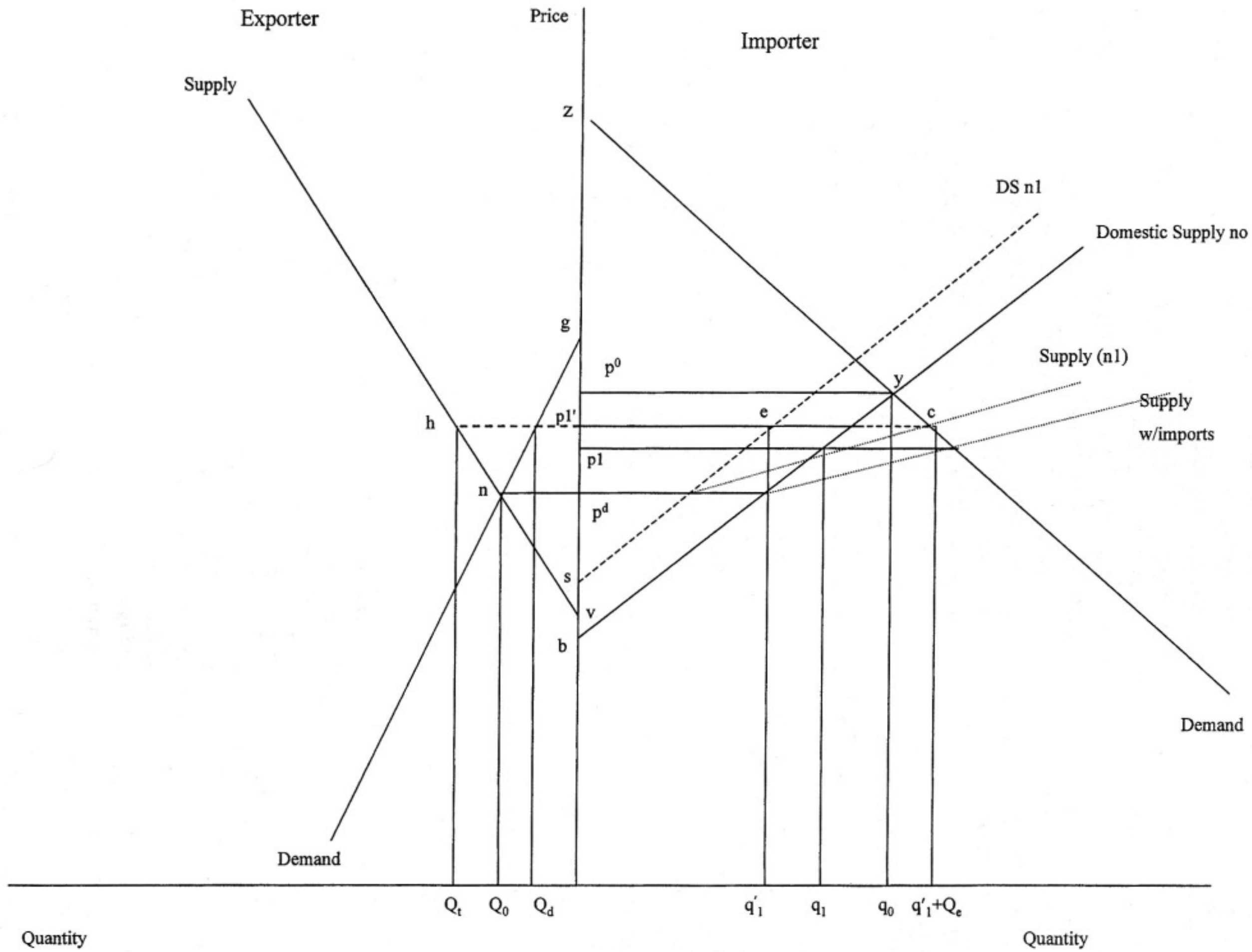

Figure 2. Exotic Pest and Domestic Welfare Changes – Increase in Consumer Surplus

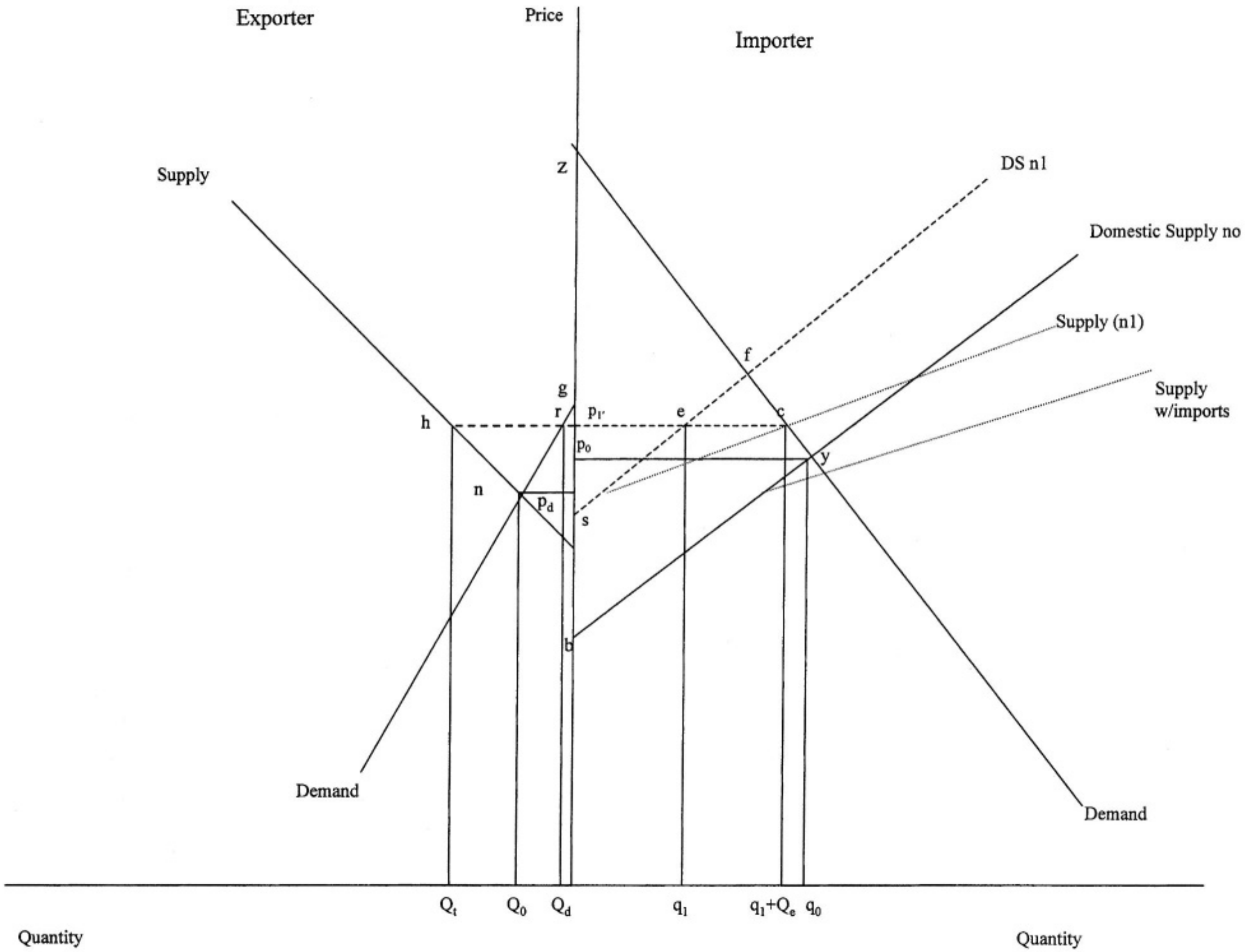

Figure 3. Exotic Pest and Domestic Welfare Changes – Decrease in Consumer Surplus

domestic market provides foreign producers with a greater incentive to control their pest populations and $\alpha = 0$, then domestic producers may advocate open borders even though free trade results in market competition.

Besides the increased production costs incurred from exotic pest introduction, domestic growers may lose their export markets due to import bans imposed by other states or countries. Figure 4 depicts a demand contraction which may occur in the importing country if an exotic pest is introduced into one of the production regions; for example, Texas is banned from shipping to California when Mexican Fruit Flies are found in the Lower Rio Grande. The pest's introduction changes the host status of a production region. If demand contracts, domestic producer surplus decreases from byp_0 with no trade to sep_0 after the pest introduction. The consumers surplus under no trade was zyP_0. After the demand contraction and the increased production costs, domestic consumer welfare decreases to lcp_0. The domestic consumers in the unrestricted area are not negatively affected as the price has not increased (the price could increase or decrease depending on the magnitude of the demand contraction and supply change). However, the consumers who live in the production regions or countries where the import bans against the infested region have been imposed have a decrease in welfare of *zycl*.

Background Information and Current Programs

The U.S., through the United States Department of Agriculture Animal and Plant Health Inspection Service (USDA APHIS), follows a basic pest protocol to deal with exotic pests and protect the U.S. agricultural producers, other citizens, and the ecosystems. The protocol is a three-pronged approach: exclusion, detection and prevention, and eradication. As trade and travel increases, U.S. efforts alone were proving less successful at preventing the introduction of exotic pests. For example, since 1992, California Department of Food and Agriculture has reported 67 new pest invaders that have become established in the state (Coppock and Kreith 1999). Thus, U.S. officials have increased cooperative efforts with Mexican and other Central American countries to decrease the number of pests that arrive at the border location. Cooperative efforts have been expanding on two of the most economically significant insect pests, the Mediterranean Fruit Fly (Medfly) and the Mexican Fruit Fly (MFF).

The MFF hosts on 40 different agricultural commodities. It has been trapped each year in the Lower Rio Grande Valley of Texas and since the early 1980s periodically in California. It has colonized almost all of Mexico. It was first trapped in Tijuana in 1953 and now has been found in Tecate and Mexicali. A strong flier, MFF infests citrus groves by migrating across Mexico's northwestern border or with infested fruit (USDA APHIS 2000).

The Medfly hosts on more than 200 different fruits, flowers, vegetables and nuts. It can be transported from one area to another in a few hours as an adult or as a larva in fruits or vegetables. All of Central America except for Mexico and Belize has a Medfly population. It has been trapped in the U.S. 21 times since 1929 (USDA APHIS 2000). Approximately 80 percent of the U.S. citrus production will be affected if the Medfly should become established.

In 1996-97, U.S. citrus production was 4.7 million tons for fresh use and 12.5 million tons for processed use, with a value of $2.4 billion (USDA NASS 1999). Mexico shipped more than 5,230 metric tons of oranges to the U.S. in 1997, valued at $3 million. The impact of Mexican citrus to U.S. price is small overall, although in certain markets during certain months Mexican citrus can influence the price. Other commodities such as mangos are not grown in the U.S. so domestic producers are affected only through substitution effects. U.S. fruits and

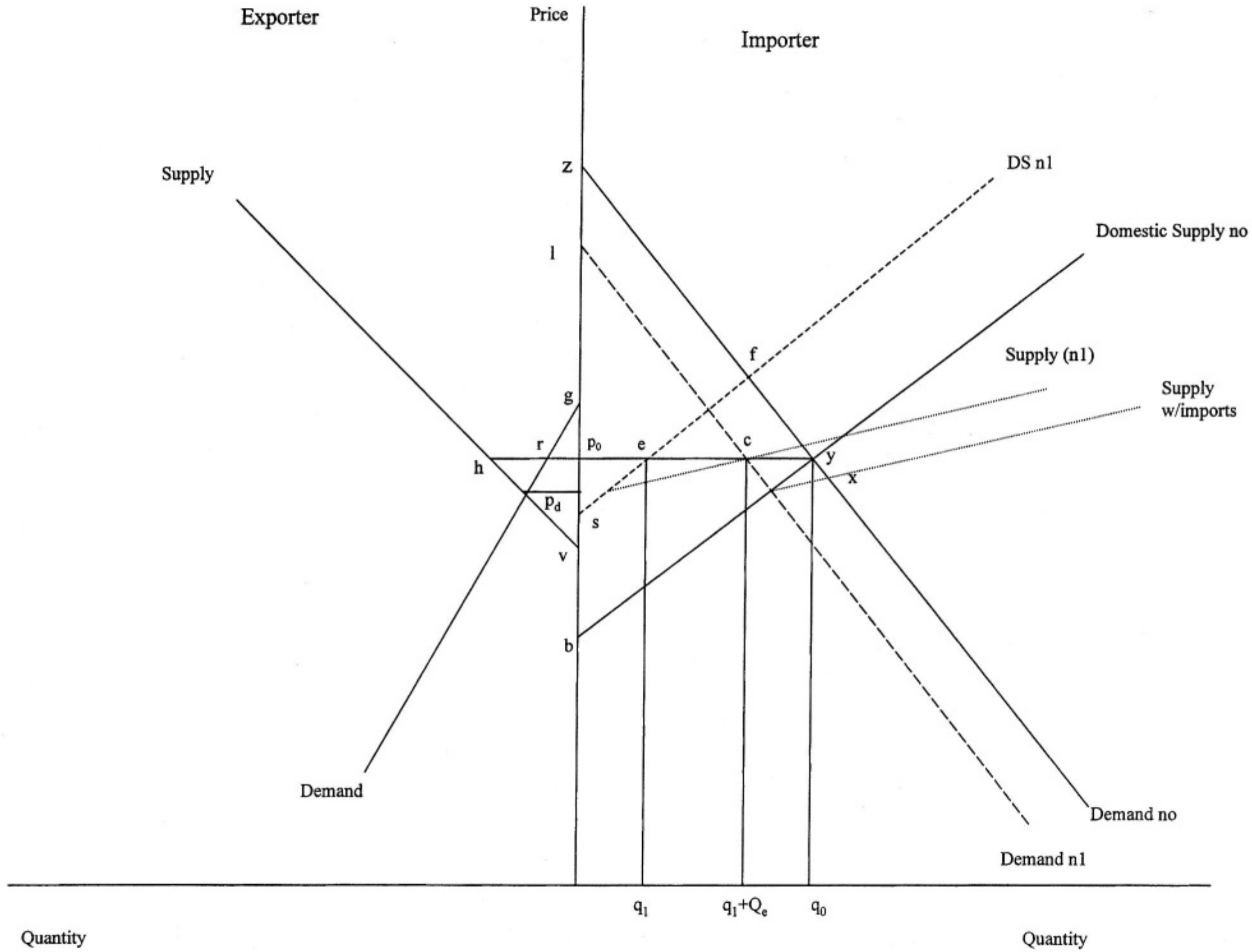

Figure 4. Exotic Pest and Demand Contraction

vegetables that would be impacted by establishment of one or both of the flies include apples, apricots, avocados, bell peppers, cherries, dates, figs, grapefruit, grapes, kiwis, lemons, tangerines, oranges, nectarines, peaches, pears, plums, and fresh tomatoes (Siebert 1990, Grimes 1992). Overall, commodities threatened by these insect pests would not be affected a great deal by increased import competition. During specific market windows, increased Mexican imports will decrease the price.

Estimated Costs of Establishment in the U.S.

If the Mexican Fruit Fly (MFF) is established and no control conducted, crop loss in the 12 most affected crops is estimated to be 20 percent of the yield (Grimes, 1992). Citrus growers would control MFF damage by using twelve or more applications of Malathion applied by air and ground per year. Even with these control measures, Grimes (1992) estimates that yields for these 12 crops will decrease 5 percent. This crop loss has an estimated value of $116.5 million (Grimes, 1992). The decrease in yield stems from both direct damage from MFF and from secondary pest outbreaks that may occur from the use of Malathion. The cost of the additional pesticide applications is estimated to be $500,000. To ship to other markets, U.S. growers will be required to follow export markets' quarantine protocols. If the quarantine cold treatment method is used, the potential trade costs is estimated to range from $28 to $43 million. Without including any of the costs from the environmental impact of using these additional pesticides, losses to consumers are more than $489 million each year. The overall net welfare change is estimated to be $346 million. In addition, urban home owners would be expected to use 2 million pounds of Malathion to maintain their gardens and fruit trees (Dowell and Krass, 1992).

Annual economic losses to the U.S. economy are expected to be $1.5 billion (Nichols 2001) if the Medfly is established in the U.S. The cost of pesticide materials and application in California would be approximately $27.2 million per year for the 1.7 million acres treated. The cost of Medfly establishment ranges from $155 to $341 million per year for California (Coppock and Kreith, 1999). If quarantine treatments such as methyl bromide fumigation were required by Asian export markets, the cost of the treatments and the product lost due to phytotoxicity is estimated to be $169 million. California output would be reduced $538 million, income would go down by $283 million, and 7,900 jobs in the state would be lost. People who had fruit trees or grew produce in their own garden would also suffer losses. In addition, the growing organic farming sector may find that the Medfly caused sufficient damage to render organic production practices unprofitable (Siebert 1990).

In another study, Medfly establishment in California was predicted to cost nearly $1.6 billion a year in crop loss and treatment (California Agriculture 1999). If foreign markets placed quarantines on California fruit, the State would lose 35,000 jobs and output would be reduced by $3.5 billion. If other U.S. states quarantined California fruit as well, job losses would be 132,000 with a $13.4 billion loss in economic activity (USDA APHIS 2000).

Environmental Effects of Control and Establishment

In addition to the cost and yield changes, there would be environmental impacts in the production regions where the MFF and Medfly are detected and established. Some control practices have minimal environmental effects. For example, mass trapping, fruit stripping, and sterile insect release have relatively minimal environmental impacts (USDA APHIS 1999a). These techniques however have not been effective at eradicating an exotic pest population, if that is an area's objective. Aerial Malathion bait and the fumigant soil treatments (chlorpyrifos, diazinon, and fenthion) are expected to have significant environmental impacts, particularly on biological resources. Ground application of Malathion has less impact but may be physically difficult due to a region's terrain and landuse patterns, and is more expensive. While these environmental effects are discussed in the context of an eradication program, they will also be present if individual growers use chemicals to control the fruit flies following establishment. Establishment will result in chemical applications each year rather than for a single eradication program period. Typical Medfly eradication programs use two to four aerial applications followed by sterile insect release (over a single growing season, a citrus grower could use 12 applications). In one eradication program in Northern California in 1980-1982, however, 30 applications were used. Malathion kills not only the Medfly and MFF but also beneficial insects. The disruption of biological control measures and secondary pest outbreaks occurred following the Californian eradication campaigns (Ehler and Endicott, 1984). Residues from Malathion bait sprays were found as far away as 12 miles in high winds. With lower wind speeds, residues were predicted to be 3.5 miles from the treatment area. Thus Malathion's effects may extend beyond the treatment area.

Malathion is not considered a high risk chemical for humans unless one eats contaminated vegetation. All the potential soil treatments though are considered moderately or severely toxic to humans and other mammals. All terrestrial and aquatic invertebrates will have significant population decreases if contact is made with Malathion and the fumigant soil treatments. Dahlsten, Garcia and Lorraine (1989) found the impact of Malathion includes total eradication of flies, caterpillars and wasps, decreased population of beneficial insects, and secondary pest outbreaks. Malathion use in the Lower Rio Grande Valley, for example, could eliminate 26.1 percent of the shrew population, 46 percent of the toads, 62 percent of the tree frogs and almost 100 percent of the terrestrial invertebrates that come in contact with the chemical.[12] Other species may be affected due to decreases in the food supply (USDA APHIS 1999a). Potential contamination of surface water and groundwater resources by pesticides could pose a hazard to both wildlife and human populations (USDA APHIS 1999a).

Exclusion

Because both the economic losses and the environmental impacts can be significant, the first goal of the U.S. government is to prevent an exotic pest from entering the U.S. borders. The U.S. has used historically quarantine protocols, import bans, and inspections to accomplish this goal.

Quarantine Protocols

Inspections for exotic pests are conducted at border crossings. With MFF and Medfly, however, imports can contain unhatched eggs or larvae; therefore, external inspection at the border may not be fully effective. Thus, unless a foreign country has no population of the exotic pest, it must follow some type of quarantine protocol which can raise costs and affect the quality of the product. These quarantine treatments must meet the Probit 9 criterion: guarantee that 99.9986 percent of the insects have been eliminated. This criterion is difficult to meet and

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[12] Terrestrial invertebrates include earthworms, dragonflies, grasshoppers, lacewings, flies, ants, honey bees and wasps.

research on acceptable treatments is ongoing. Methyl bromide fumigation is approved by APHIS for citrus, but can cause fruit losses up 60 percent which makes it an economically unacceptable treatment (Citrograph, 1992). The cost of methyl bromide treatment is $12 per ton of citrus (Carpenter, Gianessi, and Lynch 2000). It also is being regulated under the Clean Air Act and the Montreal Protocol due to its ozone-depleting characteristic.[13] Cold storage is an approved treatment but can cause chilling injury to citrus fruit. High temperature forced air treatment can also be used but costs about $120 per ton. Because of the cost and damaging aspects of many of the quarantine treatments, most growers advocate for pest-free status. With pest-free status, the quarantine treatment is waived or less stringent.

Inspections

Inspections are conducted on approximately 2 percent of products entering from a country known to harbor the exotic pests (Sills 2001, OTA 1993). These inspections increase crossing time and gridlock at the border for both produce shippers and travelers, which can increase air pollution. The fees and inspection costs can increase the price of imported goods. Although the APHIS standard is to inspect all perishable cargo within 3 hours of its arrival, with the increases in trade, it is difficult to conduct a quality inspection in this time frame. Complying with these regulations can be costly, inconvenient, and time-consuming. In fiscal year 2000, APHIS contributed $9 million and cooperators (states and other countries) contributed $114 million for agricultural quarantine inspections for both animals and plants. Users paid fees of $194.6 million for inspection services.

Even with these inspections and strict quarantine regulations, however, the Office of Technology Assessment (1993) determined that the existing U.S. policies designed to prevent the introduction of harmful invasive species were not maximizing the nation's welfare. It found that the U.S. approach is piecemeal, lacks adequate rigor and comprehensiveness, and is unable to keep pace with new pathways and pest introductions. Similarly, a GAO report (1997) suggested that the increasing number of travelers and trade had exceeded the inspection system used by USDA APHIS even though funding had been increased. Between 1988 and 1993, six new border crossings were established along the U.S. and Mexico border (GAO, 1997). In 1999, two new U.S. and Mexico border facilities were opened to conduct cargo, passenger, and pedestrian inspections. Since 1990, imports and exports have increased more than 30 percent, while passenger traffic has doubled in volume (USDA APHIS, 1999a). In 1998, USDA inspectors intercepted more than 52,000 items containing plant pests and diseases identified as economically significant to the U.S. agricultural sector (USDA APHIS 1999a), Along the Mexican border, inspections of passenger vehicles may occur for less than 0.1 percent during high-volume time, rather than for the USDA standard of 2 percent of vehicles. There is also limited coverage of the pedestrian crossings (GAO, 1997). Difficulties exist in determining the importance of these inspections. While interceptions are increasing, smuggling also appears to be higher. The cost of these inspections has become more fully the importers' responsibility through user fees.

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[13] When the regulations banning the production and importation of methyl bromide in the U.S. after January 1, 2001, were harmonized with the Montreal Protocol, quarantine uses were exempted from the phaseout schedule.

Border Cargo Release Program

Given the time lags at the border, the U.S. has worked with Mexico to develop new programs that ensure pest exclusion while at the same time facilitate trade. For example, APHIS has introduced the Border Cargo Release (BCR) program along the Mexican border to reduce the inspection of high-volume, non-host commodities such as tomatoes, squash and bell peppers. At Nogales, Arizona/Mexico, about 75 percent of the produce in 1995 was permitted into the U.S. through the BCR program (GAO, 1997). To qualify, no more than one exotic pest can be found on the commodities in a 1-year period, or no more than three harmful pests found over a 6-year period. This program benefits Mexican growers by decreasing the time to cross the border, and U.S. consumers obtain fresher, low-cost winter produce with only a small increase in risk. Concerns remain about smuggling high-risk commodities in these low-risk shipments.

Preclearance Programs

California has imposed an import ban several times over the years when Mexican-grown citrus and mangos were found to be infested with MFF (Citrograph 1986). Although quarantine protocols existed, concerns were raised that these had not been followed. In response, APHIS introduced pre-clearance programs in Mexico (and 27 other countries). The pre-clearance program, which is fully funded by the Mexican government and growers, has APHIS staff supervise the quarantine protocol at the origin of the commodity. APHIS staff is present when Sanidad Vegetal (the Mexican enforcement agency) cuts and inspects the fruit prior to fumigation. If the lots are infested, APHIS and Sanidad Vegetal reject them and the growers and/or shippers are saved the cost of fumigation and shipment to the border. As pests are kept further from the border area, U.S. growers benefit from decreased migration probabilities. The fumigation process itself is monitored by APHIS staff. Sanidad Vegetal ensures the shipments are sealed to prevent any co-mingling with non-treated fruit. Border inspectors can reinspect the shipment but pre-cleared shipments have a lower probability of being inspected and rejected (Sills 2001). Mexican growers benefit from the decreased time in crossing the border. Mexican shippers have found that pre-clearance certification is a "badge of approval" that can be used as a marketing tool to promote their products (Sills 2001).

Detection and Prevention

In addition to exclusion activities, the U.S. and Mexico attempt to detect infestations while pest numbers are still small and geographically concentrated enough to eliminate. Regions conduct systematic and periodic visual surveys and annual detection trapping programs. The U.S. spent $6.7 million on pest detection activities in 2000 (USDA APHIS 2001). While all 50 states can be impacted by the introduction and establishment of different species of fruit flies, seven eco-regions face the greatest threat for geographic, demographic, climatic and cropping reasons (USDA APHIS, 1999a). Detection efforts are therefore concentrated in these areas. They include the California Central Valley and Coastal Region, Southwestern Basin and Range, Lower Rio Grande Valley, Southeastern and Gulf Coastal Plain, Mississippi Delta, Florida, and the Marine Pacific Forest.

USDA and these areas cooperate through the National Exotic Fruit Fly Detection Program. The trapping programs seek to detect new infestations of fruit flies before the infected area exceeds one square mile in urban areas and 50 square miles in rural areas. USDA asks states to pay for half of the costs of these program. The federal government, California, Texas and

Mexico cooperate on an MFF detection and eradication program in northwest and northeast Mexico. Sanidad Vegetal, APHIS, and Mexican producers monitor and control MFF along the U.S.-Mexico border to reduce the risk of infestation in southern California and the Texas Rio Grande Valley. APHIS and Sanidad Vegetal also assist with surveillance, integrated pest control and regulatory activities to help maintain a pest-free region in Baja California, Baja California Sur, Sonora and Chihuahua. These programs include trapping activities, sterile fly releases, roadside inspections, and quarantine treatments (Curlett, 1993). In Baja California, for example, over 1,000 traps for MFF are used to monitor its population. These suppression programs keep the insect populations low or eradicated in the pest-free zones, which provides a barrier for the U.S. growers. The Mexican growers benefit from the pest-free zones, decreased pest control expenses and less stringent quarantine provisions to ship to the U.S.[14] In 1998, however, more than 50 MFFs were trapped in the Tijuana and Ensenada area of Baja California. Between 8 to 16 million sterile MFFs were released per week to combat this outbreak. (These sterile flies are reared in a Texas facility.) The U.S. and Mexico also cooperate to control MFF in the northeastern states of Tamaulipas and Nuevo Leon, including almost 1,000 traps. Matching funds are not mandated.

Lower Rio Grande Valley

In 1964, MFF eradication attempts were stopped and suppression activities consisting of MFF sterile fly releases became the objective in the Lower Rio Grande Valley. The MFF migrates from northern Mexico on infested fruit or on the insects flying into the Texas fruit groves. Pest populations usually do not reach detectable levels until the majority of the fruit has been harvested.[15] Once an MFF is found, the affected citrus is quarantined and the grower must follow a quarantine protocol, ship the remaining products to noncitrus producing states, or sell the remaining products to the processing market, which pays a 50 percent lower price (USDA-NASS 1999). USDA (52%), the Texas Department of Agriculture (33%) and the citrus industry (15%) share the cost of the sterile fly release program (Citrograph 1987).

Control (Eradication)

Once exotic pests are detected, control or eradication is attempted to keep the exotic pest from establishing and spreading to other U.S. production regions. Since 1975, a total of 15 eradication programs have been mounted against the Medfly in California, at a cost approaching $500 million (Coppock and Kreith, 1999). If the economic losses of establishment in the U.S. would have been $1.5 billion, the benefits of eradication have outweighed the cost of $500 million over the last 25 years. However, public opposition to these program exists that is unconnected to the cost. People are concerned about the aerial spraying of Malathion near their homes. Delays in starting the 1980-1982 eradication, in part due to California's unwillingness to spray chemical insecticides over cities, resulted in new emergency powers granted to the federal government to override state control (OTA, 1993). The eventual cost of this eradication project in the San Jose-Santa Clara area was at least $100 million. Yet the public seems unaware that the establishment of a permanent pest population will also result in increased chemical use to deal

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[14]No estimates of the production costs savings from the pest-free zone could be found.

[15]The MFF population naturally decreases during the hot summer months.

with economically destructive pests. If the city population lives sufficiently distant from the growing regions, perhaps it thinks the additional chemical use to control a permanently established pest population in agricultural fields will have less impact on it.

Other Cooperative Programs

Cooperative programs also exist to establish and maintain barrier areas such as pest-free zones and to decrease pest migration potential. One of the successful ongoing programs is MOSCAMED (Medfly in Spanish). The U.S. and Mexico combined efforts to eradicate the Medfly when it was first discovered in Mexico in 1977. The USDA built and maintained the sterile insect facilities in Mexico and in Guatemala. Mexico provided the staff personnel and the majority of the funding for the program to eradicate the fruit fly. The two countries eradicated the pest from Mexico in 1981 and established a Medfly barrier zone at the Mexican-Guatemalan border. The program administration was based on the bilateral management structure used in the U.S.-Mexican Screw Worm Eradication Program.[16] Each U.S. staff person had a Mexican counterpart. Subsidized by Mexico, Guatemala began eradication and barrier maintenance activities in 1977 as well. However, due to environmental concerns, the growth of the Guatemalan organic farming sector, and the negative impacts on honeybees, in 1998 the Guatemalan government ended all chemical control activities before the eradication goal was achieved (USDA APHIS 2000). Sterile insect releases continued to be used to maintain the pest barrier.

To prevent the spread of the Medfly into Mexico, MOSCAMED did and continues to support an extensive detection network (traps and checkpoints) and to produce and to release approximately 41 billion sterile Medflies annually in Mexico and Guatemala. 250 active outbreaks of the Medfly were detected in Southern Mexico in 1998 in these traps. A U.S. Science Review Panel determined that by 2005 a self-sustaining population of Medflies would exist in the U.S. if emergency action were not taken immediately. Such a Medfly population would result in a $1.5 billion of loss to the U.S. economy (Nichols 2001).

The USDA Commodity Credit Corporation gave the MOSCAMED program $23 million over 5 years to eradicate the Medfly from Guatemala. Spinosad, a new chemical, has been successful in the first years of field tests and does not kill bees. In addition, the program used Temperature Sensitive Lethal (TSL) flies, produced in Guatemala, which provided more efficient and effective results. One Guatemala region is slated to receive pest-free zone status. This Guatemala region then will be able to trade with the U.S. under less stringent quarantine protocol measures. Monitoring and surveillance activities continue, including trapping, fruit sampling and other detection activities. Quarantine checkpoints inspect cargo and travelers from South and Central America to prevent Medflies from entering Mexico and Belize (another Medfly-free country). DNA evidence suggests that one of California's most recent Medfly outbreaks arrived from Argentina, not Guatemala; therefore officials think that the Guatemala barrier is being restored. California has also begun using the sterile fruit flies produced in Guatemala as part of a Preventive Release Program (PRP). This California program releases sterile flies over the Los

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[16] This program has eradicated screw worm from Mexico through Panama where a barrier has been created at the Isthmus of Panama. Each country's share of the funding was determined by the benefits they would derive from screw worm eradication which is a function of their livestock numbers (Nichols 2001).

Angeles basin to mitigate the risk of a Medfly introduction. If a Medfly is found, this program allows APHIS and California to use more environmentally friendly and less expensive control activities to eradicate the pest.

Conclusions

The premise that phytosanitary regulations can protect domestic agriculture from exotic pests and from foreign producers' competition is too simplistic. Under certain conditions, these regulations may accomplish the producers' goals by excluding exotic pests and maintaining higher domestic prices. However, under other conditions, the import bans lead to lower returns (smaller and often a lower price market) for foreign producers, resulting in less control of their pest population. With a lower level of control, foreign pest populations can increase, and thus the probability of migration to the U.S. increases. The introduction of exotic pests can have devastating effects on U.S. agriculture. Economic losses are estimated to range from $350 million to $1.5 billion. These costs do not take into account environmental effects from additional pesticide applications and from the exotic pest’s ecosystem impacts. The fruit and vegetable producers affected by the exotic pests may lose more from the increased pest damage than from import competition. Similarly, consumers will gain less from imports (on average, prices are unlikely to fall significantly) than they will lose from pest damage to domestic producers. Thus, if an import ban would eliminate the possibility of exotic pest migration, it might maximize domestic welfare. However, if the possibility of exotic pest migration exists even if trade in the goods is prohibited, cooperative programs to decrease pest populations and improved quarantine treatments could contribute more to welfare enhancement. In the case of the Medfly, the U.S. contributes much less to the cooperative MOSCAMED program than the projected economic losses of Medfly establishment. Mexican growers benefit from the decreased production costs and the lower cost of quarantine protocol requirements. The MFF is native to Mexico and is unlikely to be eradicated from that entire country. Joint eradication efforts on the U.S.-Mexico border, however, benefit growers close to the border and provide a barrier that decreases the probability of an MFF migration further into the U.S. In Texas, suppression activities along the border and in the Rio Grande Valley have permitted Texas citrus growers to ship to their most profitable markets for most of the season. This program benefits consumers throughout the U.S. who enjoy lower citrus prices.

For many environmental issues, distributional impacts should be discussed. Why, for example, is using chemicals in Guatemala a better pest control activity than using chemical pest control in Texas? In the case of exotic species, the question may be whether to use the chemical control activities in one region or use them in all regions. If Guatemala or Mexico decided not to eradicate the exotic pest and ceased control activities, the Medfly probably would become established in the U.S.. Once established, individual growers could use chemical control activities on an annual basis. If the population level is not suppressed through these uncoordinated activities, the pest may continue its migration north. As it moves north, overall chemical use will increase as more regions attempt to control or eradicate the insect. Research continues to find more environmentally friendly chemical and non-chemical control methods to decrease the likelihood of public outcry which has affected both Guatemala’s and California’s ability to conduct eradication programs.

This paper explored a situation where two countries have, for the most part, cooperated to control two economically significant insect pests. There are other examples where cooperation has been less successful. For example, the U.S. imposed an import ban on avocados from Mexico in 1914. Although the APHIS scientific staff recommended a protocol to permit some Mexican avocado imports in 1973, the import ban was not lifted until 1995 (Roberts and Orden, 1997). Krissoff, Calvin and Gray (1997) outline problems with technical barriers in world apple markets. The World Trade Organization's Agreement on the Application of Sanitary and Phytosanitary Measures may assist in providing incentives and penalties to inspire more countries to behave in a cooperative manner.

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Conclusion

This book has focused on characterizing environmental problems and solutions along the U.S.-Mexican border. One of its main contributions has been to substantially expand the range of environmental issues considered (*e.g.,* maritime border resources, transboundary air pollution, energy and trade/transportation corridors) along the lines suggested by authors such as Kiy and Wirth (1998). Perhaps the most interesting feature of these issues is how new most of them are from the perspective of serious academic interest and how quickly they are evolving.

Water is the key exception.[1] Border water issues now represent a mature topic and will continue to be a major research focus in light of water quantity and quality problems along the border. This was underscored by the September 2001 meeting of the Mexican and U.S. presidents (hereafter "Presidential meeting") that produced a joint agreement on the importance of more effective watershed management (White House, 2001). Newer aspects of water issues keep surfacing and there is much interest in linking water quality and quantity management and groundwater management. Environmental media can be helpful in drawing different messages and directions for further action and research in both site specific and border-wide analysis for air, land and water.

The key themes of this volume are trans-border cooperation, border environmental problems, and solutions that involve looking at sources near and far from the border that influence the border environment. Scarce environmental resources at the border can spark conflict that may produce either a short-lived outcome, where the environment degrades permanently, or a long term resource solution involving cooperation on specific goals for border environmental protection. Cooperation is the only way a shared environment can be sustained. The varied approaches to articulating diverse examples, and new strategies to convey the transboundary cooperation and solutions to environmental problems themes throughout the volume demonstrate that there are many ways to address the border's environmental issues. The interdisciplinary cooperation that exists in these papers can result in mutual awareness and exchange of ideas that in turn can lead to analyses incorporating broader perspectives or different disciplines working in tandem.

The border is far from the national capitals of both countries and several authors emphasize that the border region has to gain substantial local political leverage in order to garner resources needed (financial and other) to solve environmental problems. The Commissioner for Border Affairs, Ernesto Ruffo Appel (hereafter, "Commissioner"), agrees with the view that solutions to border problems should be defined at the border and not the center of the country, as has been done for so long (Treat and Kourous, 2001). However the federal role is still vital (Kiy and Wirth, 1998). Formal binational agreements are needed that constitute foreign policy over resource management in the border regions. These agreements are stable references for binational interactions that override changes in governing administrations in both countries and provide consistent follow-through. Bi-national leadership is key and relies on commitments and reciprocity at every level. The federal budget for public infrastructure investment needs to keep pace with population growth and the public good regarding environmental quality in air, water and land. At the national level, the environmental budget pressures may speed the manner in which decentralized authority can act on environmental issues (Kiy and Wirth, 1998). The new

[1] The other main exception, which is not considered in this volume, is the Interamerican Tuna Commission. It is an active multinational organization established in 1949 to which both Mexico and the United Stated belong that has long regulated tuna fishing in the Pacific.

federal administrations in both countries appear poised to foster this decentralized structure. The Commissioner suggests a possible source of financing might be a new, binational municipal and state bond fund created by all ten U.S. and Mexican border states with possible management by the NADBank (Treat and Kourous, 2001).

There is potential to alleviate serious environmental effects at the border if the border community achieves local control over its environment while accepting financial resources from the greater geographic area. However, instead of the border community taking the primary role in environmental management, there has been a history of outside management. The latest example of this takes the form of an agency to be called the California Mexico Border Infrastructure Financing Authority. It was proposed through California Senate Bill 865 which make decisions on infrastructure projects, such as the BECC does.

The impact of border production that most residents in North America experience is lower prices for consumer goods. The adverse environmental effects occurring, due to the producing of these goods, is not readily visible to most consumers. From an economist's perspective the questions are: how to internalize the production externalities, and who should bear the costs. Standard welfare and tax programs have ignored the concentration of environmental effects at the border. U.S. border areas often get larger welfare payments because they are poor relative to the rest of the United States, while in Mexico tax payments flow toward the interior because the border area is relatively more prosperous.

Exploring the quantity of funds and how they are transferred can be made to account for the size of the environmental effects at the border. This would seem to be a useful reference when comparing with the funding that NAFTA institutions for border environmental projects receive. While BECC and NADBank's existence and their funds are seen as a recognition of the environmental impacts at the border, it is not clear that the financial allotments for these institutions, and the environmental projects they support, are correlated with the size of the environmental impacts.

The urban border is environmentally, economically, culturally and socially integrated and seamless across political boundaries, and environmental policies can be most effective taking this integration into account. Tijuana and San Diego are two border cities effectively thought of as the first world city that is setting the wave of the future (Economist, 1998). The U.S.-Mexico border is an area of enormous economic and demographic activity and growth, one of the most dynamic border regions in the world (Navins, 2000). The large concentration of people living in the region would not be there if the border did not exist (Peach and Williams, 2000). What appears to be lacking at the urban level is land use planning to avoid the urban sprawl that continues to constrain land, air, water, and biodiversity resources (Herzog, 2000). Labor, immigration, production and environmental conditions all are central considerations for this area to grapple with. Doing so will help other settings with similar conditions. Cities are replacing nations as the basic unit of economic competition, much as they were in the Middle Ages. There is more North-South integration of border cities in the two countries than East-West integration amongst border cities in the same country. The Commissioner emphasizes there is no direct communication between the east and west along the border; there is not even a direct flight between *Tijuana* and *Matamoros* or *Reynosa* (Treat and Kourous, 2001). Large urban clusters on the border are competing for skilled workers, investment capital and a share of global trade. If NAFTA had happened earlier it might have led to spreading industrial production further into Mexico. However, the presence of maquiladoras since the 1960's and the agglomeration effect of having a critical mass of players who share in the economies of scale (in terms of each reducing costs jointly from sharing established transportation and utility connections right at the border) concentrates businesses there even though costs are rising (Krugman and Hanson, 1993). The optimal strategy would be to include environmental infrastructure and amenities into the mix that investment companies make in order to do business at the border. Access to the final markets from the border is relatively low cost. Wage differentials between the border and the interior are not high enough to offset the low transportation costs and higher productivity levels at the border. There is a difference between long run and short run decision making on the part of industries maximizing profits. Wages at the border will rise over time, and keeping costs down in other ways delays the date of leaving the area for better cost structure. In general, the border has experienced economic growth, not commensurate economic development (Ganster *et al.,* 2000). The Commissioner is committed to achieving economic development through improving the quality of employment opportunities and livelihood for border residents (Treat and Kourous, 2001).

Summary of Findings by Authors

Spalding identifies environmental problems as well as conducts an assessment of the range of institutions aimed at border environmental issues. Key factors for expanding the financing of environmental improvement at the border are recognizing that the production and trade arrangements benefit all consumers, and the tax base at the border is too small for current needs, much less for projected growth. Therefore, Spalding suggests that national and binational policies that channel funds to finance border environmental infrastructure are the most viable. Spalding's suggestion is echoed by what governors of Mexico's border states, who would like to require *maquiladora* operators to contribute to the costs of providing some infrastructure, such as roads, water and sewage treatment and solid waste disposal (Treat and Kourous, 2001). While some maquiladoras make annual donations (*e.g.,* $15 per employee per year in Ciudad Juarez) to local governments to help them pay for infrastructure projects, many critics say those contributions are small compared to *maquiladora's* profits. The Commissioner warns that border economic growth is coming to a halt, stalled by the myriad of infrastructure problems that have accompanied the region's explosive growth and rapid industrialization. Spalding does address native groups in terms of their political rights, and attempts to recognize their role in managing the environment. He also suggests ways to change the border environmental institutions from reactive to proactive entities through broader planning and regulatory structure. The transparency of the decision making process through public hearings and meetings has been valuable in involving the border community in a tangible way. A July 2001 public meeting of a BECC/NADBank project in Tijuana for the rehabilitation of sewage lines throughout Tijuana drew strong public participation by a broad spectrum of Tijuana residents (Saldana, 2001).

Carter and Ortolano analyze border institutions created under NAFTA for the environment. The institutional design of each of these, in terms of the political economic framework, calls into question whether there are adequate checks and balances to prevent over-utilization of depletable financial and environmental resources. As more politicians support expanding the geographic and subject scope of BECC and NADBank, it is imperative to sustain the financial and technical resources to carry out even their initial mandate. The current allocation by NADBank to low-income communities of grant funding in greater measure than loans, is likely to continue given the requirements for repayment in terms of interest rate and payback period. Some factions argue that NADBank, rather than seeking new areas for lending, should find a way to lower its rates (Ellingwood, 2001). The sewer and water systems projects produce unreliable returns in communities that are only learning how to set rates and collect fees for public works utilities. Currently, President Fox and the Commissioner have suggested that NADBank's mandate be expanded to permit involvement in transportation, energy, and communications in order to address what Mexico needs first in terms of economic development as well as in environmental projects (Mandel, 2001). The Commissioner hopes NADBank funds could be supplemented by other entities to build the highways, railroads, airports, and seaports needed in Mexico to sustain economic growth in an expanded area of 180 miles on either side of the border instead of the current 60 miles (Treat and Kourous, 2001). Mexican President, Vicente Fox sees the need to expand NADBank's role in addressing development similar to what the InterAmerican Development Bank and World Bank have done to spark foreign direct investment (Schrader, 2001). The intent is to increase employment opportunities in Mexico so that Mexicans stay in Mexico, thereby reducing immigration stresses. Expanding the NADBank's mission beyond border pollution projects means the topic of consistent financing by the U.S. and Mexican governments must be addressed. In the Presidential meeting it was agreed that immediate measures were needed to strengthen the performance of the NADBank and BECC. Such measures would include convening a binational working group to consult with national legislatures, border states, communities, and other stakeholders in order to develop joint recommendations for changes at the end of October 2001 (White House, 2001).

Sanchez reviews the pressure of population and industrial production on environmental resources on the border, and investigates the national government attempts and constraints to deal with environmental problems. Prior to NAFTA the intent appeared to try and spread maquiladora industrial production further into Mexico. Movement to the interior has not happened, further exacerbating conditions at the border. Border residents have been involved in addressing the environmental issues partly through the willingness of the bi-national institutions to provide information access to the public.

Gianos provides geographic representation of the communities along the border, including *colonias* and "twin cities" that contribute to the designation of the U.S.-Mexico boundary zone as the most urbanized border region in the world (Herzog, 1986). These metropolitan areas, although separated by an international boundary, are socially, economically, and physically integrated in that they share hydrology, air-flows, topography, production and consumption. Income levels, education, population, ethnicity, access to water and sewage treatment, and infrastructure projects due to NAFTA environmental institutions are depicted with Geographic Information System (GIS) technology to illustrate relationships along the border. These are challenges of maintaining education levels in order to attract and retain businesses that depend on a skilled labor force. The population growth at the border, and the trade growth on a large geographic scale that is supplied by the border, will place significant stress on water and energy resources, transportation infrastructure, essential social services and environmental quality for health and quality of life (Ganster, Sweedler, Clement, 2000).

Velez-Ibanez *et al.* provide a detailed account of several New Mexico *colonias* with reference to the general trend of the way in which *colonias* fit into the continuing impact on the border environment. This is expressed in terms of a population with few financial resources attracted by the economic opportunities at the border. Most environmental problems within the border region arise from rapid population growth and the lack of public financial resources to meet expanding infrastructure needs in the *colonias* and cities along the border (Ganster *et al.,* 2000). Recommendations for binational capacity building, financial support, and economic development driven by the interest in quality of life is significant in addressing what Velez-Ibanez *et al.* characterize about border residents.

Martin illustrates how both sides of the border have become a pole of attraction, as human migration has resulted in both bi-national conflict and cooperation in terms of industrial and agricultural production. It is imperative to see the connection of population growth and migration with economic and trade policies on stressed natural resources. The continued disparity in wages and employment between the interior of Mexico and the border region, as well as the U.S., means that population movement towards the border is not likely to subside soon. The Commissioner envisions enhancing labor opportunities with worker training that improves productivity, competitiveness, and higher levels of personal development, in order to move jobs from in the maquiladora assembly industry to a more advanced manufacturing sector. This is in connection with the new Mexican administration's efforts on the border (Treat and Kourous, 2001). There is a wide gap between goals and actions in terms of resolving immigration and labor issues, and perhaps, as a result of the Presidential meeting, the gap may be addressed. Demand for labor has been the focus instead of supply of amenities for labor in terms of quality of life (housing and education). These two topics may be viewed as a loss of sovereignty on the national level (Cornelius, Martin, Hollifield, 1994). While some attempts at border enforcement address immediate local needs, it is not a solution to the larger phenomenon of illegal entry by migration that Martin characterizes. Martin's summary of the maquiladoras indicates the significant role Mexico plays in providing the largest share of employment opportunities leading to the strong migration from interior Mexico to the border and immigration into the U.S.

Frisvold and Caswell provide a comprehensive history of water problems and institutions that cover quantity and quality issues. Their game theoretic analysis of binational decisions for environmental projects and finance illustrate that the equal cost sharing requirement is not efficient, and that an effort to link quantity and quality of water into environmental projects would be helpful to address local income problems. The long term viability of projects rests on improved financial arrangements that channel money from national and international funds to the border.

Levesque and Ingram depict the border as a formidable challenge geographically, legally and politically in terms of channeling local initiative into leverage that gains recognition in an area where the national boundary may limit local political clout. In Ambos Nogales, water is the key resource in terms of quantity and quality issues regarding surface and groundwater. Scarcity of water is a reality amidst a growing population. The Ambos Nogales study examines a region in which there is potential for both conflict and cooperation over transnational problems. These problems include inadequate and inequitable water supply, surface and groundwater pollution, cross-border water transport of pollutants, flash flooding and riparian habitat preservation. The study demonstrates that adopting a binational approach to the management of border area problems offers the potential for overcoming the major divides introduced by political boundaries and the conflicts they may engender.

Fernandez presents an example of the analyses that are needed to investigate the trade policy connections as incentives to address border pollution issues. In this particular applied case, the ability to internalize wastewater emissions into the production of cotton, a tradable commodity, provides a financial incentive to reclaim wastewater emissions and avoid public health problems correlated with wastewater emissions. Data from Ciudad Juarez and El Paso provides the textile and cotton production relationship between the two urban areas, the derived demand for reclaimed wastewater due to scarce freshwater resources, and the public health damages. The data are quantifiable and reinforce the binational strategies for wastewater treatment in this shared watershed. Elimination of trade barriers, such as the quota on imported cotton to the U.S., provides incentives for Mexico to reclaim wastewater to earn revenues and avoid public health problems. The cooperative solution of wastewater treatment projects approved by the binational BECC is optimal versus unilateral action.

Michel emphasizes the need to address hydrological systems from a proactive, preventative approach to environmental stresses rather than an incremental reactionary approach, as the latter does not account for cumulative impacts over time and space with a forecasting ability to avoid resource degradation. Planning implies foresight to predict optimal environmental management in the face of cumulative impacts and growth. Various aspects of the Tijuana-San Diego watershed illustrate how environmental stresses on water result from a resource perspective, and how other resources from outside the watershed can indefinitely supplement local resource scarcity.

Booker and Ward show the possibilities for protecting instream flows for habitat in the Upper Rio Grande. These are based on efficient allocation of water quantity that takes into account values in competing uses. Through their dynamic quantitative model that integrates hydrology, economics and institutions critical for solving transboundary water problems, they demonstrate that protecting instream flows can be complementary to urban water interests, given the spatial orientation of the downstream municipality benefiting from ample instream flows. With the increasing population at the border can come an increase in the number of people who value the area's natural attributes, which in turn creates an increased demand for investment in amenities and environmental protection. Market based water transfers between irrigation and urban use can be instrumental for instream flow protection of the Rio Grande Silvery Minnow.

Action on border environmental problems has been initiated at other than the national level. It is the local border citizens immersed in the shared environment with their bi-national neighbors that have stimulated cooperation. Carlos Rincon illustrates through the Paso del Norte Air Management Region, that grassroots binational activity is alive and capable of shaping national and binational activity to the point of gaining the political leverage that is needed border-wide to solve many environmental problems. The fact that U.S.-Mexico environmental agreements stem from NAFTA requires public participation in border environmental projects. This stems from the recognition the central role the local border population should play in solving the border environmental problems. The border cities have developed clear binational relationships due to asymmetries and complementarities in endowments of natural and financial resources that lead to linkages and obstacles in establishing economic, social and political ties across an international boundary (Clement, 2001). In this manner, the scale of solving border problems may best be regional like the Paso del Norte Air Management Region. The neighboring border cities recognize the economies of scale, externalities and transactions costs that are involved in legal and economic arrangements to implement environmental management. The Paso del Norte Air Management Region constitutes a clear example of how civil society in the U.S.-Mexico border region has shaped the design of environmental policies in the region. Such policies distinguish the binational region from the rest of the two countries (Verduzco Chavez, 2001).

Halvey presents a useful comparison of the ports of entry in terms of problems with vehicle flow and correlated air pollution. The predicted improvements in air quality from implementing suggested policies are significant, based on reducing vehicle hours for trucks and other vehicles at the ports of entry. The strategies to ameliorate the bottlenecks require binational cooperation over the enforcement of laws pertaining to flows of products, people, services and pollution. The workshops sponsored by the Western Governors Association, the source of generating the alternative solutions, offer the important participation of border residents to help in solving the problems. NAFTA requires enhanced boundary enforcement not simply to create a border region of law and order to facilitate capital accumulation, but also to stymie the anticipated increase in unauthorized immigration generated by the liberalization of the Mexican economy (Navins, 2000). It is simultaneous liberalization and militarization for security and opportunity.

Sciara assesses the impact of NAFTA on the trade transportation corridor in terms of traffic related to production flows and correlation with air pollution, given diesel use in truck and rail traffic. Agreements related to "access distance" for trucks entering each country have yet to promote the adoption of vehicle technology that reduces threats to air quality. The NAFTA Highway has seen the volume of truck traffic increase by 25% a year. The lack of a North American transportation plan leads to the current protectionist battles between truckers and road safety regulators. The need for policy to control vehicle flow, reduce emissions and delays grows as the vehicle fleet volumes grow with the increase in industrialization and trade. During the Presidential meeting, President Bush emphasized his interest in processing legislation to allow Mexican truck access to distances further in the U.S. In turn, incentives may be created to have more efficient vehicles on the road with less damage to air quality.

Pasqualetti describes the energy alternatives for the border that include binational generation, transmission and distribution. By diversifying the range of supplies for stationary and mobile uses of energy, as well as addressing demand side management through energy conservation, the horizon for energy can be long term. The Presidential meeting between the Mexican and U.S. presidents, encouraged more foreign direct investment in energy including oil, natural gas and electricity transmission. These markets would represent a shift from state owned operations that now dominate the scene to more private participation in Mexico for binational uses. Service contracts also enable more private participation on a binational basis. Public and private partnerships for solving environmental problems need to be more prevalent on the border and should be considered a viable form of financing problems generated there. The September 2001 meeting also resulted in renewing a 1996 agreement to cooperate and share information on the development of energy technology and renewable energy resources.

Varady *et al.* identify hazardous materials flows, and policies to deal with these materials through government and private sector actions. Their assessment of the initial signs from the new national administrations in the U.S. and Mexico suggest there is more work to be done to solve the growing problem. Limitations in addressing the problem include lack of systematic monitoring and data sharing to obtain up-to-date statistics that could serve as a basis for promoting prevention and waste reduction. For businesses involved in production of any product along the border, the opportunity to play a positive leadership role in reducing environmental impacts can be driven by a financial goal to achieve economic efficiency in production without waste of resources used in production and location of facilities.

Minnich bases his findings on comparative time series analysis of forest management. He concludes that the Mexican strategy of preventing catastrophic blazes rather than suppressing them proves to be sound as policy for the environmental and financial resources engaged. This is a message that Dale Bosworth, chief of the U.S. Forest Service is warming up to based on the western U.S.'s current wildfire situation (Kenworthy, 2001). Fire is a part of the natural western landscape. Less intense fires that occur naturally can be less harmful if the forests are not pervaded with smaller trees and underbrush and under constant fire suppression. Seasonal fires that continue to plague western North America can be alleviated by sensible forest maintenance and allowance for cyclical fire occurrences.

Spalding demonstrates that migratory maritime species benefit from international cooperation through agreements that cover their international habitat. The threats to whales are numerous, and Spalding offers a review of the Magdelena Bay case that addresses several of the threats to whales, such as loss of habitat and tourism. Examples from the larger geographic domain of the whales suggest positive impacts on maintaining marine mammals in the Pacific through shared cooperation on data collection, maintenance, and attention towards those activities that require more controls.

Dutton *et al.* evaluate the time trend of the sea turtle populations in the Mexico-U.S. marine waters of the Pacific and Gulf of Mexico in order to assess the effectiveness of binational efforts to deal with the species through marine and land-based policies that influence their survival. Through existing arrangements to share monitoring efforts, data, and conservation measures, there has been a measurable increase in the nesting populations on land and the turtles in the marine setting in the Pacific and Gulf of Mexico. Clearly, the binational level of interaction is significant for the population of migratory leatherback and Kemp's Ridley sea turtles.

Lynch presents a critical assessment of import bans, subsidies for foreign pest control, quarantines, inspections and prevention for controlling pests generated by agricultural trade, such as the medfly and fruitfly. Cooperation between the U.S. and Mexico through joint eradication is vital for the effectiveness of this control. Even with import bans and quarantine regulations to inhibit direct migration on host commodities, exotic pests can act like trans-boundary pollution. The viability of implementing such strategies under NAFTA must reckon with different welfare effects that move in opposite directions. Import bans as an example of phytosanitary regulations may lead to lower returns for foreign producers resulting in less control of their pest populations with increased probability of border migration. It is not enough to deal with pest control domestically; it is necessary to consider controls and welfare effects in the countries of both origin and destination for the pest. The level of pest and environmental effects depend on the level of controls, and these controls affect the price and production of the commodity in the importing and exporting country. Strategies other than import bans should be investigated when the pests migrate in ways other than just on agricultural imports, such as by invading water, air, and soil resources through people, aircraft, buses, ships, trains, trucks, automobiles, airflow and water flow. Habitat for native species will be affected with significant economic losses to land uses and resources. It is estimated that 40% of threatened and endangered native species are in peril nationally (U.S. and Mexico, separately) from invasive species.

Further Directions

We believe that there are several future directions that could be researched profitably with respect to border environmental issues. Some of these are briefly noted in this volume's papers while others arose during discussions of those papers at the conference with the authors. One area on which there was widespread agreement was the important need to address linkages between the environment and human and environmental health at the border. Rather than simply viewing health from the perspective of limits on pollutants from national environmental laws for regulating air, land and water, efforts to explore preventative measures for human and environmental health are needed in terms of evaluating the feasibility from cultural, economic, and political angles. The bi-national cooperation discussed in the volume that is vital for controlling invasive insect species is as vital for controlling invasive diseases. The presence of the border office Pan American Health Organization, as well as the National Institute of Health's Centers at University of Arizona, and most recently at University of California, San Diego to coordinate efforts with Mexican health professionals implies there are valuable resources to devote towards border health issues.

Another theme that repeatedly came up was the need for more research in the area of public finance that addresses fiscal federalism and taxation that would channel funding from consumers who benefit from border economic production, to programs that address border environmental externalities from the production and population involved. Industrial taxes and municipal funds should be addressed.

More research is also needed to examine how the management of binational environmental infrastructure is actually working. For example, it would be insightful to examine the management of the water treatment facilities that have been implemented under the BECC and NADBank. The criteria that led to the project's approval might be a basis for checking how the project has followed through. Additionally, while a number of the volume's papers touch on different scales of cooperation (*i.e.,* local, state, national and international) there is a clear need for theoretical and empirical papers whose major focus is on sorting out the question of why cooperation evolved at one or all scales. Such work should help identify what factors are important for encouraging or discouraging cooperation at various levels.

There was substantial interest in using geographic information systems (GIS) to help address a wide variety of environmental issues. Those with the most experience in using GIS, however, noted that GIS only works well if data is gathered and implemented in a standardized, timely fashion. This is true for policy and management uses as well as research. To best exploit the promise of GIS, attention needs to be paid to differences in the spatial and time scale of the data from different fields (water quality, demography and air quality). Much work is also needed in establishing routine procedures for data collection and sharing.

True progress in addressing environmental management at this border, and other borders worldwide, rests in focusing on problem-driven, interdisciplinary research that recognizes the best way to build capacity for analysis is to have coherent systems of research planning, monitoring, data collection, and consistent financial support. An imperative is to have standardized methods for data and agreements to share this information with bi-national researchers. The Border Environmental Indicators Program jointly established by SEMARNAP and EPA in 1997 offers a useful list of indicators to monitor through data collection along the border over time. The indicators cover air quality, water quality, water quantity, land quality, transportation, solid waste, hazardous waste, emergency response, environmental health, biodiversity, natural disasters and economic development (U.S. EPA, 1998). GIS approaches represent one good way to combine all of this data in a coherent manner. However, unless there is a financial and institutional commitment to house this data and cooperative research, one-time efforts may quickly dissipate. There are three options for making long-term contributions:

1. Set up a new group that would capitalize on existing efforts,
2. Formally establish agreement with U.S. and Mexican counterparts on data collection and sharing and perhaps house the effort in BECC or NADBank, and
3. Create a consortium of cooperating universities such as the Southwest Center for Environmental Research and Policy (SCERP). The consortium could be the first one with

a formal mandate to collect and synthesize data through a contract from policymakers, such as BECC or NADBank who could benefit from the research generated through the consortium.

Another topic for further research is ecotourism. The papers in this volume on whales and turtles touched on that issue, but even a cursory examination of the large tourist industry in San Diego and Baja suggests a much larger context.

Another vital area to consider for further research is industrial ecology. The key issue here seems to be how to get the northern Mexico *maquiladoras* to effectively transfer their technical expertise with respect to pollution there to other private firms and government entities. This is probably the most critical with respect to investments that are planned in utilities and other environmental infrastructure.

Pasqualetti provided a useful paper on energy supply and demand at the border. This work, and the growing nature of electricity problems in the western United States suggest that more research is needed to determine the best management strategies for joint reliability of the system of merging electricity grids and natural gas and other energy resource flows. Likewise, a study looking at an integrated bi-national transportation network would be useful. Such a study should focus not only on main roads and border crossing, but also on the system of feeder roads, air, rail, and port connections.

Solid waste collection, treatment, and disposal continue to be formidable problems at the border in terms of residential, commercial, and industrial activities. How best to handle and or reduce this waste should be a topic of further research. How to best coordinate emergency response to hazardous waste, oil spill, and fires could also be profitably studied.

The Mexico-U.S. border will benefit from continued focus to improve environmental management on various topics and other borders around the world will benefit from transferable concepts and strategies generated from the focus.

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