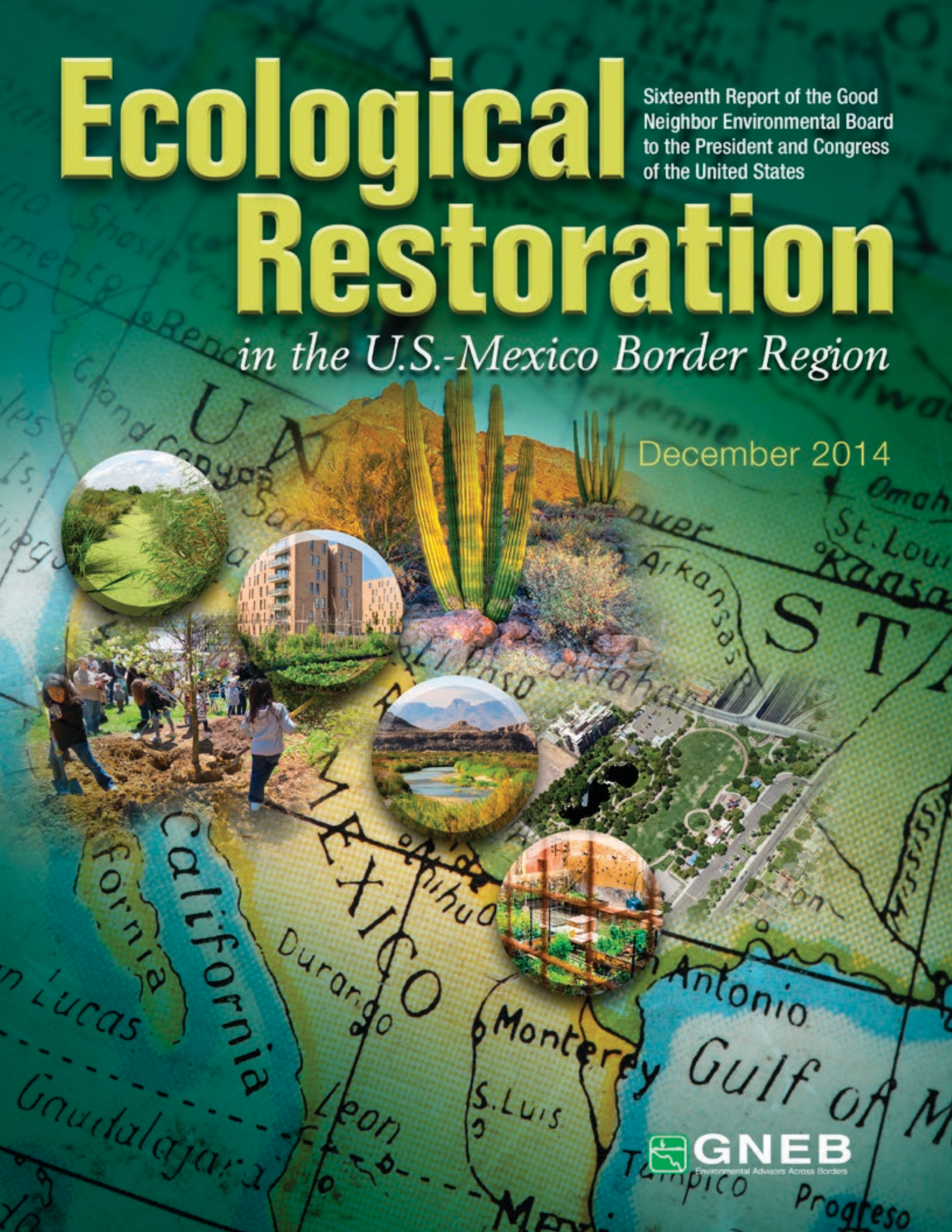
Ecological Restoration

in the U.S.-Mexico Border Region

Sixteenth Report of the Good Neighbor Environmental Board to the President and Congress of the United States

December 2014

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About *the* Board

The Good Neighbor Environmental Board was created in 1992 by the Enterprise for the Americas Initiative Act, Public Law 102-532. The purpose of the Board is to "advise the President and the Congress on the need for implementation of environmental and infrastructure projects (including projects that affect agriculture, rural development, and human nutrition) within the states of the United States contiguous to Mexico in order to improve the quality of life of persons residing on the United States side of the border."

The Board is charged with submitting an annual report to the President and the Congress. Management responsibilities for the Board were delegated to the Administrator of the U.S. Environmental Protection Agency by Executive Order 12916 on May 13, 1994.

The Board does not carry out border-region activities of its own, nor does it have a budget to fund border projects. Rather, its unique role is to serve as a nonpartisan advisor to the President and the Congress and recommend how the federal government can most effectively work with its many partners to improve conditions along the U.S.-Mexico border.

The Board operates under the provisions of the Federal Advisory Committee Act and membership on the Board is extremely diverse. By statute, the Board is composed of:

(**1**) "representatives from the United States Government, including a representative from the Department of Agriculture and representatives from other appropriate agencies;

(**2**) representatives from the governments of the states of Arizona, California, New Mexico, and Texas; and

(**3**) representatives from private organizations, including community development, academic, health, environmental, and other nongovernmental entities with experience on environmental and infrastructure problems along the southwest border."

The Board also includes representatives from Tribal governments with lands in the border region.

The recommendations in this report do not necessarily reflect the official positions of the federal departments and agencies that are represented on the Board, nor does the mention of trade names, commercial products, or private companies constitute endorsement.

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Transmittal Letter to *the* President

From the Good Neighbor Environmental Board

President Barack Obama
Vice President Joseph Biden
Speaker John Boehner

On behalf of the Good Neighbor Environmental Board, your independent advisory committee on environment and infrastructure along the U.S. border with Mexico, I am submitting to you our 16th report, *Ecological Restoration in the U.S.-Mexico Border Region.*

In collaboration with your Council on Environmental Quality, the Board selected ecological restoration as an umbrella concept under which to examine and evaluate the effectiveness of the U.S. federal government in managing multiple aspects of natural resource and environmental degradation. These areas include monocultures of invasive species; eroded soils; channelized streams; over-accumulation of woody material that provides fuel for fires, mine pits and spoil piles, excessive water withdrawals; degraded surface water quality; and disruption of landscape connectivity. Degraded natural systems lose some or all of their capacity for repair, which leads to a cascade of further degradation, particularly within the arid borderlands. In addition to large-scale land use practices such as agriculture, urbanization, energy and water infrastructure development, and international border commerce and security, the rapid population growth of the region and current environmental conditions have outstripped even the excellent binational, U.S. federal, Tribal, state and local efforts directed at resolving them.

Though the Board has discussed these issues in prior reports, in this report we focus on efforts to address them through ecological restoration. Restoration encompasses a range of activities, beginning with the cessation of activities that are causing natural resource degradation and continuing through to the monitoring of completed restoration treatments. Although U.S. federal land managers are carrying out individual actions, they would benefit from a more comprehensive approach to ecological restoration throughout the border region that incorporates new, pragmatic initiatives that improve coordination among U.S. agencies as well as active engagement among local, state, Tribal and national collaborators on both sides of the international border.

The Board, in the development of this report, and following a tradition that has been maintained since its inception, has been driven by its desire to work through consensus in constructing all of its recommendations. We hope that this report is useful to you and other U.S. government officials as we continue to think about how we can best achieve a healthier environment and a better quality of life for all of our citizens. We appreciate the opportunity to serve you and provide these recommendations, and we respectfully request a response.

Very truly yours,

Diane Austin, Chair
Good Neighbor Environmental Board

Ecological Restoration in the U.S.-Mexico Border Region Executive Summary

The U.S.-Mexico border extends approximately 1,954 miles (3,145 kilometers) from California to Texas. Within this vast landscape, marked by a primarily arid climate, lies a variety of ecosystems, critical habitats and treasured landscapes ranging from deserts and mountains to natural waterways such as rivers, streams and creeks. These features and the plant and animal species associated with them exist on both sides of the international border.

Large-scale land use practices—past and present—have created resource challenges within borderland ecosystems. These practices include the introduction and spread of invasive plant and animal species, energy development and mineral extraction, rapid and extensive human population growth and urbanization, subsidized agriculture, extensive water infrastructure development, and international border commerce and security. They have resulted in a wide range of degraded resource conditions, including monocultures of invasive species; over accumulation of woody material that provides fuel for fires; mine pits and spoil piles; drained wetlands; altered river flows; overabundant herbivores lacking pressure from predators; and disconnected wildlife movement corridors. At the same time, changing climatic conditions such as long-term drought have added to the challenges facing the region.

Well-functioning ecosystems provide a wide range of services, including food, fiber, regulation of clean water and climate stability, physical protection from

extreme events, including flooding and drought, pest mitigation, recreation, and educational and inspirational opportunities that are vital to the prosperity, safety and well-being of both the U.S. and Mexican publics. Degraded natural systems lose their capacity to provide these services. They also lose some or all of their capacity for repair, which leads to a cascade of further degradation, particularly within the arid borderlands. In this report, the Good Neighbor Environmental Board (GNEB, the Board) discusses ecological restoration in the border region, including both the challenges and potential solutions.

Ecological restoration is *"the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed."** Restoration encompasses a range of activities, beginning with the cessation of activities that are causing natural resource degradation and continuing through to the monitoring of completed restoration treatments. Ecological restoration practices and outcomes exist along a continuum reflecting the realities, needs and actions that are appropriate to the landscapes and adjacent estuarine and marine areas of the U.S.-Mexico borderlands. Humans and human values play a central role in restoration, from the initial designation of environments as degraded, to prioritization of environments for restoration, to determination of the baseline to which the environments are to be restored. Ultimately, the goal is the development of self-sustaining ecosystems that meet management objectives by repairing damaged primary processes such as water, carbon and nitrogen cycles, and initiating and directing self-maintaining processes.

Restoration in the borderlands occurs within the unique circumstances facing border ecosystems, people and institutions. Multiple levels of governance on both sides of and across the international border create challenges and opportunities. Optimizing the societal benefits of healthy ecosystems and habitats in decision making can aid managers in prioritizing and selecting among competing projects, and comparing the anticipated benefits of increasing ecosystem health with the associated costs, thus ensuring a balanced approach to conservation and development. In this report, the Board reviews current restoration activities of the U.S. federal government in the border region and pays special attention to border watersheds and actual and potential ecological restoration activities within them.

As demonstrated by examples throughout the report, U.S. federal agencies have acted on restoration opportunities in the U.S.-Mexico border region appropriate to their respective missions. Achieving more effective restoration in this region, however, requires addressing some key challenges, such as scale and connectivity, which require interagency collaboration and the translation of goals into plans and on-the-ground actions. Through recommendations detailed in Chapter Four, the Board offers a range of ways to address the challenges.

First and foremost, the GNEB recommends that the U.S. federal government, in collaboration with local, state, Tribal, and national entities in the United States and Mexico, avoid resource damages through proactive approaches. Approaches to actively maintain high-quality natural resources and ecosystems include adopting best practices for low-impact infrastructure design and agency operations and supporting conservation on private lands.

The GNEB recommends that the U.S. federal government promote ecological restoration programs and projects. This includes actively promoting existing federal initiatives to increase restoration opportunities and developing governance and funding mechanisms to reflect landscape-scale restoration needs. Given the scale and scope of the border region and the multiple, interrelated issues facing its ecosystems, the Board recommends that the U.S. federal government take an ecoregional approach to environmental protection and restoration. This approach enables landscape-scale assessments, plans and actions that transcend administrative boundaries and allow for the classification of units across the border region. It recognizes the importance of understanding and addressing migration corridors, cumulative

* SER. 2004. Society for Ecological Restoration International Primer on Ecological Restoration. Accessed from http://www.ser.org/resources/resources-detail-view/ser-international-primer-on-ecological-restoration, July 8, 2014.

impacts, connectivity, and other landscape-level factors related to resource distribution and processes, and it facilitates priority setting. This approach also requires a systematic framework across U.S. federal agencies within which to develop clearly articulated goals and objectives; clearly delineated targets, threats and potential mitigation actions; national- or regional-level strategies derived from these integrated plans; and accompanying budgets. Such a common goal structure will support coordinated restoration actions as well as measures of incremental progress towards ecological landscape-scale goals.

The GNEB recommends that the U.S. federal government actively increase engagement with Mexican agencies and partners. An effective framework for ecological restoration must be developed through active engagement among local, state, Tribal, and national collaborators on both sides of the international border and can facilitate both top-down and bottom-up management relevant at the appropriate scales. Through the U.S. Section of the International Boundary and Water Commission (USIBWC), for example, the U.S. government should engage Mexican partners in transborder watershed management and urban ecological restoration.

Water is a critical resource, especially in the arid borderlands. Therefore, **the GNEB recommends that the U.S. federal government specifically address flow management, including irrigation and wastewater, for ecological restoration benefits.** In any water planning involving binational waters, the Board recommends that the government evaluate, consider and plan for environmental flows needed for aquatic species, habitat and human recreational uses of water, taking state water law into consideration. For example, at least some of the water conserved through irrigation efficiency should be dedicated to in-stream flow to meet aquatic restoration needs. In addition, the U.S. federal government, while taking into consideration existing water rights frameworks, should work with existing state water banks or water trusts to identify means for transferring water rights to ensure environmental flows.

In sum, the Board emphasizes the importance of borderlands ecosystems and the services they provide as well as the need for better understanding and acknowledgment of the impacts of the cumulative pressure of human activities such as development, land use and alteration, and water use on these ecosystems. The Board recognizes the value of incorporating landscape-level, ecosystem-based solutions into decision making and notes that multiple restoration scenarios are necessary for achieving environmental goals across large areas.

Chapter One: Ecological Restoration

BACKGROUND

Ecological restoration is *"the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed."*[2] Restoration encompasses a range of activities, beginning with the cessation of activities that are causing natural resource degradation and continuing through to the monitoring of completed restoration treatments. Other actions include developing detailed assessments, re-establishing stream flow or wetland water level, loosening compacted soils, stabilizing slopes, establishing plant cover and re-introducing native species.

Ecological systems are complex and dynamic, and "one size fits all" solutions to degraded resources are insufficient and inappropriate. Therefore, ecological restoration is designed to repair damaged resources by enhancing their "ability to change as their environments change."[3] Humans and human values play a central role in restoration, from the initial designation of environments as degraded, to prioritization of environments for restoration, to determination of the baseline to which the environments are to be restored.[4]

> "Human society's practices are the best indication of its ethos or set of guiding beliefs. Ecological restoration is a positive statement of co-operation with natural systems. Preserving those systems still undamaged and protecting those restored would be an even more positive statement, especially if accompanied by major restorative efforts for presently damaged systems."[1]
>
> *Sixteenth Report of the Good Neighbor Environmental Board to the President and Congress of the United States*

Why Is Ecological Restoration Necessary?

Importance of Ecosystems

An ecosystem is comprised of plants, animals and microbes and the air, water, soils and other components upon which they depend, all linked together through nutrient cycles and energy flows. Although nonhuman components of the ecosystem have long been recognized as valuable to humans, in recent years, ecologists have developed the concept of ecosystem services to highlight their importance.[5,6] Ecosystem services include the many benefits (services or goods) derived from well-functioning ecosystems, including food, fiber, regulation of climate stability, pest mitigation, recreation, and educational and inspirational opportunities.[7] In this context, ecological restoration can be viewed as a "product" that can be assessed using the same tools and methodologies that are used to evaluate environmental impacts of products or processes. Restoration can increase ecosystem services such as habitat protection, regulation of clean water, carbon storage and maintenance of soil fertility.[8]

Currently, although there have been advances in modeling, an incomplete understanding exists of the value of ecosystem services such as habitat for managed and protected species; physical protection for communities and economies from extreme events, including flooding and drought; and economic and social benefits (including human health). These services are vital to the prosperity, safety and well-being of both the U.S. and Mexican publics. It is important to understand the impacts of the cumulative pressure of human activities such as development, land use and alteration, and water use on these ecosystems, as well as the value of incorporating landscape-level, ecosystem-based solutions into decision making. In addition, optimizing the societal benefits of healthy ecosystems and habitats in decision making can aid managers in prioritizing and selecting among competing projects, thus ensuring a balanced approach to conservation.

The number of people living in the U.S.-Mexico borderlands increased from about 7 million in 1980 to almost 12 million in 2003; it is estimated the border population will reach more than 18 million by 2020.[9] Rapidly growing human populations increase the demand for ecosystem

Santa Cruz River, Audobon IBA at the Chavez Siding Road Crossing Post-NIWWTP Upgrade and Los Alisos Diversions, May 2014.
Source: John Shasky, Friends of the Santa Cruz River Volunteer

services. The Millennium Ecosystem Assessment evaluated the consequences for human well-being of the ecosystem changes that have resulted from growing global demands for food, fresh water, fiber and energy during the last 50 years and specifically highlighted how the loss of ecosystem services increases the vulnerability of people living in dry regions.[10] Among other key conclusions from the assessment is that the loss of ecosystem services presents a significant barrier to achieving the Millennium Development Goals of reducing poverty, hunger and disease.

Within the border region, ecological systems that are candidates for restoration may be marked by invasive species, eroded soils, channelized streams, contaminated water supplies and dropping water tables. Degraded systems are likely to suffer from the loss of native species, as well as reductions in ecological functions such as soil fertility and pollination. Of special note, ecological restoration strategies and implementation can help address the influence of urban ecosystems on surrounding areas and the decay of ecosystem services within urban areas.

To understand the damage, as well as the most effective restoration actions, border ecosystems need to be described and evaluated in terms of their individual components (e.g., populations, structures, physical and chemical environments) and processes (human cultural activities, atmospheric inputs, water flows), and the correlations among them.[11] For example, scientists studying forests have examined rural to urban gradients and found significant differences in soil communities, source areas of

The endandered ocelot *Leopardus (=Felis) pardalis*.
Source: Elitravo and Shutterstock©

invasive species, and forest composition and structure.[12] This type of analysis forms the basis for understanding restoration challenges and techniques. For example, heat island effects, stormwater drainage patterns and development can alter physical, chemical and biological properties of soils,[13] and even biogeochemical cycles.[14] In addition, a better understanding of the links between environmental health and disease is needed to anticipate and address shared public health issues experienced on both sides of the border and target ecological restoration efforts.

Causes of Degradation

Degraded natural systems lose some or all of their capacity for repair, and this leads to a cascade of further degradation,[15] particularly within the arid lands that make up much of the U.S.-Mexico borderlands. Degraded ecosystems also represent diminished visitor experiences at national parks and other recreational areas, decreased productivity of rangelands, and increased costs for water treatment. Along the U.S.-Mexico border, the causes of degradation are many. For example, exclusion of fire from forests has allowed fuels to build up, increasing the likelihood of uncharacteristically large and hot fires that can cause significant property damage and serious human health concerns. Likewise, poor tillage and management of agricultural runoff and sewage effluent contributes to coastal "dead zones" that affect the populations of aquatic species and the humans who depend on them. Excessive water withdrawals related to agriculture, mining and rapid urbanization have led to declining water tables. Likewise, logging, grazing, military activities and border enforcement actions all have resulted in degradation. In addition, unzoned growth in urban areas on both sides of the border has degraded the resource base for infrastructure and public health and welfare.

Ecological Restoration as Part of a Continuum

Decades of ecological restoration have resulted in successes and failures in practice, increased ecological knowledge and acknowledgment that lines between "humans" and "nature" that once were seemingly distinct are indeed blurred. Consequently, it is important to recognize ecological restoration practices and outcomes along a continuum reflecting the realities, needs and actions that are appropriate to the landscapes of the U.S.-Mexico borderlands. Given the levels of degradation in some areas, the varied goals and objectives of land owners, and the need to incorporate geographically distant individual parcels as patches within larger ecological landscapes, multiple scenarios—and combinations of these practices—are necessary for achieving environmental goals across large areas.

Ecologists frame environmental variation as being ordered in space, observing that the structure and function of ecological systems—be they populations, communities or entire ecosystems—are governed by spatial environmental patterns. Many factors affect the extent to which the structure and function of ecological systems can withstand disturbance and the extent to which, once disrupted, they can be restored.[16] Some areas, including urban

and "brownfield" sites,[17] lack records of historic ecological conditions or have experienced such great shifts in environmental condition (e.g., temperature increases in urban heat islands, soil permeability loss as a result of impacts of grazing and paving) that the flora and fauna of earlier, predevelopment periods cannot be replaced. Plus, future conditions desired by stakeholders for these areas may be dramatically different than historic conditions. In these situations, recognizing that other models of "restoration" might be appropriate, the goal is to incorporate sustainable ecological attributes of species assemblages, food webs, and edaphic (soil) and hydrologic functions.[18]

Although the science of ecological restoration began with emphasis on a return to pre-disturbance systems with certain species and functions—thus distinguishing itself from reclamation and rehabilitation practices—current restoration thinking focuses more on "repair," or redressing the damage incurred to the resource. The goal is the development of self-sustaining ecosystems that meet management objectives by repairing damaged primary processes such as water and mineral cycles (e.g., carbon, nitrogen, calcium), and initiating and directing self-maintaining processes.[19] Such a "repair" approach allows for seeing that "restoration activities occur along a continuum, and that different activities are simply variations of the same theme."[20] Figure 1 presents the continuum of activities that will be considered in this report.

WHY IS THE GNEB ADDRESSING THIS ISSUE?

The U.S.-Mexico borderlands are diverse in flora and fauna and vary dramatically through the long, narrow stretch to include chaparral; coastal plains; deserts of cactus, sage bush and creosote; isolated mountain ranges with pine and oak forests; rugged canyon lands covered in yucca; rolling hills with grasses and mesquite;

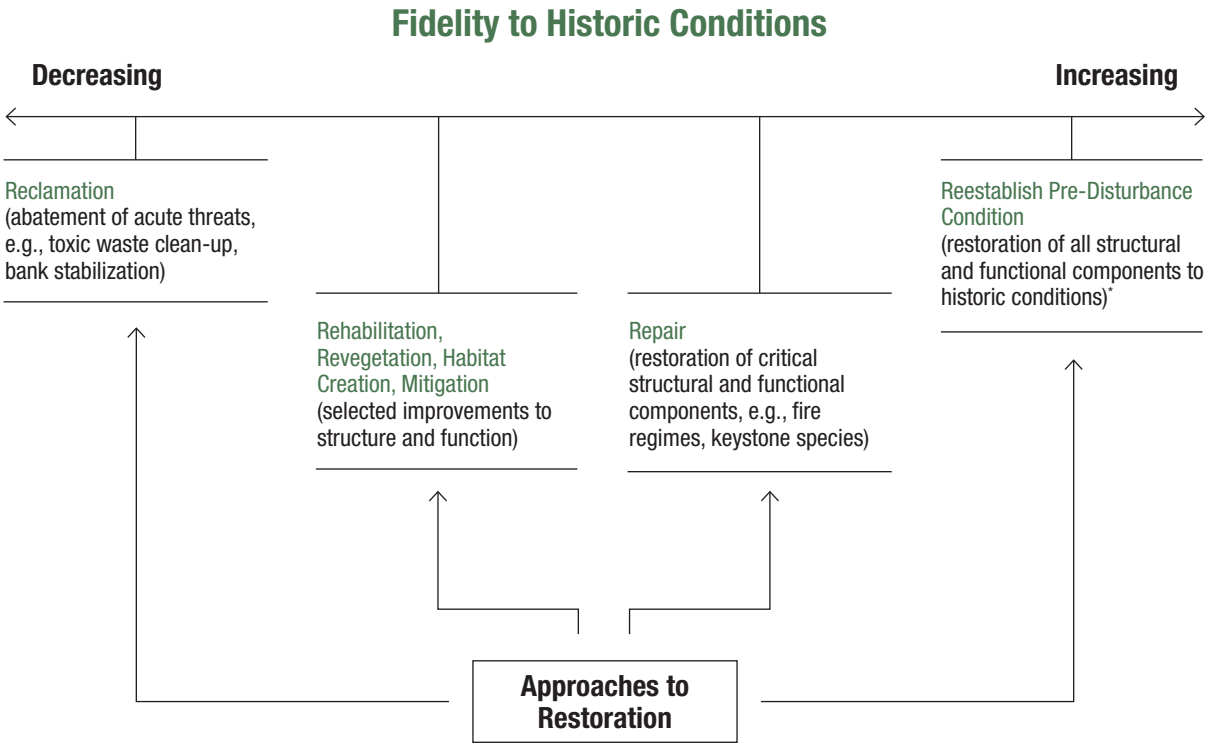


Figure 1. Restoration along a continuum.

Note: Restoring to pre-disturbance conditions is still an appropriate approach for small disturbances within an intact matrix, or for rare or localized species' habitats. Increasingly, however, restoration managers must account for both natural ecological change and external pressures such as climate change, landscape fragmentation and altered ecosystem processes under which historic conditions will not persist. Instead, managers design restoration outcomes to maximize natural resource values within existing and predicted constraints.

and fertile river delta estuaries. Major ecosystems of the border, such as the Sonoran and Chihuahuan Deserts, include many unique species adapted to dry conditions.[21] Portions of the U.S.-Mexico border also serve as important migratory pathways for many avian, mammalian and invertebrate species.

The U.S.-Mexico border extends approximately 1,954 miles (3,145 kilometers) from California to Texas. Within this vast landscape lies a variety of ecosystems, critical habitats and treasured landscapes ranging from deserts and mountains to natural waterways such as rivers, streams and creeks. These zones and associated species cross the international border. Large-scale land use practices—past and present—have left resource restoration challenges in the borderlands. These practices include:

- The introduction and spread of species such as buffelgrass (*Pennisetum ciliare* (L.) Link) and salt cedar (*Tamarix* spp.).
- Energy development and mineral extraction.
- Rapid and extensive human population growth.
- Subsidized agriculture.
- The development of extensive water infrastructure.
- International border commerce and security.

In addition, changing climatic conditions such as long-term drought have added to these challenges. A wide range of degraded resource conditions have resulted, including monocultures of invasive species, over accumulation of woody material that provides fuel for fires, mine pits and spoil piles, drained wetlands, altered river flows, overabundant herbivores due to lack of predation pressure (as shown in several wolf-elk-riparian vegetation studies across the west[22,23,24]), and disconnected wildlife movement corridors.

What makes restoration in the borderlands unique? The borderlands are characterized by:

- Multiple levels of governance across the international border.
- High levels of biodiversity.
- Primarily arid climates and scarce water resources.
- A mix of protected areas; urban areas; agricultural lands; and transportation, commerce and security infrastructure zones.

Habitat restoration site along the Rio Grande Canalization Project.
Source: U.S. Section, International Boundary and Water Commission

KEY APPROACHES FOR BORDERLANDS ECOLOGICAL RESTORATION

The following key strategies can facilitate a wide range of actions to support restoration goals.

Avoiding Resource Damages Through Proactive Approaches

Efforts to protect border ecosystems can reduce the need for restoration in the future. Also, restoration cannot satisfactorily replicate the range of components and services of a damaged ecosystem. The U.S.-Mexico border is a complex and busy place, and federal agencies develop and implement programs to address various missions and responsibilities. These program-driven actions, however, can degrade resources. Decisions about the design of border fences, urban and agricultural development, and energy and mineral resource development should be made with full consideration of the changes they will trigger and the opportunity to recover resources and services that may be lost. Various programs, such as the U.S. Environmental Protection Agency's (EPA) Green Infrastructure Program,[25] provide incentives, examples and tools to help developers, designers and engineers avoid unintended consequences of their activities. Federal agencies are required to comply with numerous (more than 100) laws, regulations, Executive Orders and Presidential Memoranda that mandate responsible environmental practices with

respect to environmental resources affected by facilities and infrastructure. Most recently, Executive Order 13514, "Federal Leadership in Environmental, Energy and Economic Performance," requires that federal agencies ensure that all construction, renovation, repair and alterations comply with the Guiding Principles of Federal Leadership in High Performance and Sustainable Buildings (the Guiding Principles). These Guiding Principles include standards related to water and energy conservation, environmentally responsible siting practices, and construction materials selection. Frameworks for evaluating impacts include natural resource condition assessments; National Environmental Policy Act (NEPA) analyses; and tools adapted from industry such as value engineering and life cycle analysis. These are being applied to a variety of development scenarios, but a key challenge is ensuring that plans are implemented and evaluated to ensure that they were carried out as intended.

2009 Memorandum of Agreement

In a 2009 Memorandum of Agreement (MOA) between the Department of Homeland Security (DHS) and the Department of the Interior (DOI) governing border security and the operations of U.S. Customs and Border Protection (CBP), the DHS "agrees to plan for, design, deploy, and maintain border security infrastructure components in cooperation with DOI in such a way as to avoid or minimize adverse effects to the natural and cultural resources in those areas where such border security infrastructure is to be constructed, operated, and maintained." The agreement also states that "CBP will implement BMPs [best management practices] that are designed to avoid or minimize impacts to natural and cultural resources. Where avoidance or minimization of adverse effects cannot be achieved through the implementation of BMPs, CBP will, in accordance with the terms and conditions of this MOA and the legal requirements, make further efforts to mitigate the adverse effects caused by construction and maintenance of border security infrastructure upon the area's natural and cultural resources."[26] Such agreements are an important first step. The plans, designs, deployment and maintenance require regular review and monitoring.

Taking an Ecoregional Approach to Ecological Restoration

Efficient and effective ecological restoration depends on careful and thorough analysis of resources, as well as implementation at appropriate scales and following established timelines. Increasingly, due to the emergence of new tools for analysis and planning, U.S. federal agencies are working from the perspective of large spatial areas and landscape ecology. Landscape assessments are used in part because species' managers recognize that organisms move across heterogeneous spaces; there are many external influences on critical habitats; and such influences affect behaviors such as migration, feeding and predator avoidance.[27,28] Across a landscape, a "recurring pattern of ecosystems associated with characteristic combinations of soil and landform that characterize that region" has been termed an "ecoregion" (ecological region).[29] An ecoregion is identified because of the relative homogeneity of ecosystems or relationships among organisms and their environments within the region, as well as relative differences when compared to other regions.[30]

Particularly when adjusted to emphasize biodiversity or other resource patterns, ecoregions offer a more practical framework than administrative definitions for identifying broad-scale partnering, planning, data collection and management, as well as strategic approaches to multiple party efforts. In the border region, such an approach avoids the arbitrary delineation such as the 62.5-mile (100-kilometer) definition established in the 1983 La Paz agreement.[31]

Several ecoregional frameworks have been developed to provide ecologically based stratification of terrestrial landscapes; each has strengths when applied in the border region. All approaches incorporate climate and account for local landforms and soil properties. The U.S. Department of Agriculture (USDA) has defined geographically associated land resource units as Major Land Resource Areas (MLRA) and has created a hierarchical tool that incorporates geology, climate, water and biological resources. Identification of these large areas has been important in statewide agricultural planning and has value in interstate, regional and national planning; the detailed soil and land use data may make this

product useful to project-level restoration assessment. The EPA framework, as adopted by the Commission for Environmental Cooperation (CEC), distinguishes elevation-related life zones, which pull "islands" into ecoregion boundaries based on their characteristics rather than their spatial location. The World Wildlife Fund for Nature (WWF) defines watershed-based ecoregions and is the most advanced framework for river systems. Both the CEC and WWF approaches cross the international border. In addition, globally available data on climate and landforms, as well as Mexican investments in soils data, make extension of local land classification units across the border region much more feasible today than just a few years ago. **Figure 2** is an example of a product of the CEC's ecoregional analysis.

The CEC map (Figure 2) identifies seven ecoregions that extend to the U.S. side of the U.S.-Mexico border, within the 62.5 miles (100 kilometers) outlined by the La Paz agreement. From west to east, and including major urban areas within them, these are:

11.1.1 California Coastal Sage, Chaparral and Oak Woodlands (San Diego, Tijuana).

10.2.2 Sonoran Desert (Yuma, Mexicali, Tucson).

12.1.1 Madrean Archipelago (Nogales, Douglas).

10.2.4 Chihuahuan Desert (Las Cruces, El Paso, Ciudad Juárez).

9.4.6 Edwards Plateau.

9.6.1 Southern Texas Plains/Interior Plains and Hills With Xerophytic Shrub and Oak Forest (Laredo, Nuevo Laredo, Monterrey).

9.5.1 Western Gulf Coastal Plain/Planicie de la costa occidental del Golfo (Matamoros, Brownsville).

Ecoregional frameworks can support restoration planning and assessment in the following ways:

- Identifying the number and condition of ecological systems within the area.
- Identifying species migration corridors and barriers to connectivity.
- Identifying the contributions of different types of restoration and accumulated value of small projects based on relative similarities of ecological sites (e.g., for distinguishing relative degrees of similarity among places at each hierarchical level).
- Evaluating cumulative impacts of infrastructure development such as energy facilities and transmission corridors, and identifying mitigation opportunities in landscapes affected by such development.
- Incorporating landscape-level factors related to resource distribution and processes such as wildland fire.
- Providing a common framework for understanding and communicating resource conditions and agency actions.

Figure 2. Map displaying the Commission for Environmental Cooperation's ecological regions along the U.S.-Mexico border.

Source: Adapted from "North American Terrestrial Ecoregions—Level III," Commission for Environmental Cooperation, http://www3.cec.org/islandora/en/item/10415-north-american-terrestrial-ecoregionslevel-iii-en.pdf, which contains detailed descriptions of each Level III ecoregion

- Making it possible to scale assessments for specific issues and at different levels to address multiple, interrelated issues.
- Providing a systematic framework within which to develop clearly articulated goals and objectives; clearly delineated targets, threats and potential mitigation actions; national- or regional-level strategies derived from these integrated plans; and accompanying budgets.
- Allowing assessment and planning processes to be built on principles of engagement and nested collaboration.
- Facilitating both top-down and bottom-up management that is relevant at the appropriate scales.

Coordination, Collaboration and Partnering

Today, many ecosystems are not adapted to their current environments; environmental conditions continue to change; and resources are very limited. Therefore, "self-sustainability" is a key characteristic of restoration success. In the context of ecological restoration, sustainability means that the restored system has the potential to persist indefinitely under existing environmental conditions.[32] Sustainability also requires that stakeholders embrace (or accept) the restoration outcomes based on their values, necessitating coordination, collaboration and clear lines of accountability for all involved parties to ensure successful restoration endeavors. The scale of ecological resources, along with the complexity of restoration projects and the range of activities and external inputs that must be included, necessitates cooperative actions. Federal ecosystem restoration projects and programs must take into account Tribal, state and local concerns.

Across the region and among agencies and stakeholders operating at multiple levels, programmatic goals and high-level objectives must be accompanied by detailed planning objectives. Large-scale strategic restoration objectives should be coherent with local planning objectives, and metrics must be developed that translate across multiple levels of decision making and reporting. Throughout this report are examples of partnerships and interagency collaboration.

Establishing Metrics to Define, Achieve and Measure Success

> "You cannot manage what you do not measure."[33]

Metrics are key to measuring progress toward goals, raising awareness and understanding, and informing restoration decision making.[34] The development and application of metrics can connect local, state and federal agencies, as well as nongovernmental stakeholders, and help them align their restoration goals and activities. Appropriate metrics are based on ecological principles that articulate the scientifically recognized attributes of ecological integrity,[35] as well as human health and welfare.[36] Additionally, the metrics must be understandable to many stakeholders, applicable to a variety of situations, and relatively easy and inexpensive to apply.

Unfortunately, throughout the border region, there is a general lack of complete assessments of degraded areas. Important attributes of these areas, such as soil conditions, are required to inform seeding and planting efforts and contribute to improved techniques for planting in dry climatic conditions. Such assessments, however, are often missing or partial. To further complicate matters, fragmented metrics and inconsistent standards among the different government, nongovernmental, and private stakeholders make it difficult to assess the success, sustainability and resilience of large-scale restoration projects.

U.S. FEDERAL GOVERNMENT ROLE IN RESTORATION

The U.S. federal government manages numerous lands in the border area (see **Figure 3**) and holds land in trust for the benefit of American Indian Tribes (see **Figure 4**). In national parks and forests and elsewhere on federal lands, including military bases, restoration actions focus on reestablishing characteristic native taxa and ecosystem processes. Typical actions include managing invasive species and fuel loads, excavating and regrading roads and filled wetlands, planting native species, and managing river flow. These actions will be discussed throughout this report. This section is intended to illustrate the range of mandates and activities that are undertaken to protect, repair and restore border ecosystems.

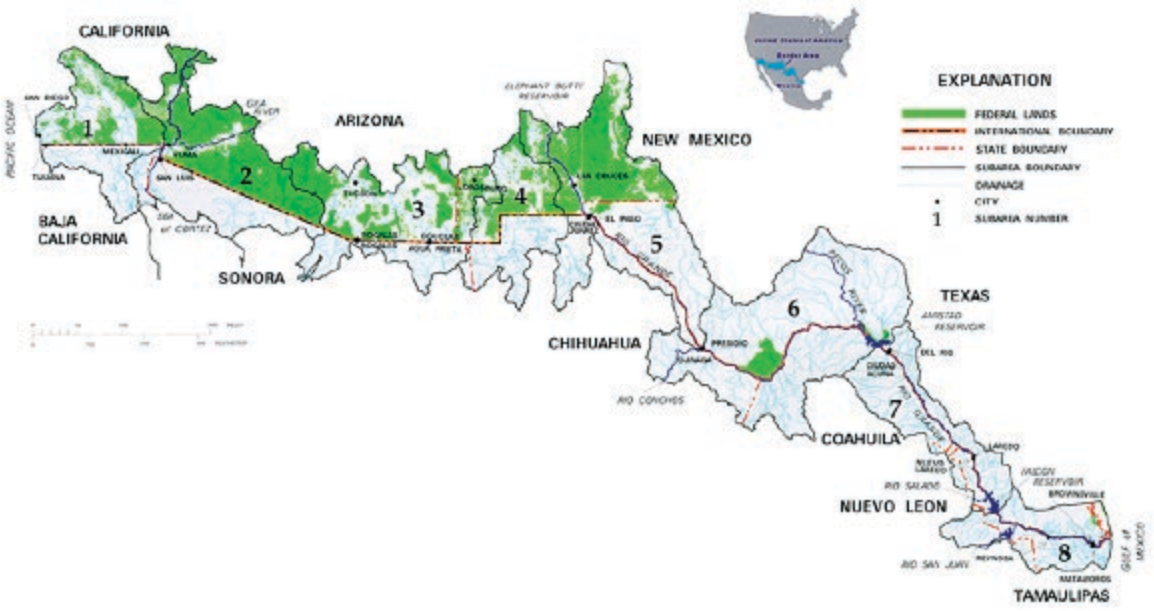


Figure 3. U.S. federal lands and drainage basins along the U.S.-Mexico border. The border area has eight sub-areas with similar hydrologic and physiographic features.

Source: "Fact Sheet: United States-Mexico Border Area, as Delineated by a Shared-Water Resources Perspective," DOI, http://www.cerc.usgs.gov/FCC/docs/Fact_sheets/Fact_1/DOI_US-MX_Border_FCC_Fact_sheet_1.html

Figure 4. Tribal lands in the U.S.-Mexico border region.

Source: "U.S.-Mexico Border Region—Región Fronteriza México-Estados Unidos," U.S.-Mexico Border 2020 Program, http://www2.epa.gov/sites/production/files/documents/Border2020-map.pdf

Public Lands

The U.S. Department of the Interior (DOI) and its respective bureaus are engaged in a range of restoration activities on public lands in the U.S.-Mexico border area. For example, the Bureau of Land Management (BLM), the National Park Service (NPS), and the U.S. Fish and Wildlife Service (FWS) actively implement restoration activities on resources under their jurisdiction. Despite their bureau's multiple-use mandate, BLM managers are charged with restoring rangelands (grasslands, shrub lands, deserts) to standards following "fundamental properties of watersheds, ecological processes, water quality and habitat.[37] The NPS has a "no-impairment" mandate embedded in its founding Organic Act of 1916, and NPS Management Policies clearly direct restoration of degraded resources resulting from human disturbances.

The FWS (along with the National Marine Fisheries Service [NMFS] of the National Oceanic and Atmospheric Administration [NOAA]) has primary responsibility for administering the Endangered Species Act (ESA). Through the ESA, these agencies develop recovery plans that identify specific measures for species viability. The plans also include strategies for recovery and address roles for key partners in the recovery of these species. The FWS also manages refuges along the border and, like other DOI and Forest Service units, actively addresses degraded waterways and habitats through restoration.

Within the border region, the NMFS is limited in geographic scope to the coastal areas and watersheds of California and Texas. In those locations, it supports projects that aid in the recovery of threatened and endangered species listed under the ESA, as well as their prey, and fish stocks managed under the Magnuson-Stevens Fisheries Conservation and Management Act. The Bureau of Reclamation's Mission is "to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public." The vision for implementing this includes "[m]anaging Reclamation's facilities to fulfill water user contracts and protect and/or enhance conditions for fish, wildlife, land, and cultural resources."[38]

Through a variety of laws such as the Clean Water Act and the Comprehensive Environmental Response,

Compensation, and Liability Act (CERCLA), EPA is charged with limiting the amount of harmful chemicals entering the environment. To fulfill its responsibilities, the Agency actively restores wetlands and improves upland condition through waste removal and site remediation.

Private Lands

U.S. federal agencies also have responsibilities to private landowners. Various DOI bureaus, including the FWS and BLM, discussed in the previous section, reach out to private landowners under various authorities using contracts, grants and cooperative agreements. Other agencies have explicit mandates to work with private landowners.

For example, the Natural Resources Conservation Service (NRCS) is a nonregulatory agency within the USDA that works with the Nation's private landowners and land managers through conservation planning and implementation efforts. In the border region, the NRCS works with ranchers and farmers to provide conservation planning and technical and financial assistance in an effort to protect, restore and enhance impaired natural ecosystems. Following the mission of "Helping People Help the Land" and through its guiding principles—service, partnership

Santa Cruz River, Audobon IBA at the Chavez Siding Road Crossing Pre-NIWWTP Upgrade and Los Alisos Diversions, June 2004.
Source: John Shasky, Friends of the Santa Cruz River Volunteer

and technical excellence—the NRCS helps develop conservation plans that include improvements to water quality and quantity, productive soils, plant communities, open space, food and fiber, and rural and urban communities. The NRCS identifies MLRAs and develops ecological site descriptions to characterize land areas by climate, soil and water features, and related plant communities and ecological dynamics, thereby providing land managers the information needed for identifying appropriate land uses.[39] Through "Working Lands for Wildlife," the NRCS is providing assistance to improve, restore and maintain habitat for seven listed and at-risk species. The NRCS has worked with the FWS to ensure that the specific conservation practices landowners use will benefit the focal species and not negatively impact that species and other species that may occur on the enrolled properties.

The FWS also works with private (nonfederal) landowners who have habitat for listed and at-risk species on their lands through two kinds of voluntary agreements: Safe Harbor Agreements for listed species and Candidate Conservation Agreements with Assurances for candidate and other at-risk species. For their specific conservation actions that remove threats and improve, restore and maintain habitat, landowners enrolled in these agreements receive assurances that they will not be asked to do more than agreed upon, and should their ongoing land management practices described in the agreement impact the species, they are covered by an incidental take permit. A diversity of partnerships with state and local agencies and conservation organizations has been established to assist in developing these agreements by working with landowners and implementing conservation actions.

The Service's Partners for Fish and Wildlife Program is another way the FWS works with private landowners by providing technical and financial assistance to landowners who are willing to work with the Service and other partners on a voluntary basis to help meet the needs of federal trust species by restoring and creating habitat.

Chapter Two: Current Activities of the U.S. Federal Government

As indicated in Chapter One, the U.S. federal government is involved in ecological restoration throughout the border region through agencies with an explicit mandate to restore degraded habitats and others that incorporate general environmental protection into their regular activities. The first two sections of this chapter describe federal government involvement in research and implementation related to ecological restoration in the region. The final section discusses opportunities to expand ecological restoration there.

RESEARCH

Ecological restoration is a dynamic process, requiring responsiveness to changing environmental, social and political conditions. Thus, ongoing research is critical to project-based and large-scale environmental restoration efforts. Many federal agencies conduct research to determine resource conditions and implications for management. For example, the National Park Service (NPS) collects data on long-term trends of select resource indicators. Individual land units support or conduct research ranging from basic biological inventory to developing techniques for treating invasive buffelgrass (*Pennisetum ciliare* (L.) Link). This section describes some of the activities of three of the most active federal agencies conducting research in support of ecological restoration in the border region.

Department of the Interior—U.S. Geological Survey

The U.S. Geological Survey (USGS) is the science bureau of the U.S. Department of the Interior (DOI)

GNEB Board Member Francisco Zamora (far left) briefs U.S. Government Officials at Laguna Grande Restoration Site B1.
Source: Andrew Pernick with the Bureau of Reclamation

and provides basic and applied science to understand threats, resource responses and techniques to support restoration actions in the U.S.-Mexico border region. The USGS is an internationally recognized leader in modeling natural systems and making robust forecasts of the future states of those systems. Monitoring, modeling and forecasting change within transboundary watersheds provides unbiased science and leadership in the borderlands region.[40] One example is the USGS' role in the Colorado River Pulse Study (see the case study on Minute 319 and the Pulse Flow in Chapter Three).

The USGS also provides integrated, cross-discipline thinking, data collection and analyses to help synthesize information, described in its 2013 comprehensive assessment of ecological, social, health, commerce and security issues in the borderlands document, "United States-Mexican Borderlands—Facing Tomorrow's Challenges through USGS Science."[41] The USGS applies geographical, geospatial, biological, hydrological and geological sciences to complex binational issues, and provides insight into natural systems and their relation to human activity. Resulting information is useful to federal land management bureaus in the DOI, such as the Bureau of Land Management (BLM), and other federal agencies associated with homeland security, agriculture, environment and health.

In addition, the USGS is responsible for the implementation of the 1964 Waste Resources Research Act and oversees the work of the Nation's 54 water research centers—one in each state, the District of Columbia, Puerto Rico, the U.S. Virgin Islands and Guam. These Institutes together have produced path-breaking research, innovative information and a technology transfer program in addition to training more than 25,000 students during the past 50 years.

Department of Agriculture–U.S. Agricultural Research Service

The U.S. Department of Agriculture (USDA) Agricultural Research Service (ARS) has been instrumental in developing tools for assessing and managing rangelands. The ARS in Las Cruces, New Mexico, continues to lead research and applications of rangeland condition assessment and state and transition models critical to understanding the level of degradation in ecosystems. Ecological restoration can help prevent and address problems such as the reintroduction of cattle fever ticks in Texas. Without attention, the spread of these ticks would cause devastating monetary losses for U.S. beef and dairy producers; therefore, ARS scientists in Kerrville, Texas, are developing and testing new interventions to eliminate the ticks within U.S. borders. In addition, following the concept of One Health,† researchers and managers are evaluating the role of overabundant white-tailed deer and non-native ungulates on efforts to manage disease vectors.‡

National Oceanic and Atmospheric Administration

Through its science and stewardship programs, the National Oceanic and Atmospheric Administration (NOAA) advances the understanding of and ability to anticipate changes in the environment by improving

† One Health is an organizing concept and effort to apply "a broader understanding of health and disease demands a unity of approach achievable only through a consilience of human, domestic animal and wildlife health and through 12 organizing principles, identifies the linkage to environmental quality and ecological integrity" (http://www.oneworldonehealth.org/).

‡ Group for Emerging Babesioses and One Health Research and Development in the U.S. 2010. One Health approach to identify research needs in bovine and human babesioses: workshop report. *Parasit Vectors.* 3: 36. Published online Apr 8, 2010. doi: 10.1186/1756-3305-3-36.

Site visit conducted at Morelos Dam in preparation for Minute 319 pulse flow event, Arizona.
Source: Andrew Pernick with the Bureau of Reclamation

society's ability to make scientifically informed decisions, and by conserving and managing ocean and coastal resources. With regard to ecosystem restoration, NOAA's National Ocean Service (NOS), National Marine Fisheries Service (NMFS), National Weather Service (NWS), Office of Oceanic and Atmospheric Research (OAR), and National Environmental Satellite Data and Information Service (NESDIS) provide science, modeling, technical assistance and decision support tools that can inform and support restoration activities along the border region. The Office for Coastal Management within the NOS administers programs under the Coastal Zone Management Act (CZMA): the Coastal Zone Management Programs (CZMPs) and the National Estuarine Research Reserve System (NERRS). The CZMPs are established to manage and balance competing uses of and impacts to coastal resources while the NERRS is a network of coastal areas protected for long-term research, water-quality monitoring, education and coastal stewardship. The States of California and Texas are the only states in the U.S.-Mexico border region that are eligible to participate in the program and both states have chosen to develop these programs (see page 41 for a case study of state-federal partnership in habitat restoration at the Tijuana River NERR).

The CZMA emphasizes the primacy of state decision-making regarding the coastal zone. Federal consistency is a powerful tool that states use to manage coastal uses and resources and to facilitate cooperation and coordination with federal agencies. Federal consistency requires federal agency activities, including habitat restoration activities, that have reasonably foreseeable effects on any land or water use or natural resource of the coastal zone must be consistent to the maximum extent practicable with the enforceable policies of a coastal state's federally approved coastal management program. The National Centers for Coastal Ocean Science (NCCOS) conduct research on coastal ecosystem restoration, ecosystem characterization and biogeographic assessment. Using geographic information systems (GIS) to integrate and analyze biological, physical, chemical and socioeconomic information about coasts, NCCOS provides border communities in southern California and south Texas with the information and tools to develop practices and policies that reduce pollution and improve coastal health.

The three NWS River Forecast Centers (RFCs) in the U.S.-Mexico border region—California-Nevada, Colorado Basin, and West Gulf—provide information on river flow observations and forecasts. This information is used by the U.S. International Boundary and Water Commission (USIBWC) to assist in the distribution, regulation and conservation of border region water resources in accordance with the rights and obligations that the governments of the United States and Mexico assume under numerous boundary and water treaties.[42]

NOAA's Climate Program Office (CPO) provides science, data and information to understand how climate conditions are changing. Using NOAA's long-term climate observing, monitoring, researching and modeling capabilities, scientists quantify where and how climate conditions have changed in the past and predict where and how they are likely to change in the future. The NOAA Climate Prediction Center provides seasonal and inter-annual outlooks on various climate-related variables (e.g., drought, El Niño events, storms and other weather hazards).

IMPLEMENTATION

Ecological restoration is conducted at many levels, although most common are those projects that are species-centric or site-based. Limitations in the effectiveness of isolated restoration projects, however, point to the need for large-scale restoration programs and initiatives, including those that cross the U.S.-Mexico border. Using case studies, this section illustrates each of these types of implementation.

Species-Centric Restoration

Species-based work usually includes habitat restoration, which ranges from addressing a landscape process such as fire or flooding to emphasis on a single food source for the species. In southern Arizona, the U.S. Fish and Wildlife Service (FWS) is actively implementing a wide range of endangered species recovery actions, including the following:

- Captive propagation and translocation (Sonoran pronghorn antelope [*Antilocapra americana sonoriensis*]).
- Habitat enhancement projects (gating of cave roosting habitats for endangered bats).
- Monitoring of endangered cats (jaguar [*Panthera onca*], ocelot [*Leopardus (=Felis) pardalis*] and jaguarundi [*Herpailurus (=Felis) yagouaroundi cacomitli*]).
- Management of grassland habitats for natural diversity (at the 117,107-acre [47,392-hectare] Buenos Aires National Wildlife Refuge [NWR]).
- Restoration of endangered fish habitats (at the 2,369-acre (959-hectare) San Bernardino NWR).

Planning for the recovery, listing of threatened or endangered species, and designation of critical habitat also are very active.

Site-Based Restoration

Extending beyond species-centric restoration, the goal of site-based restoration is to improve the habitat upon which multiple plant and animal species depend. The challenges of site-based restoration are many and include overcoming habitat fragmentation, understanding species dependencies and securing resources. As for species-centric restoration, careful and well-designed monitoring is critical to long-term success.

Palo Alto Battlefield National Historic Park

Palo Alto Resaca

The Palo Alto Resaca is a key landscape feature of the core battlefield. It played a strategic role in placement of battle lines and affected troop movements during the 1846 battle. The site has been degraded through tillage agriculture, ranching and drainage projects during the last 85 years that have altered the topography, soil, vegetation and hydrology of this landscape. Although buildings and debris from trenching have been removed, the current condition of the site detracts from the integrity of the historic setting and ecological landscape that the park was established to preserve and interpret. Work has begun to fill ditched areas and restore predisturbance contours, as well as to replant these areas with native species. Although this is a small project, the work will support similar efforts by the U.S. Fish and Wildlife Service (FWS) to establish wildlife corridors along the Rio Grande.

The NPS frequently is challenged to restore both natural resources and cultural landscapes. Palo Alto Battlefield National Historic Park is one example. This park sits near the mouth of the Rio Grande, near Brownsville, Texas. In 1846, this became the site of the first major battle of the war between Mexico and the United States over disputed territory north of the Rio Grande.

Characteristic of prairie at the park are dispersed small stands of mixed brush and several lengthy "resacas."

Resacas are abandoned stream courses on the Rio Grande delta that appear as sinuous, shallow channels across the landscape. The resacas fill with water after rainstorms and remain ponded for weeks or months, creating wetlands that are either unvegetated or support wetland plants that are more tolerant of ponded water than the adjacent prairies, dominated by gulf cordgrass (*Spartina spartinae* (Trin.) Merr. ex Hitchc.). Resacas provide important habitat for:

- Waterfowl species (e.g., American wigeons [*Anas americana*], pintails [*Anas acuta*], Northern shovelers [*Anas clypeata*]).
- Wading birds (e.g., roseate spoonbills [*Platalea ajaja*], night herons [*Ardeidae* spp.], snowy egrets [*Egretta thula*]).
- Shorebirds.
- Raptors.

They also provide important habitat for several threatened and endangered species such as the ocelot, Aplamado falcon (*Falco femoralis septentrionalis*) and jaguarundi.

Federal Support for Habitat Restoration on Nonfederal Lands: Examples from the Natural Resources Conservation Service

The Natural Resources Conservation Service (NRCS) has effectively utilized Farm Bill conservation programs to help incentivize landowner program participation in habitat protection and restoration programs. In fiscal year 2013 (FY 2013), for example, Conservation Technical Assistance (CTA) impacted more than 3,994 individuals and resulted in conservation plans being written on more than 2,086,409 acres (844,343 hectares). Conservation plans provided the framework for ecosystem enhancement and readied landowners to apply for financial assistance programs. The Conservation Stewardship Program (CSP) is directed at agricultural producers to help them maintain and improve their existing conservation systems and adopt additional conservation practices.

Collaboration With Livestock Growers

The Natural Resources Conservation Service (NRCS) works with livestock growers to enhance environmental conditions in areas used for grazing. In Sells, Arizona, the Tres Equis Range and Livestock Association manages a 55,000-acre (22,000-hectare) grazing area along the border region. The primary resource concern is maintaining plant communities that optimize the rangelands' soils, elevations and precipitation totals. To date, 11 miles (18 kilometers) of fencing has been installed to control the timing and intensity of grazing. To accelerate ground cover, 9,066 feet (2,763 meters) of diversions and water spreaders were constructed to supplement natural precipitation in areas where plants could effectively use additional moisture, while reducing damage from uplands runoff. Soil erosion was addressed by installing 38 grade stabilization structures, four sedimentation basins and 100 acres (40 hectares) of range planting. Three livestock ponds were constructed to improve grazing distribution. Four vegetation monitoring plots were established to document vegetation changes on 13,832 acres (5,598 hectares) of deferred grazing. Currently, the field office is working on a range inventory of the Association's mountain pasture.

Threatened and endangered species within the Texas border region include, for example, the ocelot, jaguarundi, and several endangered and culturally significant plant species. The NRCS is working actively with landowners and partners to restore vital ocelot and jaguarundi habitat under the Grassland Reserve Program (GRP), Environmental Quality Incentives Program (EQIP), and Continuous Conservation Reserve Program State Acres for Wildlife Enhancement (CCRP-SAFE) program. EQIP, for example, provides financial and technical assistance to agricultural producers to address natural resource concerns and deliver environmental benefits. Education efforts also are in place to help prevent the destruction of critical native habitat of culturally significant indigenous or at-risk plant species.

The south Texas border region is an essential migratory habitat for a number of insect, bird and animal

species. The Monarch butterfly (*Danaus plexippus)* and neotropical bird populations depend on this area's ecosystems for suitable and abundant habitat along their migration journey. The Migratory and Shore Bird Habitat Initiative (MSBHI), begun in FY 2013, focuses conservation planning efforts on migrating, shorebird and grassland nesting-bird habitats. The NRCS established a special funding area through the Wildlife Habitat Incentives Program (WHIP) to help private landowners with brush management, grass planting, prescribed burning and prescribed grazing to emulate open prairie and savannah-type ecosystems that are dependent areas for grassland bird species.

Natural Resources Conservation Service-Tribal Ecosystem Restoration Partnerships

The U.S.-Mexico border region is home to a number of federally recognized Tribes. The Natural Resources Conservation Service (NRCS) supports these Tribes, on and off reservations, through efforts such as ecosystem restoration projects. The NRCS partners with Tribes to preserve and enhance ecosystems for generations to come, in turn, supporting the preservation of traditions, propagation of wildlife and restoration of culturally significant plants. In California, for example, the NRCS is working with the Quechan Tribe to remove salt cedar and establish native plant revegetation along the Colorado River at the junction of Arizona, California and Mexico. The Manzanita Band of the Kumeyaay Nation worked with the NRCS on a Poly Farm project and on conservation practices including micro-irrigation and windbreak installation, forested lands, wildfire fuels management and revegetation, and prescribed grazing management planning.

At that same time, efforts to target invasive species—such as salt cedar (*Tamarix* spp.), giant cane (*Arundinaria gigantea* (Walter) Muhl.) and desert willow (*Chilopsis linearis* (Cav.) Sweet)—continue all along the border. These three plants occur in varying abundance along the Rio Grande and can present environmental and cultural challenges. In the west Texas border region alone, 143 brush management applications were certified on 33,210 acres (13,440 hectares) with the NRCS obligating $2,356,379 for species control. The three species generally are viewed as invasive by

Imperial wetland.
Source: Imperial Irrigation District

the landowners, operators and managers. However, the same view is not necessarily held by Native American Tribes or members of other cultural groups; management actions, therefore, are best implemented in the context of ongoing partnerships and cooperation (see the Ysleta del Sur Pueblo example, below).

The Ysleta del Sur Pueblo Hueco Tanks Traditional Lands

The Tigua Indians of Ysleta del Sur Pueblo is one of several federally recognized Native American Tribes in the border region. The Hueco Tanks Traditional Lands is a 3,573-acre (1,446-hectare) property, located at the El Paso and Hudspeth county line adjacent to the Hueco Tanks State Park, that is sacred to the people of Ysleta del Sur Pueblo.[43] This property is a traditional hunting and ceremonial ground for the Pueblo. Species such as scaled quail, also known as blue quail and cotton top (*Callipepla squamata*), are of cultural significance to the people of the Pueblo as a food source and for ceremonial purposes. The property is located approximately 30 miles (50 kilometers) from the Pueblo's main housing and governmental district, and overgrazing by a neighboring property owner's cattle and other mitigating factors have left the property in poor ecological condition.

Because the property is not held in trust, it is treated as private land, and the Pueblo collaborates with the NRCS to address ecological restoration. Preliminary data provided through the NRCS in the form of a

biological survey in 2009 documented the poor ecological condition of the Hueco Tanks property, with the majority of vegetation being small shrubs and cactus. Through a Grasslands Restoration project, remote sensing technology was used to demonstrate the sheer magnitude and dominant presence of creosote bush (*Larrea tridentata* (DC.) Coville) (a high water use plant species) at the site. The creosote bush reduced grassland habitat and, consequently, compromised the wildlife species that depend on that habitat.

History of the Ysleta del Sur Pueblo Hueco Tanks Traditional Lands

The Tigua Indians of Ysleta del Sur Pueblo originated from the Pueblo of Isleta, just south of Albuquerque, New Mexico. During the Pueblo Revolt of 1680, Tigua ancestors were forcibly displaced by the Spanish to the Pueblo's current checkerboard land configuration within the cities of El Paso and Socorro, Texas. Traditionally, the Pueblo has maintained a peaceful existence in this region relying on sustainable activities such as hunting and agriculture. By 1987, due to infringement by non-Indians, only 68 acres (28 hectares) of Tribal lands remained. Through acquisition of properties, however, most not held in trust by the U.S. government, the Pueblo has been able to build its land base up to its current 74,050 acres (29,970 hectares) of non-adjoining properties in El Paso, Jeff Davis and Presidio Counties in west Texas. This undeveloped land in the middle of a metropolitan area is of great significance to the people of the Pueblo, helping keep Tribal members connected to the earth and the principles of the ancestors and providing sites to educate the youth in the old teachings of how to tend the land, and preserve and conserve resources.

The Ysleta del Sur Pueblo began restoring the site by eradicating species such as creosote and tar bush (*Flourensia cernua* (DC)) through herbicide control, installing three large water tanks with rain catchment fans and wildlife watering holes, and erecting proper fencing to control cattle. The Tribe hosted a Working Effectively with American Indians training course, which included NRCS employees who serve both federally recognized Texas Tribes, as well as presenters from the Ysleta del Sur Pueblo and Kickapoo Traditional Tribe of Texas.

The Hueco Tanks property requires additional habitat restoration, conservation and remediation, and is a priority for the Pueblo and its Environmental Management Office (EMO). Completion of a comprehensive land survey will permit the Pueblo to implement the conservation measures that are greatly needed to sustain and re-develop areas within the Hueco Tanks Traditional lands. Acting as stewards, it is imperative for Pueblo people to protect and maintain the lands in a sustainable manner in order to uphold their traditions and culture and safeguard resources for the future. The creation of conservation policy and the implementation of infrastructure and strategies to continue Pueblo traditions as guardians of the land serve to enhance and strengthen the Pueblo's overall sovereignty.

The ultimate wildlife management goal for the Hueco Tanks Traditional Lands and for other Pueblo properties such as the Chilicote Ranch[44] is long-term conservation of rangelands and native wildlife species for cultural, aesthetic, historic and recreational purposes. The Pueblo has recently received NRCS support for a Seasonal High Tunnel[45] that will be used on a Tribal community garden under a CSP range management contract, along with financial assistance for fencing (through WHIP funding) and for brush management and a pumping plant for livestock water (through EQIP).

A Partnership of U.S. Customs and Border Protection and Federal Land Managers

Cross-terrain movement by undocumented migrants and U.S. Border Patrol personnel has had a negative impact on the environment and contributed to the deterioration of ecological function in upland ecosystems along the border.[46] Illegal border activity and continued border security operations create challenges for restoration; however, the Department of Homeland Security (DHS) has undertaken specific restoration projects, including enhancing habitat where feasible. In 2009, DHS and DOI signed a Memorandum of Agreement:

> …for the mitigation of natural and cultural resource impacts that have occurred or may occur in connection with U.S. Customs and Border Protection (CBP) construction activities to secure the borders of the U.S. from the threat of terrorism, the implements of terror, and illegal human and narcotics trafficking. It is specifically intended to address the actions CBP and DOI will

take to minimize, avoid, or mitigate potential impacts to natural and cultural resources arising out of CBP border security projects.[47]

With more than $12 million in funding from DHS, DOI has made progress on multiple habitat restoration and conservation projects, including assessments, revegetation and other habitat restoration, and habitat acquisition, primarily for threatened and endangered species. New research is improving the DOI's understanding of ecosystem-level effects of border security response.[48] CBP continues its partnership with DOI bureaus along the southwest border to execute revegetation projects and monitor their success as mitigation for CBP impacts.

Example: Agave Restoration at Coronado National Memorial

When the Tactical Infrastructure, also known as the border fence, was constructed along the southern boundary of the Coronado National Memorial (Sierra Vista, Arizona), more than 3,700 mature agave (*Agave palmeri* Engelm.) plants, which provide forage for lesser long-nosed bats (*Leptonycteris curasoae yerbabuenae)* were removed. Since 2011, the Park has collected seeds, and planted more than 5,000 agave seedlings. Under an intra-agency agreement, the NRCS Tucson Plant Materials Center (AZ) grew out the seedlings to be planted. The park has sponsored four volunteer days to plant the agave seedlings. Volunteers have included interested public, Arizona Native Plant Society members, Boy and Girl Scout troops, and grade school summer program students from Sierra Vista.

The agave seedlings and site maintenance has occurred on 10 acres (4 hectares) that were used during construction as an equipment and materials laydown area. This site was denuded of vegetation and the soil was compacted; this damage encouraged the spread of Lehmann's lovegrass (*Eragrostis lehmanniana* Nees). The park has implemented controls of this invasive plant, as well as other pests that damage the agave seedlings. The expected outcome of this conservation action is to restore the agaves that were removed from the environment during construction and provide future forage for the endangered lesser long-nosed bats.

Regional-Scale Restoration

Although site-based restoration can generate direct benefits, large-scale efforts are needed to address fragmentation, restore wildlife corridors, reduce threats from flooding and fire, and more. Regional-scale restoration requires higher levels of coordination and broader strategies than either species-centric or site-based restoration. Wildland fire, including fuel treatments taken to restore fire regime and related ecosystem composition and structure, is managed through the National Interagency Fire Center (NIFC), located in Boise, Idaho. The NIFC has no single director or manager; the eight agencies and organizations that are part of NIFC rely on interagency cooperation for decision making. Other management structures such as Landscape Conservation Cooperatives (LCCs) and Climate Science Centers, which reflect the complex nature of many resource dynamics, have been developed and are being tested for coordination of landscape assessments and action. These networks of partners have yet to define roles for LCCs in coordinating multi-agency management activities.

Multispecies: San Diego Multiple Species Conservation Program

The San Diego Multiple Species Conservation Program (MSCP) provides for large, connected preserve areas that address a number of species at the habitat level rather than species-by-species, and area-by-area. This creates a more efficient and effective preserve system, as well as better protection, for the rare, threatened and endangered species in the region. Contributing to the MSCP, the San Diego NWR, operated by the FWS, has initiated several projects to restore populations of Cactus wren (*Campylorhynchus brunneicapillus couesi*). Plant species restoration has focused on populations of cactus Otay tarweed (*Deinandra conjugens* (D.D. Keck) B.G. Baldw.), San Diego Ambrosia (*Ambrosia ambrosioides* (Cav.) Payne), Mexican Flannelbush (*Fremontodendron mexicanum* Davidson), Coast Live Oak (*Quercus_agrifolia* Née var. *oxyadenia* (Torr.) J.T. Howell) and Engelmann Oak (*Q. engelmannii*

Greene). Refuge managers also are restoring ecosystems such as vernal pools[49] and coastal sage scrub habitats, critical habitat for the threatened coastal California gnatcatcher (*Polioptila californica californica*) and endangered Quino Checkerspot butterfly (*Euphydryas editha quino* (=*E. e. wrighti*). Practices typically include seed collection, cultivation, planting and maintenance of native species; translocation of endangered and threatened species; invasive species control; and qualitative and quantitative monitoring. Monitoring data show that native species richness and cover are increasing throughout the site.

Restore New Mexico

In the early 19th century, grasslands dominated much of New Mexico. Over the past century, however, grasses have given way to invasive and noxious species—such as creosote, mesquite (*Prosopis* L.) and salt cedar—as a result of overuse, drought and other factors. These changes can be seen on coarse scale maps (Figure 5). The first map shows vegetation levels before European settlement; note the overwhelming presence of grasslands across the state. The second map shows conditions in 2006, in particular the vast expansion of shrub-dominated landscapes. The third map indicates progress in restoring grassland cover across the state.

In 2005, the New Mexico BLM launched the Restore New Mexico initiative with the goal of restoring disturbed lands on a landscape scale through an ambitious partnership approach. Landscape restoration has focused on controlling invasive brush species, improving riparian habitat, reducing woodland encroachment, and reclaiming abandoned oil and gas well pads. BLM is more than halfway to achieving its goal of 4 million acres (1.6 million hectares) restored and has become a model for a large-scale program involving numerous agencies, organizations, ranchers and industry groups.

The Malpai Borderlands Group

Now in its 20th year as a formal organization, Arizona's Malpai Borderlands Group (MBG) has proven successful in large landscape-scale conservation on the border with Mexico. This grassroots,

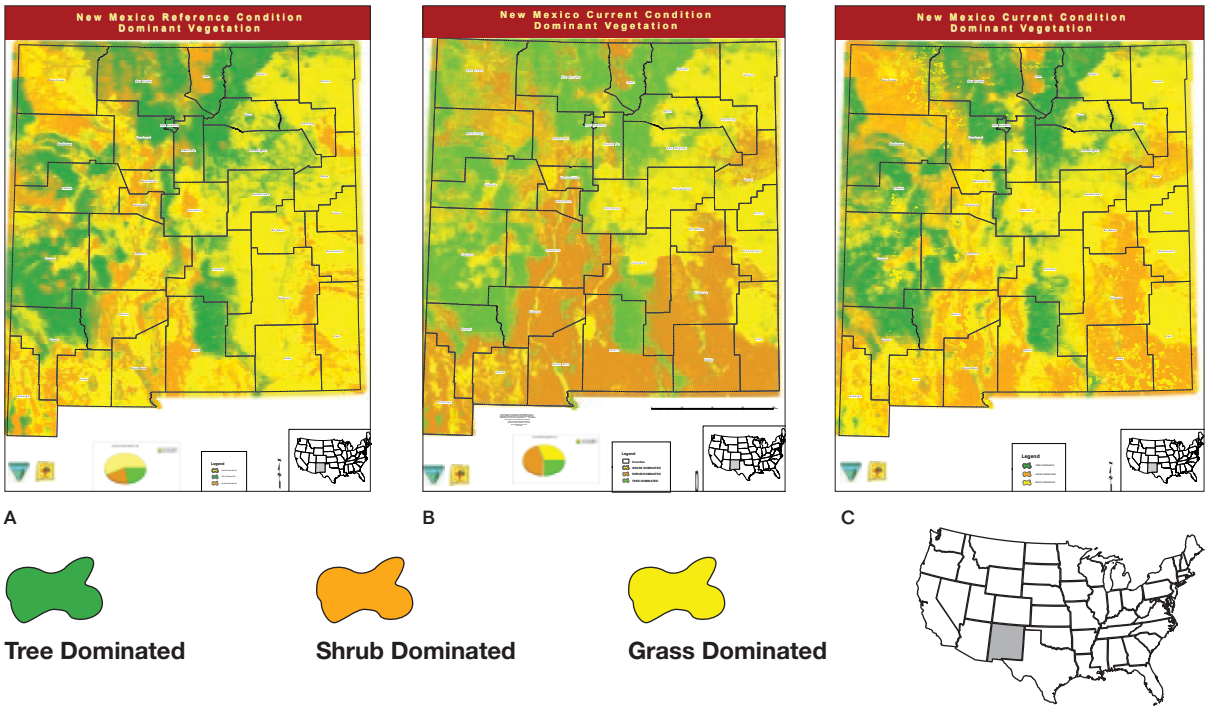


Figure 5. Estimated vegetation cover conditions at the time of European settlement (Map A) have been altered through a variety of human activities leading to widespread loss of grasslands by 2006 (Map B). BLM and its partners have made significant progress in restoring grassland cover while supporting grazing allotments across the state (Map C).

Source: Bureau of Land Management

landowner-driven nonprofit organization attempts to implement ecosystem management on nearly 1 million acres (400,000 hectares) of virtually unfragmented open-space landscape in southeastern Arizona and southwestern New Mexico. Four major ecosystems—the Rocky Mountains, the Sierra Madres, the Sonoran Desert and the Chihuahua Desert, with elevations ranging from 3,500 to 8,500 feet (1,100 to 2,600 meters)—include mountains, canyons, valleys and riparian corridors. Several rare, threatened, and endangered plant and animal species are found here; it is the only place in the United States where Gould's turkey and white-sided jackrabbits occur naturally and also is home to popular big-game species such as Coues deer (*Odocoileus virginianus couesi*), mule deer (*Odocoileus hemionus)*, pronghorn (*Antilocapra americana*) and desert bighorn sheep (*Ovis canadensis nelsoni*).

Fewer than 100 families reside in the Malpai borderlands area and many have been there for generations. The nonprofit MBG was formed to bring ranchers, scientists and key agencies together to carry out a series of conservation programs and activities, including land restoration, endangered species habitat protection, cost-sharing range and ranch improvements, and land conservation projects. Through conservation easements that block subdivision and development, the group has protected 78,000 acres (32,000 hectares) of private land. Innovative forms of cooperative land management such as "grassbanking" allow neighboring drought-stricken ranchers to move their herds to the Diamond A Ranch under reciprocal conservation agreements and thereby rest their own lands and natural resources. Habitat restoration projects focused on native grassland and savanna habitats include an ambitious goal of restoring fire as a natural landscape process. As a result, the MBG and partners have conducted prescribed fire burns on more than 69,000 acres (28,000 hectares).

The MBG has recognized the importance of monitoring and communication of results. Monitoring has documented improved ecological conditions over thousands of acres. Outreach to neighbors and cooperators has focused on new scientific and land management information and also has included workshops and tours with neighboring Mexican ranchers, scientists and governmental authorities.

The Lower Rio Grande Valley Wildlife Corridor

In south Texas, one of the fastest growing areas in the United States, approximately 95 percent of the habitat has been cleared. The FWS and state and local entities—including Texas Parks and Wildlife and many nonprofit organizations, private landowners and local communities—are focused on restoring, protecting and connecting habitat in south Texas. In one example, the Lower Rio Grande Valley National Wildlife Refuge and its many partners have been working since 1979 to create a wildlife corridor along the Rio Grande from Falcon Dam to the Gulf of Mexico. Land that either has good habitat or connects to habitat is purchased from willing sellers for inclusion in the refuge.

When complete, the Lower Rio Grande Valley National Wildlife Refuge wildlife corridor will be an east-west corridor that follows the Rio Grande and links into the southern tip of a sister refuge, the Laguna Atascosa National Wildlife Refuge. Through Laguna Atascosa, the connected habitat will extend up into the great Texas ranchlands, where private landowners are doing very important work to protect habitat on their own land. Recognizing their stewardship, the refuge supports private landowners who have an interest in managing wildlife on their property. The refuge offers private landowners interested in being part of the wildlife corridor technical assistance, conservation easements and other management tools. The FWS also has an agreement with Mexico where efforts are under way to create a similar wildlife corridor on the south side of the Rio Grande. Despite these efforts, connectivity of habitat blocks along the Rio Grande has not been achieved and habitat block sizes are too small to effectively maintain populations of megafauna such as the endangered ocelot.

Binational Restoration

As described above, regional-scale activities can and do take place across the U.S.-Mexico border. The Rio Grande/Rio Bravo watershed exemplifies both

the potential for and the challenges associated with binational ecological restoration.

The Big Bend reach of the Rio Grande is burdened by diminishing flows, climate change and the presence of two exotic and invasive species. The Big Bend Binational Initiative was established in 2010 to coordinate federal, state and private conservation activities in this area of west Texas. Support for these activities by the U.S. and Mexican governments is based on the 1997 Letter of Intent for Joint Work in Natural Protected Areas on the U.S.-Mexico border, the March 18, 2000 agreement on Cooperation in Management and Protection of National Parks and Other Protected Natural Areas, and the Joint Declaration of Sister Park Partnerships signed on March 23, 2006. These activities are further strengthened by more recent commitments by U.S. Secretary Salazar and Mexican Minister Elvira to "build upon our shared history of ecosystem and species conservation." U.S. and Mexican agencies are working together to establish the Big Bend reach of the Rio Grande and its tributaries as the aquatic center pieces of an emerging binational conservation area. The Rio Grande, its tributaries, the surrounding Sky Islands and the intervening arid grasslands form the core of this biological region. Through programs like the National Park Service Sister Parks Initiative, work is intended to (1) increase binational conservation capacity and cooperation; (2) develop and implement conservation projects and the necessary support science to demonstrate improved resiliency to climate change; and (3) complete a conservation assessment of the region.

Current restoration objectives are focused on restoring gallery forests along tributaries to improve riparian aquifers and resilience to climate change, managing and eliminating exotic invasive riparian plants along a 45-mile reach of the Rio Grande, and improving hydrology on severely degraded desert grassland sites. In support of these projects, the initiative is working to understand and quantify the role exotic riparian plants play in diminishing aquatic habitat, developing binational conservation monitoring protocols and increasing the capacity of the Sister Parks Initiative.

CHALLENGES

The examples in the preceding section illustrate that through innovative approaches, progress toward ecosystem restoration has been made. The cases also point to specific issues that, if addressed, would increase the success of individual projects and the potential for regional-scale restoration. This section identifies some key challenges.

Working in the Border Environment

Increased drug cartel activities along the border have heightened the need for security for professional and volunteer staff conducting restoration. For example, at Organ Pipe National Monument, staff require an armed law enforcement escort as they conduct field activities in many sections of the Park. Likewise, the standard operating procedures (SOPs) at each border NRCS field office include preventative safety measures such as every employee having a cell phone and satellite Global Positioning System (GPS) messenger equipment when working along the border, as well as OnStar vehicles.

Building and Maintaining Capacity

Even where goals are clear, metrics have been developed, and partners have been identified, lack of project/program management, staff and funding hampers ecological restoration efforts in the border region. Annual federal budget allocations fluctuate, are rarely provided in a timely manner, and may not reflect multiple-year planning needs that are the reality of restoration projects. Restoration projects must compete for limited resources, and, despite the long-term value of and future savings associated with restored ecosystems, immediate needs frequently take priority and leave restoration projects with insufficient resources. For example, despite efforts of the BLM-supported Seeds of Success Program, plant materials are rarely available for the correct species and correct locations. Cross-agency funding of invasive plant control is unwieldy, and restoration dollars for fuel treatments are all too often diverted to Wildland Urban Interface fire response.

Responding to External Stressors

Managers typically can find ways to restore attributes of degraded resources once impacts to those resources have ceased. The reality of work today is to improve organism health and ecological integrity in the context of constant inputs of invasive species, and contaminants, all within a constricted range of ecological "space" and range of ecological processes that can facilitate resource recovery. Managers now must identify "sustainable" resource conditions under shifting climate envelopes with no certainty of how the restored biological community components will respond to novel environments and biological neighbors.

Example: National Wildlife Refuges—Confronting Multiple Complex Challenges

In south Texas at the Lower Rio Grande Valley and Laguna Atascosa National Wildlife Refuges, FWS managers are working to restore 10,000 acres (4,000 hectares) of native Tamaulipan Brushland. Managers are faced with a range of challenges, including past agricultural land practices (e.g., clearing, grazing), changes in the fire regime (e.g., increased ignitions and fire frequency, past fire suppression), and establishment of invasive plants and animals (e.g., alien grasses and forbs, alien aquatic organisms, forest pests). Although many of these acres have been planted with the assistance of the Cooperative Farming Program and local conservation nongovernmental organizations, seedling survivorship among sites varies between 20 to 80 percent. Problems for long-term success include lack of flooding of the Rio Grande, which flooded historically one to two times per year, and native plant competition with exotic grasses such as guineagrass (*Urochloa maxima* (Jacq.) R. Webster), Kleberg bluestem (*Dichanthium annulatum* (Forssk.) Stapf) and buffelgrass. Managers also cite a lack of mapping, assessment and restoration work on site soils.

Addressing Emerging Issues

Two emerging issues warrant special attention: scaling and connectivity. Given the size of the U.S.-Mexico border region and the limited resources available for restoration activities, managers must seek efficiencies

of scale. Project work typically is conducted on sites less than 100 acres (40 hectares). In some cases, work is implemented with a broader vision of ecological integrity across large areas, but work is driven more by local species habitat requirements, and not species range and large-scale ecological processes such as regional stream flows and animal movement. Each of these projects requires separate assessments, goal structuring and planning, the use of or procurement of trained equipment operators, the collection and increase of plant materials, localized herbicide treatments and monitoring.

The need for connectivity is another important concern, especially in light of the fragmentation of habitats, multiple jurisdictions and political boundaries, as well as physical barriers such as the border fence. Connectivity is necessary at all scales, from the local to the ecoregional, but it is generally lacking across the border region. For example, along the Rio Grande, habitat blocks are too small to effectively maintain populations of megafauna such as the endangered ocelot, and those that exist are not adequately connected.

Related to both of these issues is a concern with the timing of restoration activities. If projects are not coordinated, then even where they are successful individually, and where plans may be in place for expansion to other

Emerging wetland and riparian habitats (A & B) at Rio Bosque Wetlands Park.
Source: John A. Sproul, Jr., Rio Bosque Wetlands Park Center for Environmental Resource Management, The University of Texas at El Paso

areas, gains may be lost if invasive species regain a foothold, wide ranging species leave the project area but cannot survive elsewhere, and removal of significant stands of salt cedar is off-set by a lack of cottonwood (*Populus* spp.) planting elsewhere for native birds that also can use salt cedar stands for shelter.

OPPORTUNITIES FOR IMPROVING ECOSYSTEMS AND INCREASING SUCCESS

In addition to the projects and initiatives already under way in the border region, and despite the challenges identified in the preceding section, there are many opportunities for the U.S. federal government to incorporate environmental restoration in existing programs and routine operations. This section describes some of those opportunities.

Identifying and Implementing Effective Partnerships, Approaches and Science

Ecological Integrity Framework as a Tool for Developing Cross-Agency, Cross-Project Standards

Ecosystems are complex interlinkages of living and nonliving components that fulfill particular functions. As noted elsewhere, a key challenge in ecological restoration has been identifying appropriate goals and metrics for measuring success. Ecological integrity has been defined as "the ability of an ecological system to support and maintain a community of organisms that has species composition, diversity, and functional organization comparable to those of natural habitats within a region."[50] An ecological system has integrity when it can withstand and recover from perturbations imposed by natural environmental dynamics or human disruptions. An Ecological Integrity Framework, developed by scientists at The Nature Conservancy and built into the core methodology of NatureServe, provides a logical, step-by-step approach to help managers identify ecosystem conditions and thresholds for change.[51] A key opportunity for federal managers, and their collaborators and partners, is to adopt this framework.

Resilience Thinking as a Concept to Address Uncertainty

In ecological systems, the concept of resilience emerged in the early 1970s as a challenge to stability thinking. Resilience thinking has evolved into a more elaborated theory in which adaptability and transformability are key ingredients. Adaptability refers to the capacity of a system (or parts of a system) to learn and adjust within a range of variability, or within

a stability domain. Transformability is the capacity to evolve into a fundamentally new system when existing conditions are untenable. Resiliency approaches can be successful when the resiliency "of what" and "to what " are clearly articulated, and key challenges must be addressed to unpack the social dimensions of resilience in the context of specific places and problems, and to move towards interdisciplinary understanding of social-ecological systems.[52]

The Desert Landscape Conservation Cooperative

The Desert Landscape Conservation Cooperative (Desert LCC) was formed by the Bureau of Reclamation and the FWS and encompasses portions of five states: California, Nevada, Arizona, New Mexico and Texas, as well as a substantial portion of Northern Mexico. It is a binational, self-directed, nonregulatory regional partnership that seeks to provide scientific and technical support, coordination and communication to resource managers and the broader Desert LCC community "to develop a coordinated, science-based response to climate change and other landscape-scale stressors."[53] The Desert LCC is guided by a 24-member steering committee comprised of representatives of resource management entities as well as interested public and private entities in the Mojave, Sonoran and Chihuahuan Desert regions of the southwestern United States and northern Mexico.

The Desert LCC also is one of the 22 LCCs created by DOI to address the impacts of climate change on America's water, land and other natural and cultural resources. It is focused on acquiring and sharing information to support the development of landscape level strategies for understanding and responding to climate change impacts and other large-scale ecosystem stressors such as land use change, invasive species, wildfire and drought.[54] As the Desert LCC "matures," it has the potential to move beyond information sharing and play a more active role in multi-project coordination.

In 2014, the FWS asked the National Academy of Sciences to convene an *ad hoc* committee to examine the LCC program. The National Research Council study, "Evaluation of the Landscape Conservation Cooperatives," anticipated to be released in summer 2015, will evaluate the purpose, goals and scientific merits of the program within the context of similar programs, and whether the LCC program has resulted in measurable improvements and progress toward its stated goals.[55]

Emerging Science for Urban Ecosystems

Urban ecological restoration is a critical need and focus for the U.S.-Mexico border region because border communities face heightened environmental and public health risks associated with ecosystem degradation (e.g., risks arising from floods, fire, dust, water contamination and newly emergent disease vectors). In urban areas, restored soils, air and watersheds can have direct positive environmental and health benefits as well as provide many important social and economic benefits such as enhanced social cohesion, increased real estate values, and improved recreational opportunities. The many challenges facing urban ecological restoration necessitate finding ways to: (1) recognize and take into account the role of human values, perceptions and actions in shaping the landscape; (2) address gaps that thwart the equitable co-production and use of knowledge for problem solving, solutions oriented research and action; and (3) respond to rapid global geopolitical and economic change.

The National Science Foundation (NSF) funds 26 Long Term Ecological Research (LTER) Stations across the country. In 1997, NSF funded two Urban Ecology LTERs, including the Central Arizona-Phoenix area, as one of the first comprehensive efforts to understand the ecology of cities. This research will yield valuable information to identify and restore natural resource values within urban constraints. To date though, no federal program exists to support active management in degraded sections of cities under a broad ecological restoration context. This will become increasingly important as growing cities must address carrying capacities within existing infrastructure and expansion into new areas, including the annexation of *colonias* into municipal boundaries.

Landscape-Level Assessments for BLM Lands

The BLM adopted an ecoregional direction for its Rapid Ecoregional Assessments (REAs), and along with input from partner agencies, stakeholders and American Indian Tribes, will use information from these studies to develop landscape-level management strategies for BLM-managed lands. This approach will help coordinate the partners' efforts to achieve vital resource management goals beyond administrative jurisdictions. To accomplish this, the ecoregional direction will identify focal areas on BLM-managed lands for conservation and development, including focal areas for conserving wildlife habitats and migration corridors, and focal areas for potential energy development and urban growth. The results of an initial review validate the importance and value of a landscape-scale approach to understanding the conditions, trends and opportunities across the landscape, and applying this information in managing smaller, local land areas.[56]

Multi-Level and Cross-Border Coordination

Many opportunities exist to coordinate efforts across U.S. federal agencies, with Mexico, and with Tribal, state and local entities. Communication and coordination can help reduce overlap, duplication of effort and inefficiencies in ecological restoration efforts. The Western Regional Partnership (WRP) provides a proactive and collaborative framework for senior-policy level federal, state and Tribal leaders to identify common goals and emerging issues in the states of Arizona, California, Nevada, New Mexico and Utah. The WRP also works to protect natural resources, while promoting sustainability, homeland security and military readiness.

In another example, management of invasive species is a key element of many ecological restoration initiatives, and is a priority subject in the biodiversity work program of the Commission for Environmental Cooperation for North America. The U.S. National Invasive Species Council (NISC)[57] provides high-level interdepartmental coordination of federal invasive species actions and works with other federal and nonfederal groups to address invasive species issues at the national level.[58] Yet to date, the NISC has focused only in the United States. The Mexican *National Strategy on Invasive Species in Mexico: Prevention, Control, and Eradication* identifies coordination among different government branches, sectors, institutions and the general public as one of five key cross-cutting strategic actions.[59] Efforts to integrate across the U.S.-Mexico border could increase the success of both initiatives.

Minimizing Degradation and Extending Restoration Activities

Many U.S. federal agencies that are active along the U.S.-Mexico border are not directly involved with environmental restoration. Nevertheless, through careful planning and action, they can reduce environmental degradation and, in some cases, extend the reach of restoration activities. The following are some examples.

U.S. Environmental Protection Agency

The 1983 La Paz Agreement empowers the federal environmental authorities in the United States and Mexico to undertake cooperative initiatives. The agreement is implemented through multi-year binational programs for which the U.S. Environmental Protection Agency (EPA) and Mexican Secretary for the Environment and Natural Resources (Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT)) serve as National Coordinators. The Border 2020 Program is the latest environmental effort implemented under the Agreement. It builds on the Border 2012 Environmental Program, emphasizing regional, bottom-up approaches for decision making, priority setting and project implementation to address the environmental and public health problems in the border region.

The mission of the Border 2020 program is to protect the environment and public health in the U.S.-Mexico border region, consistent with the principles of sustainable development. In this program, sustainable development is defined as "conservation-oriented social and economic development that emphasizes the protection and sustainable use of resources while addressing both current and future needs and present and future impacts of human actions."[60]

Department of State

Under Executive Order 11423, as amended, the Secretary of State has the authority to receive applications for and to issue Presidential permits for the construction, connection, operation or maintenance of certain facilities at the borders of the United States with Canada and Mexico. Permits are required for the full range of facilities at the border, including land crossings, bridges, pipelines, tunnels, conveyor belts and tramways. This authority applies to all new border crossings and to all substantial modifications of existing crossings at the international border. Working with federal agencies such as the Department of Transportation (DOT), the General Services Administration (GSA), the Department of Homeland Security's (DHS) CBP, and EPA; coordinating closely with concerned state and local agencies; and inviting public comment, the Department of State (DOS), determines whether a proposed border-crossing project is in the U.S. national interest. Consistent with the National Environmental Policy Act (NEPA), in considering an application for a Presidential permit, the Department takes into account environmental impacts of the proposed facility and directly related construction.

The DOS and the Mexican Secretariat of Foreign Relations co-chair the U.S.-Mexico Binational Bridges and Border Crossings Group (BBBXG), which is comprised of federal and state agencies with an interest in border crossings, including the DOT, DHS, GSA, and state departments of transportation as well as their corresponding agencies in Mexico. The BBBXG meets three times a year to discuss operational matters involving existing and proposed bridges and border crossings and their related infrastructure, and to exchange views on policy as well as technical information. These meetings include a public session where stakeholders, local government agencies and project sponsors have an opportunity to address the group.

Department of Homeland Security

To help Border Patrol agents consider the environment as they carry out their responsibilities in some of the most remote regions of the United States, the DHS' CBP, in conjunction with the DOI, developed an Environmental Cultural Stewardship Training Virtual Learning Course. This effort is enhancing the training of all Sector Public Land Liaison Agents (PLLAs) to help them communicate within the cultural and environmental community. Included in this enhanced training is the Archaeology and Paleontology for Law Enforcement Officers course, which is a joint CBP and BLM class. In coordination with federal land management partners from the FWS and BLM, CBP also developed a 3-day PLLA Environmental Overview class. Within the Yuma Sector (Yuma, Arizona), CBP is piloting a 2-hour training on sensitive cultural or ecological resources, tailored to the local area and flexible to allow for the changing border conditions. CBP also is implementing cultural and ecological briefings for any agent who is assigned to work at Camp Grip (Wellton, Arizona).

CBP, through the Border Patrol Facilities and Tactical Infrastructure Program Management Office, also is conducting environmental Best Management Practice (BMP) training and education for field personnel who are involved in construction, maintenance or repair projects. This training is held both quarterly and at the initiation of each project on the southwest border so personnel can be notified of any BMPs or environmental requirements generally or specifically required during execution of the project.

Department of Transportation

DOT environmental review policies call for avoiding or minimizing adverse effects where possible and restoring or enhancing environmental quality through federally assisted transportation programs and other DOT actions. For federally assisted transportation projects, mitigation expenses are generally eligible as part of project costs. Some Federal-Aid highway programs explicitly allow for environmental restoration. Transportation decisions are made through a state and metropolitan transportation planning process that allows states and communities to plan for long-range transportation needs and short-term transportation improvement programs. DOT planning policies call for consideration of plans for protecting environmental resources and mitigation of adverse impacts in development of statewide and metropolitan transportation plans.

The Federal Highway Administration (FHWA) and seven other federal agencies developed "Eco-Logical," a process that promotes ecosystem-based mitigation and integration of plans and data across agency and disciplinary activities. The FHWA is working with transportation, resource and regulatory agencies to implement the Eco-Logical approach on a national scale. Ecosystem-based mitigation and integrated planning can be used to make infrastructure more sensitive to terrestrial and aquatic habitats, and make mitigation of unavoidable impacts more effective.

U.S.-Mexico Joint Working Committee on Transportation Planning

The primary focus of the U.S.-Mexico Joint Working Committee on Transportation Planning (JWC) is to cooperate on land transportation planning and the facilitation of efficient, safe and economical cross-border transportation movements. The group is co-chaired by transportation professionals from the Federal Highway Administration (FHWA) and the Mexican Secretariat of Communications and Transportation (SCT) and includes representatives from the DOS, the Mexican Secretariat of Foreign Relations, and the departments of transportation of the four U.S. border states and the six Mexican border states. The General Services Administration (GSA) and DHS' CBP also participate in JWC meetings. The JWC promotes effective communication concerning transportation planning between U.S.-Mexico Border states and works to develop a well-coordinated land transportation planning process along the border. Among other efforts, the JWC works to establish methods and procedures to analyze current and future transportation infrastructure needs and evaluate transportation demand and infrastructure impacts resulting from future changes in land transportation traffic. The JWC is supporting the development of a compendium of border-wide regional master plans with a comprehensive and prioritized assessment of transportation needs along the border, including the Port of Entry (POE).

The U.S.-Mexican border is one of the busiest, most economically important borders in the world. Eighty percent of U.S.-Mexican trade crosses the land border on trucks and trains. Here, the DOT works with relevant stakeholders to ensure binational planning of transportation infrastructure such as access roads and bridges, and operations such as transportation performance and intelligent transportation systems. This involves close coordination with the government of Mexico, as well as relevant border states and metropolitan planning organizations. This transportation planning is conducted by the binational border transportation working group: the U.S.-Mexico Joint Working Committee on Transportation Planning (JWC). The DOT also is engaged in President Obama's High Level Economic Dialogue (HLED) with Mexico. The HLED work plan was designed to coordinate shared interests and priorities affecting the growth and competitiveness of the U.S. and Mexican economies, focusing on those linkages where the two countries can collaborate to promote mutual prosperity.

North American Development Bank and the Border Environment Cooperation Commission

The North American Development Bank (NADB), and its sister institution the Border Environment Cooperation Commission (BECC), are binational institutions created by a side-agreement to NAFTA to "preserve, protect and enhance the environment of the border region in order to advance the well-being of the people of the United States and Mexico." More specifically, the BECC evaluates and certifies infrastructure projects for funding by the NADB.

The institutions are governed by a single, 10-member Board of Directors, comprised of one representative each from the DOS, DOT, EPA, and Mexican government equivalents, as well as a representative of a border state from each country, and a representative of the general public who resides in the border region from each country.

As part of the process to obtain grants through the Border Environment Infrastructure Fund of NADB, BECC develops and provides an Environmental Infrastructure Document to EPA. This document reviews impacts to threatened and endangered species in the project area.

Chapter Three: Border Watersheds and Ecological Restoration

Throughout the U.S.-Mexico border region, water is a critical factor affecting environmental and economic conditions. The water supply system in the U.S.-Mexico border is comprised of two major river systems and includes 20 transboundary aquifers.

Various commissions, agencies, districts and other entities have been established to help determine how scarce border water resources can be utilized optimally and their quality safeguarded.[61] Watersheds are critically important to ecological, social, political and economic conditions across the region, and this chapter is devoted to border watersheds and ecological restoration within them.

The GNEB has addressed watersheds and water resources along the border since its first annual report. The fourth, eighth and fifteenth GNEB reports were entirely on water; the fourth report advocated the institutionalization of a border-wide watershed approach. In addition, major parts of the fifth and twelfth reports were about water and water issues. This chapter builds on the earlier work and recommendations of the GNEB, focusing on the potential and challenges for ecological restoration within the three largest border watersheds, the Colorado and Rio Grande/Bravo (see Figure 6), and the Tijuana (see Figure 7).

Key goals of agencies and organizations involved in watershed restoration in the border region include:

1. Reintroduction of self-sustaining populations of extirpated native fish species
2. Restoration of riparian plant communities

3. Restoration of upland plant communities
4. Restoration of wetlands
5. Reestablishment of flow and sediment equilibrium
6. Reestablishment of base flow conditions
7. Reduction or elimination of invasive species
8. Reestablishment of a healthy stream/riparian system.

WATER RESOURCE ISSUES

Water resources of the U.S.-Mexico border include shared rivers, aquifers and reservoirs and lakes. The two major border rivers are the Colorado and the Rio Grande and there are many minor rivers such as the Tijuana, New, San Pedro and Santa Cruz Rivers. Major reservoirs and lakes include the Amistad and Falcon reservoirs on the Rio Grande and the Salton Sea in California. The Pacific Ocean and the Gulf of Mexico also form part of the border water resources.

Managing the supply, quantity and use of scarce border water resources is challenging, as governance is fragmented. In Mexico, the federal government manages surface and groundwater and establishes water quality standards; in the United States groundwater management lies with the states (and each state has a different regulatory regime) while surface water management may be addressed by various state and federal agencies. States administer water rights, set water quality standards (subject to U.S. Environmental Protection Agency [EPA] review) and can develop large-scale water projects.

The interaction between groundwater and surface water is critical; often groundwater provides spring flow, a key ecological resource. For example, San Felipe Springs near Del Rio, Texas provides surface water to the Rio Grande and habitat for the plants and animals, such as the Rio Grande bugheal (*Trichocoronis rivularis* A. Gray), a submersed aquatic plant that is found only in small, spring-fed systems near Del Rio and in northern Coahuila and Nuevo León.[62]

Precipitation varies widely along the border, with annual precipitation varying between 3 inches per year in Imperial Valley, California and 28 inches per year in Brownsville/Matamoros (Nogales, Arizona, 19; San Diego, California, 12, and El Paso, Texas, 8).[63] The region also experiences drought and heavy rainfall, including flooding.[64]

Two primary water treaties govern water resources of both countries: the Convention of 1906 and the 1944 Water Treaty. The Convention of 1906 applies to the international reach of the river between El Paso, Texas-Ciudad Juárez, Chihuahua and Fort Quitman, Texas, in Hudspeth County, the county just downstream of El Paso County. The 1906 Convention (a treaty) provides for the United States to deliver to Mexico 60,000 acre-feet (70 million cubic meters) per year of Rio Grande water for agricultural use at Ciudad Juárez. In case of extraordinary drought, the water delivered to Mexico can be reduced.[65] The Water Treaty of 1944 allocated the waters of the Colorado River and Rio Grande between the two countries; provided for the construction of reclamation

Figure 6. The Rio Grande and Colorado River watersheds.
Source: International Boundary and Water Commission (IBWC)

works on the main channel of the international reach of the Rio Grande; allowed the newly created International Boundary and Water Commission (IBWC), United States and Mexico, to give preferential attention to the solution of border sanitation problems; and provided the IBWC with authority to apply and interpret the terms of the Treaty with the consent of the two governments.

The IBWC has responsibility for applying the boundary and water treaties between the two countries and settling differences that may arise out of application of these treaties. Application of the treaties has required major modifications to the Rio Grande and its channel. For example, the Rio Grande Rectification Project covers 86 river miles (140 river kilometers) from El Paso, Texas-Ciudad Juárez, Chihuahua to Fort Quitman, Texas. Its purpose is to provide flood protection and to stabilize the international boundary line. It was constructed in the 1930s in accordance with the Convention of February 1, 1933, to address problems that occurred when the twisting river shifted, thereby affecting the international boundary. To stabilize the boundary, loops in the river were removed, shortening the channel length from 155 miles to 86 miles (249 kilometers to 140 kilometers) and resulting in a rectified river channel in the center of the floodplain and flood control levees in both countries.

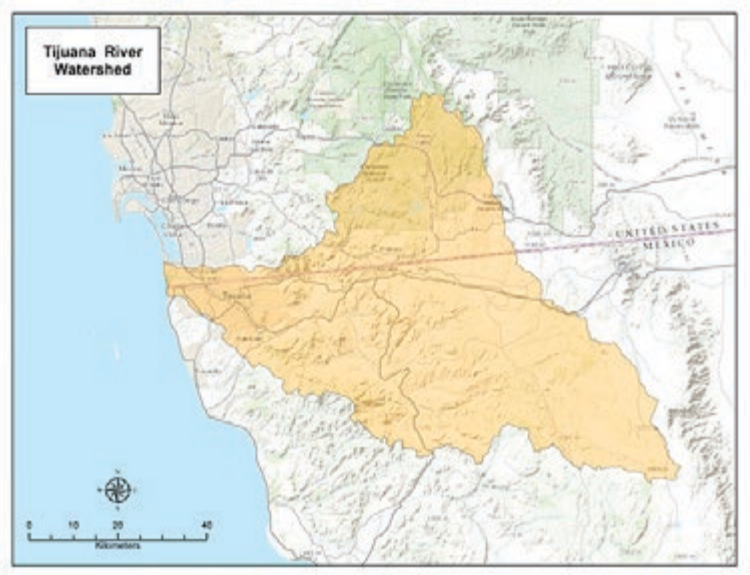


Figure 7. The Tijuana River watershed.
Source: International Boundary and Water Commission (IBWC)

CHALLENGES FOR ECOLOGICAL RESTORATION IN BORDER WATERSHEDS

Achieving the ecological restoration goals outlined above will require overcoming institutional, ecological and geomorphological challenges, among others.

Institutional Challenges

For the Colorado River and Rio Grande, the major institutional challenge for ecological restoration of border water resources has been the emphasis on water for agricultural, industrial and municipal uses over other uses. The 1944 Water Treaty contains a specific order of preferences, giving the highest priority to domestic and municipal uses followed by agriculture and stock raising, electric power, other industrial uses, navigation, fishing and hunting, and any other beneficial uses that may be determined by the IBWC.[66] This emphasis on irrigation and municipal supplies affects not just the rivers regulated by treaty but also other rivers, lakes and aquifers in the border region. Except in flood conditions, all U.S. waters of the Rio Grande under both the Convention of 1906 and the 1944 Water Treaty belong to water rights holders, and in the United States, these water rights are granted by state agencies. Coupled with other management practices, the priority of uses has reduced water availability for fish and other aquatic organisms.

Because of agricultural, livestock, industrial and municipal demands, addressing environmental needs poses special challenges. Among the more specific consequences of the prioritization of irrigation and municipal needs for the Colorado River and Rio Grande are:

- Dams are managed largely for agricultural irrigation purposes, making restoration of river flows, such as release of water during non-irrigation season, difficult. For these rivers, like many in the Southwestern United States, irrigation accounts for the vast majority of surface water use.

DOI Deputy Secretary Michael Connor plants a tree at Laguna Grande Restoration Site B1.
Source: Andrew Pernick with the Bureau of Reclamation

- Much of agriculture uses flood irrigation, in part due to low cost of water.
- Riparian and aquatic habitats are not explicitly recognized as water uses in the international treaties, although fishing and hunting are acknowledged.
- Although in recent years there has been a gradual shift from agricultural to municipal water rights as some farmers decide to sell their water shares, this shift has not led to more water being physically present in the river, but just to a change in use.

Ground water resources are managed by both state and local authorities, with very limited federal involvement. These groundwater resources can be of vital importance to ecological restoration due to their role as the source of aquifer-fed springs that feed into larger water bodies, as well as their role in providing base flow to larger river systems. In a region that has been affected by drought in recent years, the lack of surface water also has led to increased groundwater pumping, putting spring flow from aquifers in peril. Thus, overpumping of local and transboundary aquifers can pose challenges to ecological restoration of riverine systems.

Unfortunately, the link between groundwater and surface water has not been recognized in international treaties. An effort to work more collaboratively on shared aquifers, however, has occurred within the context of the Border 2020 program as well as through the Transboundary Aquifer Assessment program, an unprecedented effort to align earth science data (hydrology, geology, precipitation, etc.) and collaboratively map four priority aquifers, the Santa Cruz River Valley aquifer and San Pedro aquifer underlying Arizona and Sonora, the Hueco Bolson aquifer near El Paso/Ciudad Juárez, and the Mesilla/Conejos-Médanos aquifer at the New Mexico-Chihuahua border.[67] The reports provide foundational information on current aquifer characteristics that are important for policy makers, land managers and stakeholders involved in water management, including efforts to restore or prevent degradation to ecological systems. They are the culmination of binational field visits, workshops, identification and analysis of available data and needs, and cooperative task assignments to fill gaps. The Arizona-Sonora transboundary collaboration and the IBWC Cooperative Framework, established by a Joint Report to facilitate U.S.-Mexico coordination and dialogue, can serve as a model for meeting similar informational and analytical needs about aquifer characteristics elsewhere along the U.S.-Mexico border region.

Getting from assessments of these aquifers, to more specific management—including managing aquifers in a way to assure that base flows of rivers are maintained—is a difficult institutional challenge. Although there has been some effort to police groundwater pumping in local aquifers that is directly tied to the Rio Grande, there continues to be controversy: Texas and New Mexico have been in disagreement for many years over the pumping of groundwater along the Rio Grande in New Mexico and its impacts on flow.[68] In Texas, pumping has received some regulation through groundwater districts, although a landowners "right of capture," long acknowledged since a Texas Supreme Court ruling in 1904, now is recognized in state law.

Physical Challenges

Physical changes to the region's water resources include dams and changes in the release of waters, as noted above, channelization, reduced snowpack and snowmelt in the spring, pumping of local aquifers, and reduced inflows from tributaries from Mexico. Fundamentally, this has reduced flows within the rivers

themselves, and increased the highs and lows in the flow regime. Key physical challenges include:

- **Channelization and rectification in the Upper Rio Grande.** The straightening of the river in defined banks flanked by levees limits the natural variability of channel formation. Although some of this channelization is related to urban areas where there are defined land use patterns that limit the ability to allow channels to meander, other areas are decidedly rural yet have been unnaturally straightened. This also limits the riverine habitats that might otherwise exist.

- **Irrigation and climatic change.** The elimination of peak flows in the spring due largely to the irrigation release schedules of the dams for agricultural purposes, along with climatic changes that have seen reduced snow packs and spring inflow, has had a profound impact on the Rio Grande. For one, these reduced "flushes" have allowed vegetation like salt cedar to gain a foothold and dominate the riverine banks and channels themselves.

- **Reduced flow from Mexico and the Río Conchos.** Under the terms of the 1944 Water Treaty between the United States and Mexico, the United States has the right to one-third of the water that originates from six Mexican tributaries. The amount of water is supposed to average at least 350,000 acre-feet (432 million cubic meters) per year, in cycles of 5 years. In the past 2 decades, Mexico has not always provided its waters to the United States, even in higher water years because of flooding. Nowhere has this been more true than the flows coming from the Río Conchos, which enters the Rio Grande near the twin cities of Ojinaga, Chihuahua and Presidio, Texas.

Ecological and Geomorphological Challenges

Flood control has been a major challenge. Because of development in the floodplains along the Rio Grande and policies to keep the river from shifting course, levees and other devices have limited overbank flow. Reduced inflows from dam management and overpumping of groundwater have diminished flooding over the banks, and the river banks have been starved of floodwaters that contribute to ecological restoration. Several examples of ecological and geomorphological challenges include:

- **Channel degradation below dam and aggradation beyond.** Dams over time cause the river channel to degrade below the dam structure, with the river getting starved of nutrients and sediment and aggrading beyond this initial degradation.[69] In the Rio Grande, sediment buildup occurs well upstream and downstream of the dams, essentially choking the river channel itself.

- **Reduced floodplain.** The combination of lower overbank flow regimes and urban and rural development has affected the normal floodplain cycles and their evolution. Finally, the development of levees has further impeded the normal floodplain flows.

- **Non-native species introduction.** Non-native species of concern include salt cedar (*Tamarix* spp.), giant reed (*Arundo donax*), giant salvinia or Kariba-weed (*Salvinia molesta* Mitchell), hydrilla (*Hydrilla verticillata* (L.f.) Caspary) and water hyacinth *(Eichhornia crassipes*). Invasive species along the Colorado River and Rio Grande and their tributaries have profoundly affected flows, quantity, quality and sediment buildup, and have had other unforeseen effects.

- **Biological controls of invasive species.** These can have unintended consequences and transboundary side effects. To attack the invasive species salt cedar, the Animal Plant and Health Inspections Service (APHIS) of USDA released a non-native beetle as a biological control of salt cedar. Although the results have shown great promise in salt cedar stands in the Rio Grande Basin, the Tunisian beetle (*Diorhabda sublineata*) also attacked athel (*Tamarix aphylla)* trees in Mexico near Ojinaga. Athel trees grow to a height of 60 feet (18 meters).[70]

- **Reintroduction of threatened and endangered species.** In the fifteenth GNEB report, the reintroduction of the endangered Rio Grande silvery minnow (*Hybognathus amarus*), a species extirpated since the 1960s in the Rio Grande, was highlighted. The release of the minnow was a partnership among several state and federal agencies and the recovery continues to be monitored.[71]

- **Loss of important habitat for fish and wildlife.** Channelization, including straightening of the river and removal of side channels, has eliminated the slow-water habitats that serve as spawning and nursery grounds for native fish as well as the off-channel aquatic habitats that provide refugia for fish when the river is dewatered. Frequent mowing of the river's banks for flood control purposes has eliminated riparian plant communities that provide important wildlife habitat.
- **Construction of the border fence.** Construction of the border fence mandated by Congress has, in certain areas, had the side effect of destroying habitat corridors and affecting aquatic ecosystems. The Nature Conservancy's Southmost Preserve in South Texas was cut in half by the border fence, affecting the wildlife corridor of the endangered ocelot (*Leopardus pardalis*).[72] The GNEB's December 2009 letter to the President on the border fence highlights the construction of the triple fence in the Tijuana River estuary.

OVERCOMING THE CHALLENGES: ECOLOGICAL RESTORATION IN THE REGION'S THREE MAJOR WATERSHEDS

Ecological restoration along riparian corridors can bring back both flora and fauna, and improve water quality at the same time. The success of restoration efforts depends on the availability of water. Therefore, a key to ecological restoration of rivers is to reestablish a pattern of flows to which native species of plants and animals have adapted. In changing conditions, successful restoration also requires ongoing data collection and adaptation. Often, in addition, a key aspect of the restoration effort is to obtain water rights for the restoration sites. Water rights are held by Tribes or granted by state governments, so federal agencies must collaborate with Tribal and state entities to achieve restoration goals. Some border states have established water trusts to legally hold water rights for future users.

Water and wastewater infrastructure can be managed for flow restoration and other important aspects of ecological restoration initiatives and projects. Dams are a central feature of border water management, along with flood control levees, hydroelectric power plants and wastewater treatment plants. The long history of dam construction, channelization, and land development in both the Rio Grande and Colorado River watersheds has made passive restoration of these rivers impossible; intervention is required to manage flows to support a sound ecological environment. By undertaking a combination of active and passive measures, it could be possible to reestablish floodplain and riverine habitats created and sustained by the rivers; pave the way for reoccupation of these habitats by native species; and restore the ability of rivers to provide ecological services that have direct benefits for people such as water purification, flood control and nutrient cycling. This section describes ecological restoration initiatives within the border region's three major watersheds.

The Tijuana River Watershed

The Tijuana River watershed drains 1,750 square miles (4,532 square kilometers), three-quarters of which lies in Mexico. It is located within one of the fastest growing regions along the border with approximately 4.5 million people (3 million in San Diego County,[73] 1.5 million in the City of Tijuana[74]). Its headwaters lie partly in Mexico and partly in the United States, and it is considered a world biodiversity hotspot. The Tijuana River empties into the Pacific Ocean at Imperial Beach, California. Rapid growth and resulting development have greatly reduced and damaged the abundance and distribution of the watershed's unique biota and related habitats. Key impacts include habitat destruction, trash dumping, degraded water quality, sediment accumulation, off-road vehicle travel and invasion by exotic plant species. The IBWC, United States and Mexico, has been working with stakeholders in both countries to address some of these impacts and has developed a draft agreement establishing a framework for binational cooperation on transboundary issues in the Tijuana River Basin. This agreement is expected to be finalized in late 2014 as an IBWC minute. The agreement will provide the means for U.S.-Mexico cooperation on issues related to the watershed with a particular focus on trash, sediment and water quality. Two programs within the Tijuana River watershed illustrate the benefits and complexities of ecological restoration along the U.S.-Mexico border.

Water-harvesting gabion stabilized by downstream cottonwood, post-hurricane Odile, October 16, 2014.
Source: Arizona Department of Environmental Quality

CASE STUDY: *Urban Forest Management*

The City of San Diego received a CalFire planning grant to develop an Urban Forest Management Plan. City staff, along with consulting urban foresters, key stakeholders and the Community Forest Advisory Board are in the process of developing the plan. A draft plan is expected in early 2015.

A vigorous and engaged urban forestry program is critical to meeting San Diego's commitment to ecological restoration, climate change, carbon sequestration, stormwater reduction and water conservation. With these goals in mind, the city will develop a long-range urban forest management plan to guide the city's urban forest into the future.[75]

CASE STUDY: *Tijuana River National Estuarine Research Reserve*

The 2,293-acre (928-hectare) Tijuana River National Estuarine Research Reserve (TRNERR), located in Imperial Beach in southern California, is a partnership between the United States and the state of California that links the National Oceanic and Atmospheric Administration (NOAA), California State Parks, and the U.S. Fish and Wildlife Service (FWS). It preserves one of the largest remaining examples of coastal wetland habitats in southern California. Situated in a highly urbanized location, 15 miles (24 kilometers) south of San Diego and immediately adjacent to Tijuana, Mexico, the TRNERR faces critical issues of habitat restoration and recreational use, as well as management of endangered species, wastewater and sediment.[76] The Reserve has a long history of coupling rigorous science with ecosystem restoration, and presently is completing major studies focused on synthesizing restoration and ecosystem science to inform effective decision-making for future restoration actions.

Long-term environmental monitoring is critical to environmental restoration efforts. The TRNERR participates in the NERR System-wide Monitoring Program (SWMP), which provides researchers, resource managers, educators and other coastal decision makers with standardized, quantitative measures to determine how reserve conditions are changing in both the short- and long-term. SWMP provides quantitative measurements of short-term variability and long-term changes in the water quality, biological systems, and land-use/land-cover characteristics of estuaries and estuarine ecosystems for the purposes of informing effective coastal zone management. SWMP currently has three major components that focus on: (1) abiotic indicators of water quality and weather; (2) biological monitoring; and (3) watershed, habitat and land use mapping.

The Colorado River Watershed

The 1,450-mile (2,334-kilometer) Colorado River runs from the Rocky Mountains of Colorado to the Gulf of California, supplying water to more than 33 million people in Arizona, California, Colorado, New Mexico, Nevada, Utah, Wyoming and Mexico. The Colorado River Basin drains 243,000 square miles (629,000 square kilometers).[77] Demand for its water outstrips supply. This supply-demand imbalance is projected by the Bureau of Reclamation to be 3.5 million acre-feet (4.3 billion cubic meters) by 2050, mostly due to population growth and the associated increase in demand for water and to an estimated 9 percent reduction in water flow due to increasing temperatures and reduced precipitation.[78] The impacts of this imbalance are especially visible in the Colorado River Delta, lying in the U.S.-Mexico border region, where the dynamic environment created by the interaction of the river's flow and the ocean's tide once supported freshwater, brackish and saltwater species. This section will highlight two initiatives aimed at restoring the ecology of this region.

Example: Lower Colorado River Multi-Species Conservation Program

The Lower Colorado River Multi-Species Conservation Program (LCR MSCP) was created to "balance the use for the Colorado River water resources with the conservation of native species and their habitats." The program area reaches more than 400 miles (644 kilometers) of the lower Colorado River, from Lake Mead to the border with Mexico. With the Bureau of Reclamation as its implementing agency, the program works toward the recovery of species listed under the Endangered Species Act and aims to reduce additional species listings. The program's Habitat Conservation Plan includes habitat restoration and maintenance, as well as species-specific conservation measures, and incorporates research, monitoring and adaptive management.[79] The 57 participating entities include local, state, Tribal and federal agencies as well as private water users, with program costs evenly divided between the federal government and nonfederal partners.[80]

CASE STUDY: *Minute 319 and "Pulse Flow"*

In November 2012, the IBWC, United States and Mexico, signed Minute 319,[81] a 5-year agreement addressing a broad range of joint cooperative measures between the two countries for Colorado River management. The major elements of Minute 319 are that it:

- Extends humanitarian measures from a 2010 agreement (Minute 318) to allow Mexico to defer delivery of a portion of its Colorado River allotment while it continues to make repairs to earthquake-damaged infrastructure.
- Provides additional Colorado River water to Mexico during certain high elevation reservoir conditions at Lake Mead when additional water is available to users in the United States, providing benefits to both countries.
- Establishes proactive Basin operations during certain low elevation reservoir conditions at Lake Mead by applying water delivery reductions in order to deter more severe reductions in the future.
- Establishes a program whereby Mexican water resulting from conservation and new water sources projects could essentially be held in the United States for subsequent delivery to Mexico as determined through its planning processes.
- Through conservation projects, generates water for the environment of the Colorado River limitrophe (border) and delta.
- Provides for U.S. investment in water infrastructure and environmental projects in Mexico. These investments provide water benefits to U.S. entities in exchange for their funding and generate water for Mexico over the long term.
- Outlines potential opportunities for future cooperation between the United States and Mexico in areas such as environmental restoration, water conservation, system operations, and new water sources projects.
- Creates a pilot project to provide water for environmental flows for the Colorado River.[82]

Case Study: Minute 319 and "Pulse Flow" (continued)

In March-May 2014, the one-time "Pulse Flow" of 105,392 acre-feet (130 million cubic meters) of water was released downstream from Morelos Dam to aid the environment in the Colorado River Delta, primarily the riparian corridor. Under normal conditions, water is not released downstream from Morelos Dam so the river channel is largely dry. The Pulse Flow, coupled with 52,696 acre-feet (65 million cubic meters) of water (known as the Base Flow), for delivery at lower flow rates within Mexico and during a longer period of time, are expected to provide for the restoration of about 2,300 acres (930 hectares) of riparian habitat, allowing for seed germination for native willow (*Salix gooddingii*) and cottonwood trees (*Populus fremonti*) as well as other native species and water to sustain their growth.

On May 15, 2014, the Colorado River recorded a milestone when it connected, for a short period of time, with the ocean for the first time in years at a location known as the upper part of the estuary, about 15 miles from the Gulf of California. Because of the complexities of the Colorado River system, scientists were uncertain whether the water would reconnect with the Gulf some 94 miles (151 kilometers) downstream from Morelos Dam. The success in reconnecting the river with the ocean is a significant achievement in the implementation of Minute 319.

Under Minute 319, water for the environment was provided through participation of the Mexican and U.S. governments and nongovernmental organizations from both countries, marking the first time the two countries have delivered water for environmental purposes. This pilot project has generated interest from hundreds of international scientists and journalists who documented the progress of the pulse flow. A binational team of scientists and conservationists developed and is implementing a plan to monitor the success of the restoration efforts under Minute 319, specifically the impacts of environmental flow deliveries on the vegetation, wildlife and hydrology of the riparian corridor of the Colorado River in Mexico. The team has observed germination of native and nonnative species in several locations along the river, and the effects of the water deliveries on the surface water and groundwater are being assessed.

One of the unexpected aspects of the implementation of the pulse flow was the response of local community members who live near the border, many of whom had the opportunity to see the river full of water for the first time. The excitement and delight of having their river back was evident as hundreds of people gathered to swim, splash and enjoy the river during the few weeks it flowed with water. When monitoring ends in 2017, the team will generate a report to inform potential future efforts of this nature.

The U.S. Department of the Interior (DOI) recognized Minute 319 with its Partners in Conservation Award in January 2014, an award established to highlight conservation achievements that include collaborative activity among a diverse range of entities. The award recognizes the engagement and contribution of many partners from the governments of both the United States and Mexico, the seven U.S. Colorado River Basin states, nongovernmental organizations and academia.

The Rio Grande Watershed

The 355,000-square mile (920,000-square kilometer) watershed of the Rio Grande (or Río Bravo, as it is known in Mexico) presents unique challenges. The 1,896-mile (3,051-kilometer) river flows from south central Colorado to the Gulf of Mexico, forming part of the U.S.-Mexico border along the way (see **Figures 8** and **9**). Only a small percentage of the river's natural discharge reaches the Gulf of Mexico due to human diversions. More than a century of water development has changed the river's flow pattern, and in recent decades, the amount of water has declined.

The lack of planned water deliveries from Mexican reservoirs to the Rio Grande has created multiple difficulties—from generating periodic water deficits under the treaty, which affects Texas water users, to reducing in-stream flow in the Rio Grande—with resulting environmental impacts. Securing a specific commitment

from Mexico to proactively manage its reservoirs to deliver water to the United States in a scheduled manner would offer the opportunity to deliver water in a method that maximizes environmental benefits, much like the base flow and pulse flow deliveries planned for the Colorado River. Although scheduling water releases to benefit the habitat of Big Bend National Park and adjacent protected areas in Mexico has been discussed for a number of years, an agreement with Mexico has remained elusive.

Within the U.S.-Mexico border region, the Rio Grande has lost a significant portion of its original complement of fish species due to a century of dam building, changes to natural flow patterns, diversions, channelization, and other changes to the river and its floodplain. A comprehensive approach to river restoration would address factors that have caused native fish to disappear and avoid serious constraints on Rio Grande management (see Species-Centric Restoration, **Chapter Two**). The reach above the Rio Conchos has been especially hard hit, having lost one-half to two-thirds of its native fish species.[83] Only one species, however, is extinct; the remainder still exist elsewhere in the Rio Grande Basin or in other rivers and could be reestablished under suitable conditions. According to the Water Policy Review Advisory Commission, a proactive approach toward the recovery of native fish, before they are listed as threatened or endangered under the U.S. Endangered Species Act, could minimize disruptions to water users while providing greater flexibility in the choice of conservation measures.[84] This section highlights two restoration initiatives within the Rio Grande watershed.

Figure 8. The Rio Grande/Bravo Basin.
Source: http://www.fws.gov/southwest/mrgbi/resources/dams/

Figure 9. The Rio Grande/Bravo Basin Dams.
Source: U.S. Department of the Interior, Bureau of Reclamation

CASE STUDY: *The Rio Grande Canalization Project*

The Rio Grande Canalization Project extends 106 miles (171 kilometers) along the Rio Grande from Percha Dam, New Mexico, downstream to American Dam in El Paso, Texas. Its purpose is to facilitate delivery of Rio Grande water to Mexico in accordance with the Convention of 1906 and to provide flood protection. Constructed between 1938 and 1943, the project has a normal flow channel, a floodway, and 130 miles (210 kilometers) of flood control levees. As with the Rio Grande Rectification Project, construction resulted in the river being shortened and straightened. Five sediment control dams were built from 1969 to 1975 to control sediment and flood runoff to the Canalization Project.

In 2009, following preparation of an Environmental Impact Statement evaluating different alternatives for managing the Project, the U.S. Section of the IBWC issued its Record of Decision (ROD). In accordance with the ROD, the USIBWC committed to restoring native trees, shrubs and grasslands on up to 30 restoration sites and other areas of the floodplain totaling approximately 2,500 acres (1,012 hectares) along the Rio Grande in southern New Mexico stretching from below Percha Dam to the New Mexico-Texas state line. The USIBWC also is purchasing a parcel for restoration. One restoration goal is to create habitat for the endangered southwestern willow flycatcher. Working with the USIBWC, the U.S. Fish and Wildlife Service (USFWS) already has planted some 5,000 trees and cleared 350 acres (142 hectares) of invasive, nonnative salt cedar on nine sites. The USIBWC has begun monitoring the restoration sites. One challenge has been the impact of the ongoing drought on native populations of willows. Installation of 53 shallow groundwater monitoring wells at 20 restoration sites will provide valuable data that will assist with planning tree planting depths and irrigation needs.

The success of the restoration effort depends on the availability of water. Therefore, a key aspect of the restoration effort is to obtain water rights for the restoration sites; the USIBWC must coordinate at the state and local levels to secure water rights (surface or groundwater). The Elephant Butte Irrigation District Board (EBID) approved a policy to allow EBID surface water to be used for agricultural purposes on USIBWC restoration sites. Through this voluntary, market-based approach, the USIBWC acquired an initial volume of irrigation water and, on June 30, 2014, initiated irrigation of native vegetation at a restoration site along the Rio Grande near Las Cruces, New Mexico. Some 60 people turned out for a ceremony to celebrate this milestone in the restoration effort. The USIBWC is working to acquire additional water rights from willing sellers.

CASE STUDY: *Devils River—State, Federal and Local Involvement*

In January 2011, the Texas Parks and Wildlife Department (TPWD) acquired the approximately 18,000-acre (7,300-hectare) Devils River Ranch along the southern stretch of the Devils River.[85] A year of negotiation resulted in a leveraged sale involving state and federal funds and significant private contributions to achieve this priceless conservation acquisition. The property consists of native riparian woodlands, Edward Plateau oak woodlands and grasslands, and Tamaulipan and Chihuahuan desert scrub habitat with 10 miles (16 kilometers) of river frontage immediately upstream of the Amistad National Recreation Area. In 2011, TPWD added 20,000 acres (8,100 hectares) to the original 18,000 acres (7,300 hectares) in what is now called the North Unit of the Devils River State Natural Area (SNA). The Southern Unit—also known as the Big Satan—provides habitat for endemic plants, fish and wildlife, including a rare salamander and several rare fish along this tributary to the Rio Grande.

Case Study: Devils River—State, Federal and Local Involvement (continued)

The Devils River is one of the most ecologically intact rivers in Texas; its waters tumble over limestone past rugged ridges, canyons and grassy banks. Located on the Devils River north of Del Rio, Texas, the Devils River SNA is managed through conservation easements and holds 10.8 miles (17.4 kilometers) of river and lake frontage of the Devils River and Lake Amistad. A series of springs within the SNA's karst topography provides a substantial base of the river's flow. Three types of stream conditions characterize the river: long, deep pools; wide shallow areas; and relatively deep, turbulent rapids. The river is free of impoundments, generally inaccessible, and essentially unpolluted. The SNA's purpose is to protect the area's natural and cultural resources, with special emphasis on endangered and threatened species, aquatic life and spring flows, and to provide recreational and educational opportunities that do not compromise resource stewardship objectives. The TPWD is presently developing a management plan with significant public and federal input for the two units of the SNA.

This state, federal and local partnership represents a successful public/private effort to conserve special properties for future generations. The acquisition provides permanent protection and management of important grasslands and woodlands, riverine and riparian habitats, and world-class rock art sites. It also provides increased managed public access to the wildest and most pristine river in Texas, and one of the most unspoiled rivers in the continental United States.

MEETING MULTIPLE OBJECTIVES THROUGH ECOLOGICAL RESTORATION

Both the quality and quantity of water available within an ecosystem is determined by the condition of the watershed and the activities that take place within it. Although activities such as mining, logging and urban development generally remove vegetation and can degrade soils, increase erosion and impair water quality, efforts can be undertaken to repair the damage. This section describes efforts to restore water quality and quantity within border watersheds.

CASE STUDY: *The New River and the Salton Sea*

The New River starts in Mexicali, Mexico, approximately 15 miles (24 kilometers) south of the border, and flows north into the United States at Calexico, passes through the Imperial Valley, and drains into the Salton Sea, California's largest lake, some 66 miles (106 kilometers) north of the California-Baja California border. In 1999, two pilot wetlands (see Figure 10) were constructed in Imperial and Brawley, California, to improve water quality in the New River. The construction of these wetlands led to improvements in the quality of the water before it was discharged back into the New River and entered the Salton Sea (see Table 1).[86]

The Salton Sea provides essential habitat for hundreds of fish and wildlife species and is an important cultural and recreational resource. It has no outlet, and dissolved salts contained in the inflows concentrate in the Salton Sea through evaporation. The salinity of the Salton Sea currently is nearly 1.5 times the salinity of ocean water and has been increasing as a result of evaporative processes and low freshwater inputs. Further reductions in inflows from water conservation, recycling and transfers will lower the level of the Salton Sea and accelerate the rate of increasing salinity. This projected salinity increase, if not addressed, will in turn reduce the suitability of fish and wildlife habitat and affect air quality by exposing lakebed playa that could generate dust. Despite 2003 state legislation intended to help restore the Salton Sea ecosystem, the California legislature has not taken action.

Imperial Site Water Quality Summary (Averages) January 2001 to October 2013			
Parameter	**Inlet**	**Outlet**	**% Change**
Dissolved Oxygen (DO)	8.19	6.92	–15.5
Total Nitrogen (mg/L)	6.8	3.6	–46.6
Total Phosphorus (mg/L)	1.38	0.80	–41.8
Selenium (µg/L)	.0080	.0064	–20.3
Biological Oxygen Demand (BOD) (mg/L)	13.0	10.59	–18.6
Fecal Coliform (MPN/100 mL)	89,087	488	–99.5
Total Suspended Solids (TSS) (mg/L)	191	12	–93.6
Brawley Site Water Quality Monitoring Summary (Averages) January 2001 – October 2013			
Parameter	**Inlet**	**Outlet**	**% Change**
DO	3.44	7.68	+123
Total Nitrogen (mg/L)	7.8	2.16	–72.1
Total Phosphorus (mg/L)	1.40	0.69	–51.1
Selenium (µg/L)	0.0106	0.0100	–6.1
BOD (mg/L)	12.20	10.62	–13.0
Fecal Coliform (MPN/100 mL)	904,636	693	–99.9
TSS (mg/L)	207	14.0	–93.3

Table 1. New River Pilot wetlands monitoring summary
Source: Stephen Charlton, Imperial Irrigation District, personal communication, September 22, 2014

Figure 10. The Salton Sea watershed.
Source: "Salton Sea Watershed Map," California Department of Water Resources, http://www.water.ca.gov/saltonsea/documents/watershed.cfm

Recently, though, the Salton Sea Restoration and Renewable Energy Initiative was launched by the Imperial Irrigation District, in partnership with Imperial County, to leverage funds generated by new renewable energy projects located at the sea to help finance activities for air quality management and habitat restoration. Projects sited on portions of exposed lakebed will serve a dual purpose: producing renewable energy while doubling as groundcover to mitigate air emissions. Under state legislation enacted in 2013,[87] planning and implementing projects at the sea will be driven locally by the Salton Sea Authority, with support from state and federal governmental agencies.

CASE STUDY: *Water Harvesting, Range Restoration and Local Economies*

Overgrazing, mining and urban development all have contributed to habitat fragmentation and loss throughout the arid border region. The conditions have been exacerbated by years of drought. Upland woodlands and grasslands are important as rangelands and wildlife corridors. Riparian areas and wetlands play a disproportionate role in sustaining biological diversity by providing forage, cover, nesting and migration corridors. Unfortunately, it is estimated that fewer than 10 percent of those areas remain.[88] A watershed-scale approach to ecological restoration considers education, public-private partnerships, and the development of restoration economies focused on sustainability. In southern Arizona, partnerships involving the Cuenca Los Ojos Foundation (CLO), Borderlands Restoration (BR), and both public and private stakeholders are bringing sustainable land-management and restoration practices to public and private lands, and are incorporating monitoring and evaluation to help guide future projects.

Managing more than 200,000 acres (81,000 hectares) of privately owned land strategically located in southern Arizona and northern Sonora at the headwaters of the Rio Yaqui watershed, CLO is focused on restoring the biodiversity of the borderlands region. Over the past 30 years, its founders have privately funded water harvesting and range restoration practices to restore migratory corridors for birds and large mammals, while securing the livelihoods of rural agricultural producers. These practices include installation of erosion-control features in the form of simple low-lying rock check dams and larger gabion-style check dams.[91] Over time, these features trap waterborne sediment while slowing down erosive stormwater runoff. As these features are covered in sediment, they decrease the slope of drainages while creating natural sponges for water storage and availability during dry periods. This restores vegetation and wildlife habitat and also helps improve water quality through attenuation of particle associated pollutants.

Research on Water Harvesting Best Practices

In recognition of its ecological restoration successes, Cuenca Los Ojos Foundation (CLO) has won multiple awards in both the United States and Mexico and is looked to as a natural learning laboratory to extend proven practices elsewhere. The U.S. Geological Survey (USGS) has partnered with CLO and Borderlands Restoration (BR) to document the impacts of installing rock check dams and larger gabion-style check dams in the Mexican Highlands.[89] Researchers demonstrated increasing vegetation in the Cienega San Bernardino using a remote-sensing analysis coupled with field data over a 27-year period, despite drought conditions.[90]

On September 17, 2014, CLO's San Bernardino Ranch was impacted by extreme flooding from Hurricane Odile. Many gabions were damaged, but some held together thanks to stabilization by native vegetation. The ability of trees and grasses to regenerate diminishes reliance on limited resources for repair. In response, CLO is investigating natural regenerative strategies that can help restore water harvesting features impacted by extreme weather events.

Another partnership between the USGS, the National Park Service (NPS), U.S. Department of Agriculture (USDA) Agricultural Research Service's (ARS) Southwest Watershed Center, and the University of Arizona is documenting decreased storm peak flows and increased water availability using a paired-watershed approach, with one that has been fitted with rock-detention structures for watershed restoration purposes by CLO, and one that has not.

Case Study: Water Harvesting, Range Restoration and Local Economies (continued)

To help address the serious economic challenges of the border region, the BR, the first limited profit, limited liability (L3C) company in Arizona, has partnered with CLO with the aim of building a restoration economy around public and private lands.[92] Profits gained from habitat restoration are reinvested in job training, local capacity building and restoration infrastructure. This is accomplished in part by hiring local workers to implement the successful technologies demonstrated by CLO. BR now is working with the USGS, CLO and the privately held Babocomari Ranch on water harvesting practices to improve soil conservation and water availability for the San Pedro River. As a major tributary, the Babocomari River supports water flows to the San Pedro Riparian National Conservation Area. BR also is partnering with the Bureau of Land Management (BLM) to experiment with pollinator-supporting native plant material collection, growth and installation on public lands while training local residents to do the work.

Managing Treated Wastewater for Ecological Restoration

Although constructed wetlands help improve water quality, they also do much more. The Rio Bosque Wetlands and the Santa Cruz River provide important ecological services within the border region. Both face ongoing challenges resulting from drought and high water demand but also provide unique opportunities for ecological restoration tied to effluent-management practices. The Rio Bosque Wetlands Park demonstrates how local partnerships can help restore ecological corridors. The Santa Cruz River requires international partnerships to help sustain its riparian functions.

Rio Bosque Wetlands Park

The Rio Bosque Wetlands Park is a 372-acre (151-hectare) City of El Paso park located in southeast El Paso County near the town of Socorro, Texas. The park is enclosed by irrigation canals and drains on three sides, and the western boundary of the park lies adjacent to the Rio Grande, which forms the international border between the U.S. and Mexico in this area. Water used to flow naturally through the park in the fall and winter before the Rio Grande was confined within levees in the 1930s.

Common native riparian areas are largely gone from the river valley, but partnerships between the U.S. Fish and Wildlife Service, IBWC, Ducks Unlimited, the El Paso/Trans-Pecos Audubon Society and local utilities are restoring cottonwood-willow habitat along the main water channel of the park. Today, the Rio Bosque Wetlands is supported by treated wastewater from the adjacent Roberto Bustamante Wastewater Treatment Plant. El Paso Water Utilities and El Paso County Water Improvement District agreed to make this water available when it was not being used for irrigated agriculture. In addition, a well at the park's inlet keeps a 0.5-mile (0.8-kilometer) reach of the old river channel constantly wet.

Prolonged drought intensifies the challenge of restoring these habitats, but Rio Bosque is showing progress. Here, returning bird species are being detected at point-count stations located within reestablished riparian habitat. This offers a glimpse of what can be accomplished when stakeholders foster partnerships and water is returned to the environment.

Santa Cruz River

The Santa Cruz River watershed highlights multiple binational challenges: water supply, water quality, groundwater, wastewater, and flooding, which have affected the communities of Nogales, Arizona, and Nogales, Sonora. The headwaters of the Santa Cruz River are in the San Rafael Valley of Arizona. It then travels south and enters Mexico before turning north again and reentering Arizona where it recharges groundwater in the Santa Cruz Active Management Area. The 1980 Arizona Groundwater Code recognized the need to aggressively manage the state's finite groundwater resources. To support the growing economy, areas with heavy reliance on groundwater were identified and designated as Active Management Areas

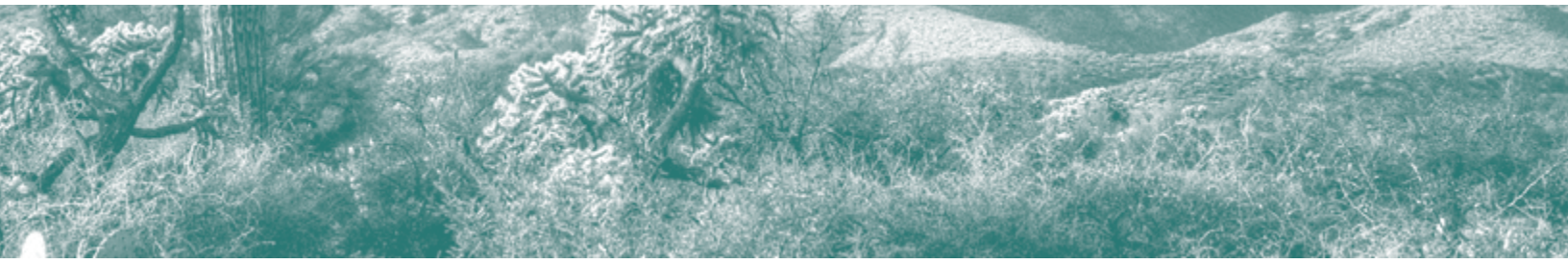
Effluent from the Nogales International Wastewater Treatment Plant, which flows into the Santa Cruz River.
Source: U.S. Section, International Boundary and Water Commission

(AMAs). The AMAs are subject to regulation under the Groundwater Code and carry out programs consistent with their goals, while considering and incorporating the unique character of each AMA and water users. The major portion of the Santa Cruz River watershed lies in Mexico. Therefore, effective watershed planning and ecological restoration must be undertaken with stakeholders from both sides of the border.

Historically, flow in the Santa Cruz River varied widely with changes in natural conditions and human use. Since 1951, however, river levels have been maintained by a steady flow of treated effluent from the Nogales International Wastewater Treatment Plant (NIWTP). The USIBWC operates the NIWTP, and Mexico pays to have its wastewater treated by the plant. The effluent is discharged to the Santa Cruz River, where it marks the start of the 14 miles (23 kilometers) of perennial flow within the river. The resulting southwest cottonwood–willow riparian environment is one of the most endangered ecosystems in the United States and is designated as a critical habitat for the endangered Southwestern Willow flycatcher.[93] The area also is recognized as an Important Bird Area (IBA) by the Audubon Society.

Under Minute 276,[94] Mexico has the right to reclaim the portion of the effluent that originates in Nogales, Sonora. New wastewater infrastructure and management practices in Nogales, Sonora, combined with drought and improved groundwater recharge, have negatively affected habitat downstream of the NIWTP. Discharges from Sonora have diminished from 12.38 million gallons per day (MGD) in 2012 to 10.69 MGD in 2013—a loss of 1.69 MGD. The combined impacts are most readily visible north of the Chavez Siding crossing where a once lush riparian corridor has lost its willows, and cottonwoods are showing signs of stress.

Future expansion and modifications of wastewater infrastructure in Nogales, Sonora, may further reduce the flow to the NIWTP and impact the cottonwood-willow habitat along an important ecological corridor in Arizona. Careful management of wastewater infrastructure and treatment plant effluent is needed to restore ecological conditions within the Santa Cruz River. Given the success of Minute 319, there are opportunities for a similar multi-stakeholder collaborative approach in this region as well.



Chapter Four: Recommendations

As demonstrated by examples in this report, federal agencies have acted on restoration opportunities in the U.S.-Mexico border region appropriate to their respective missions. Achieving more effective restoration in this region, however, requires addressing some key challenges. This report has demonstrated that it is difficult for individual units in single agencies to tackle central concerns such as scale and connectivity. Large-scale restoration efforts must address processes that are not confined to an individual site such as a park, or even to a state level program. The first step in achieving connectivity is interagency collaboration, but much work is needed to translate goals into plans and on-the-ground actions. The recommendations presented in this chapter offer a range of ways to address these challenges.

1. PROTECT ECOSYSTEMS: AVOID THE NEED FOR RESTORATION

- Actively maintain high-quality natural resources and ecosystems and adopt best practices for low-impact infrastructure design and agency operation. For example, identify and implement best management practices to prevent and mitigate erosion resulting from construction of the border fence and associated infrastructure, and aggressively explore the use of information and remote sensing technologies that will enhance border security while reducing the physical footprint of interdiction activities along the border.

- Support conservation on private lands, maintaining extension services while expanding tools such as easements and other incentive programs.

- Reduce the number of non-native species entering border ecological zones. Strengthen U.S. Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS) efforts and collaborate with Mexican officials to screen for cross-border transport of non-native species.

2. PROMOTE ECOLOGICAL RESTORATION PROGRAMS AND PROJECTS

- Develop a common goal structure across U.S. federal agencies to support coordinated restoration actions and measures of incremental progress towards ecological landscape goals. As part of this effort, identify and implement opportunities for federal agencies (e.g., U.S. Department of Transportation [DOT], U.S. Environmental Protection Agency [EPA], National Oceanic and Atmospheric Administration [NOAA], U.S. Army Corps of Engineers [USACE]) to prioritize ecological restoration activities in underrepresented areas such as urban environments and transboundary ecosystems.

- Develop performance indicators and metrics-based plans for high-priority species, community, and ecosystem recovery, similar to efforts applied in ecoregional assessments and the Lower Colorado Multi-Species Conservation Program. Include development of a science-based recovery plan for native Rio Grande fish from Caballo Reservoir (New Mexico) to Presidio (Texas) that balances the restoration of native fish and their habitats with the continued best management practices of the Rio Grande for all domestic and international obligations and requirements.

- Adopt ecoregional approaches to assessments and priority setting along common resource issues and identify opportunities for restoration among state, Tribal, nongovernment and international partners. For example, priorities for restoration work for the Big Bend Rio Bravo project were identified based on an understanding of resources and impacts of like resources on both sides of the border.

- Identify gaps or inconsistencies in the application of data, tools and models for assessing ecological restoration in the border region and provide resources for existing assessments such as the U.S.-Mexico Transboundary Aquifer Assessment Program, and expansion of the USDA's Management Land Resource Areas (MLRAs), including local ecological site descriptions into Mexico.

- Expand the scope of federal programs to include natural resources issues, including ecological restoration, and use best practices to measure the environmental effects and benefits of the projects. For example, address ecological restoration through the Border Environment Cooperation Commission (BECC) and North American Development Bank (NADB) and EPA's Border 2020 program.

- Improve governance and funding mechanisms to reflect landscape-scale restoration needs.

  – Draw upon lessons learned and the National Research Council's evaluation of Landscape Conservation Cooperatives (LCCs) to improve coordination of direct restoration actions across multiple federal agencies and other public and private entities.

  – Explore funding mechanisms for multi-year restoration projects that allow managers to conduct initial assessment, prioritization, integrated and multi-level planning, decision making, design, implementation, and operation and maintenance in a manner similar to the project structure of EPA's Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Program.

  – Identify federal funding for water conservation projects (e.g., cost sharing with Rio Grande Project water users to improve irrigation efficiency) and coordinate with other entities (e.g., the BECC, NADB, Texas Water Development Board) to encourage greater investment in water conservation and make more water available for ecological restoration.

Vacant lot in San Diego being converted into a food forest and site for urban ecological restoration.
Source: University of California, San Diego

- Establish a grant program to support border restoration projects undertaken by nonfederal entities. For example, the grant program could provide support to several nongovernmental organizations working along the Rio Grande to achieve goals identified in the Rio Grande native fish recovery plan, or native plant material development in southern Arizona.

- Actively promote existing federal initiatives to increase restoration opportunities.

  - Improve research and management related to native and invasive species to promote native species for restoration and invasive species management. Among other actions, create and implement interagency invasive species strike teams and expand the role of USDA Natural Resources Conservation Service (NRCS) Plant Materials Centers in Tucson, Arizona; Las Lunas, New Mexico; and Kingsville, Texas, to promote native species.

  - Systematically monitor the border fence and supporting infrastructure for effects resulting from its construction and develop actions to modify, redesign or mitigate the negative outcomes realized or anticipated by the existing construction and fence-related operations such as lighting. Update mitigation gaps for impacted species and habitats and fulfill commitments to address resource damages under the U.S. Customs and Border Protection (CBP)-Department of the Interior (DOI) Memorandum of Agreement.[95]

3. ACTIVELY INCREASE ENGAGEMENT WITH MEXICAN AGENCIES AND PARTNERS

- Reopen discussion with Mexico and Canada regarding the transboundary environmental impact assessment (TEIA) process with the goal of determining the feasibility of this mechanism to address transnational impacts, and encourage transborder cooperation on environmental infrastructure projects. TEIAs should be used in and around the Ports of Entry to assess opportunities for ecological restoration at these locations.

- Through the U.S. Section of the International Boundary and Water Commission (USIBWC), engage Mexican partners in transborder watershed management and urban ecological restoration. For example, working with USIBWC, EPA and NOAA should authorize and provide funding to create a Special Area Management Plan[96] for the Tijuana River Watershed.

- Through the USIBWC, open talks with Mexico that are modeled on the broad-based participation that

2007 downstream aerial view of Morelos Dam showing normal conditions.
Source: International Boundary and Water Commission

has occurred in the Colorado River and that aim to find common ground for sustainable management of shared water resources, including ecological restoration. In particular, the USIBWC should work with authorities in Mexico for more continuous releases of water from the Rio Conchos in a way that is beneficial to downstream users and ecological restoration.

- Explore involvement of Mexican agencies in multi-agency initiatives and programs such as the National Invasive Species Council and the National Interagency Fire Center. Build upon this involvement to develop and revitalize agreements such as the Memorandum of Understanding between the DOI and the Mexican government regarding the Forgotten River stretch of the Rio Grande (the 200-mile [322-kilometer] reach of the Rio Grande that extends from below El Paso to its confluence with the Rio Conchos at Presidio-Ojinaga) and elimination of the salt cedar there.

- Given the success of Minute 319 in providing water for the environment of the Colorado River Delta region, encourage the IBWC to include an environmental component in the expected Minute 319 successor agreement and to consider future agreements of this nature. Partnerships similar to those that formed to execute Minute 319 can support the development of an amendment to Minute 276 (or a new minute) focused on securing wastewater effluent for the Santa Cruz River.

4. EVALUATE OPTIONS FOR FLOW MANAGEMENT, INCLUDING IRRIGATION AND WASTEWATER, FOR ECOLOGICAL RESTORATION BENEFIT

- In any water planning involving binational waters, evaluate, consider and plan for environmental flows needed for aquatic species, habitat Active Management Area (AMA) and human recreational uses of water. For example, a positive development in recent efforts is providing water for the environment in the Colorado River Delta region, pursuant to Minute 319.

- Work with existing state water banks or water trusts to identify means for transferring water rights to ensure environmental flows, taking into consideration existing water rights frameworks. This may include the purchase of water rights for ecological flows and, to encourage donations of water to an environmental water trust, will require review of existing tax law or possible revisions to tax law to make such donations tax deductible (like a charitable donation) or eligible for a tax credit.

- Develop policies to require some of the water conserved through irrigation efficiency be dedicated to in-stream flow to meet aquatic restoration needs, consistent with state policies.

Appendices

LIST OF ACRONYMS

AMA	Active Management Area
APHIS	Animal Plant and Health Inspections Service
ARS	Agricultural Research Service
BBBXG	U.S.-Mexico Binational Bridges and Border Crossings Group
BECC	Border Environment Cooperation Commission
BLM	Bureau of Land Management
BMP	best management practice
BOD	biological oxygen demand
BR	Borderlands Restoration
CBP	U.S. Customs and Border Protection
CCRP-SAFE	Continuous Conservation Reserve Program State Acres for Wildlife Enhancement
CEC	Commission for Environmental Cooperation
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CLO	Cuenca Los Ojos Foundation
CONAGUA	Comisión Nacional del Agua (National Water Commission [Mexico])
CPO	Climate Program Office
CSP	Conservation Stewardship Program
CTA	Conservation Technical Assistance
CZMA	Coastal Zone Management Act
CZMP	Coastal Zone Management Program
DHS	Department of Homeland Security
DOI	Department of the Interior
DOS	Department of State
DOT	Department of Transportation
EBID	Elephant Butte Irrigation District
EMO	Environmental Management Office
EPA	U.S. Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
ESA	Endangered Species Act
FHWA	Federal Highway Administration
FY	fiscal year
GIS	Geographic Information Systems
GNEB	Good Neighbor Environmental Board
GPS	Global Positioning System
GRP	Grassland Reserve Program
GSA	General Services Administration
HLED	High Level Economic Dialogue
IBA	Important Bird Area
IBWC	International Boundary and Water Commission, United States and Mexico
JWC	U.S.-Mexico Joint Working Committee on Transportation Planning
LCC	Landscape Conservation Cooperative
LCR MSCP	Lower Colorado River Multi-Species Conservation Program
LTER	Long Term Ecological Research
MBG	Malpai Borderlands Group
MGD	millions of gallons per day
MLRA	Major Land Resource Area
MOA	Memorandum of Agreement
MSBHI	Migratory and Shore Bird Habitat Initiative
MSCP	Multiple Species Conservation Program
NADB	North American Development Bank

NAFTA	North American Free Trade Agreement
NCCOS	National Centers for Coastal Ocean Science
NEPA	National Environmental Policy Act
NERRS	National Estuarine Research Reserve System
NESDIS	National Environmental Satellite Data and Information Service
NIFC	National Interagency Fire Center
NIWTP	Nogales International Wastewater Treatment Plant
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NPS	National Park Service
NRCS	Natural Resources Conservation Service
NSF	National Science Foundation
NWR	National Wildlife Refuge
NWS	National Weather Service
OAR	Office of Oceanic and Atmospheric Research
POE	Port of Entry
PLLA	Public Land Liaison Agent
REA	Rapid Ecoregional Assessment
RFC	River Forecast Center
ROD	Record of Decision
SCT	Mexican Secretariat of Communications and Transportation
SEMARNAT	Secretaría de Medio Ambiente y Recursos Naturales (Mexican Secretary for the Environment and Natural Resources)
SNA	State Natural Area
SOP	standard operating procedure
SWMP	System-wide Monitoring Program
TEIA	Transboundary Environmental Impact Assessment
TPWD	Texas Parks and Wildlife Department
TRNERR	Tijuana River National Estuarine Research Reserve
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
USIBWC	United States Section of the International Boundary and Water Commission
WHIP	Wildlife Habitat Incentives Program
WRP	Western Regional Partnership
WWF	World Wildlife Fund for Nature

GLOSSARY OF TERMS

Active Management Area – Area with heavy reliance on mined groundwater, subject to regulation pursuant to the Arizona Groundwater Code.

At-risk species – Species that have either been proposed for listing as endangered or threatened under the Endangered Species Act (ESA), are candidates for listing or have been petitioned for listing. Biologists commonly refer to species as "at-risk" if they face possible extinction or extirpation from a geographic area.

Biogeochemical cycles – The flow of chemical elements and compounds between living organisms and the physical environment.

Brownfields – Real property for which expansion, redevelopment or reuse may be complicated by the presence or potential presence of a hazardous substance, pollutant or contaminant.

Candidate species – Plants and animals for which the U.S. Fish and Wildlife Service (FWS) has sufficient information on their biological status and threats to propose them as endangered or threatened under the ESA, but for which development of a proposed listing regulation is precluded by other higher priority listing activities. The current list of FWS candidate species is available at http://www.fws.gov/endangered/what-we-do/index.html.

Drainage Basin – The area drained by a river and all its tributaries. Also called catchment area or drainage area.

Ecological integrity – The ability of an ecological system to support and maintain a community of organisms that has a species composition, diversity and functional organization that is comparable to that of natural habitats within a region; the ecological system has integrity, or a species population is viable, when elements of composition, structure, function and ecological processes occur within their natural ranges of variation and can withstand and recover from most perturbations imposed by natural environmental dynamics or human disruptions.

Ecological restoration – The process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed; an intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity and sustainability.

Ecosystem (Ecological Systems) – A dynamic and interrelating complex of plant and animal communities and their associated nonliving (e.g., physical and chemical) environment. An ecosystem is comprised of plants, animals and microbes as well as the air, water, soils and other components upon which they depend, all linked together through nutrient cycles and energy flows.

La Paz Agreement – The 1983 Agreement on Cooperation for the Protection and Improvement of the Environment in the Border Area, which empowers the federal environmental authorities in the United States and Mexico to undertake cooperative initiatives and is implemented through multi-year binational programs.

Listed species – A species, subspecies or distinct vertebrate population segment that has been added to the federal lists of Endangered and Threatened Wildlife and Plants as they appear in sections 17.11 and 17.12 of Title 50 of the Code of Federal Regulations (50 CFR 17.11 and 17.12).

NatureServe – A nonprofit conservation organization whose mission is to provide the scientific basis for effective conservation action. NatureServe and its network of natural heritage programs and conservation data centers are the leading source for information about rare and endangered species and threatened ecosystems.

Reclamation – A process of addressing damage to an ecosystem that includes stabilization of the terrain, assurance of public safety, aesthetic improvement and usually a return of the land to what, within the regional context, is considered to be a useful purpose.

Rehabilitation – A process of addressing damage to an ecosystem that emphasizes the reparation of ecosystem processes, productivity and services.

Regional-scale restoration – Actions that address coarse metrics such as large-scale disturbance (water flow or fire regime), vegetation cover type (forest, open canopy) and wildlife movements. This approach requires a more thoughtful analysis of the role of human activity in the landscape, and implementation must include a representative sample of areas with high levels of ecological integrity.

Resilience – The ability of an ecosystem to regain structural and functional attributes that have suffered harm from stress or disturbance. This concept has gained prominence as an approach to addressing uncertain conditions, and to working with natural change in ecosystems.

Site-based restoration – Actions that focus on degradation within a limited delineated area. This approach addresses restoration needs where impacts have been regarded local and intensive (small mining sites, small weed infestations, old parking areas or corral, chemical releases); these actions often are the focus of land managers because the impacts can be addressed within typical budget and project timelines.

Special Area Management Plan (SAMP) – Defined under the Coastal Zone Management Act as a comprehensive plan providing for natural resource protection and reasonable coastal-dependent economic growth containing a detailed and comprehensive statement of policies, standards and criteria to guide public and private uses of lands and waters, and mechanisms for timely implementation in specific geographic areas within the coastal zone.

Species-centric restoration – Actions that focus on a single species or group of species using similar habitats. This approach to restoration has become problematic when broader related resources such as food webs, overall habitat biodiversity and natural disturbance processes are ignored.

Trust resources – Those natural resources an agency is charged with managing and conserving through legislation. For federal agencies, these include: certain anadromous fish; certain endangered species; certain marine mammals; federally owned minerals; bald and Golden Eagles; migratory birds; national Wildlife Refuges and Fish Hatcheries (and resources therein); national Parks and Monuments (and resources therein); and Tribal resources, in cases where the United States acts on behalf of the Indian Tribe.

Trust species – This includes migratory birds, threatened species, endangered species, interjurisdictional fish, marine mammals and species occurring within federally designated units such as National Parks, National Wildlife Refuges and Marine Sanctuaries.

Urban ecological restoration – The process of assisting the recovery of ecosystems that have been degraded, damaged or destroyed where the human built environment is pervasive (e.g., cities and metropolitan areas). This is an intentional activity that initiates or accelerates the recovery of urban ecosystems understood as coupled human-natural systems.

Urban ecosystem – An integrative concept that highlights how human-built environments (e.g., parks, buildings, infrastructure, urban land use) in cities and metropolitan areas also include plants, animals and microbes—together with air, water, soils and other components upon which life depends—all linked together through nutrient cycles and energy flows.

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NOTES AND REFERENCES

[1] Cairns, J. 2002. "Rationale for Restoration." In *Handbook of Ecological Restoration,* edited by M.D. Perrow and A.J. Davy, 10–23. Cambridge, United Kingdom: Cambridge University Press.

[2] SER (Society for Ecological Restoration). 2004. *Society for Ecological Restoration International Primer on Ecological Restoration.* Accessed July 8, 2014. http://www.ser.org/resources/resources-detail-view/ser-international-primer-on-ecological-restoration

[3] Pulliam, H.R. undated. "What Is restoration?" Accessed July 8, 2014. http://borderlandsrestoration.org/our-approach/what-is-restoration/

[4] Clewell, A.F., and J. Aronson. 2013. *Ecological Restoration, 2nd Edition*. Washington, D.C.: Island Press.

[5] Bakshi, B., and Small, M.J. 2011. "Incorporating Ecosystem Services Into Life Cycle Assessment." *Journal of Industrial Ecology* 15 (4): 477–478. (doi:10.1111/j.1530-9290.2011.00364.x)

[6] National Wildlife Federation. 2014. "Ecosystem Services." Accessed June 1, 2014. http://www.nwf.org/Wildlife/Wildlife-Conservation/Ecosystem-Services.aspx

[7] Brown, T.C., J.C. Bergstrom, and J.B. Loomis. 2007. "Defining, Valuing, and Providing Ecosystem Goods and Services." *Natural Resources Journal* 47 (2): 329–376. Retrieved from http://0-search.ebscohost.com.lib.utep.edu/login.aspx?direct=true&db=a9h&AN=27430406&site=ehost-live&scope=site

[8] Rey Benayas, J.M., A.C. Newton, A.Diaz, and J.M. Bullock. 2009. "Enhancement of Biodiversity and Ecosystem Services by Ecological Restoration: A Meta-Analysis." *Science* 325 (5944): 1121–1124. Published online 30 July 2009 (doi:10.1126/science.1172460)

[9] Updike, R.G., E.G. Ellis, W.R. Page, M.J. Parker, J.B. Hestbeck, and W.F. Horak, eds. 2013. *United States–Mexican Borderlands—Facing Tomorrow's Challenges Through USGS Science: U.S. Geological Survey Circular 1380.* Reston, VA: U.S. Geological Survey. http://pubs.usgs.gov/circ/1380/

[10] The Millennium Ecosystem Assessment Board. 2005. *Living Beyond Our Means: Natural Assets and Human Well-being*. Millennium Ecosystem Assessment Board. http://www.millenniumassessment.org/documents/document.429.aspx.pdf

[11] McDonnell, M.J., and S.T.A. Pickett. 1990. "Ecosystem Structure and Function Along Urban-Rural Gradients: An Unexploited Opportunity for Ecology." *Ecology* 71 (4): 1232–1237.

[12] McDonnell, M.J., S.T.A. Pickett, P. Groffman, P. Bohlen, R.V. Pouyat, W.C. Zipperer, R.W. Parmelee, M.M. Carreiro, K. Medley. 1997. "Ecosystem Processes Along an Urban-to-Rural Gradient." *Urban Ecosystems* 1 (1): 21–36.

[13] Pavao-Zuckerman, M.A. 2008. "The Nature of Urban Soils and Their Role in Ecological Restoration in Cities." *Restoration Ecology* 16 (4): 642–649.

[14] Kaye, J.P., P.M. Groffman, N.B. Grimm, L.A. Baker, and R.V. Pouyat. 2006. "A Distinct Urban Biogeochemistry?" *Trends in Ecology & Evolution* 21 (4): 192–199.

[15] Whisenant, S. 1999. *Repairing Damaged Wildlands*. Cambridge, UK: Cambridge University Press. (doi: 10.1017/CBO9780511612565)

[16] McDonnell, M.J., and S.T.A. Pickett. 1990. "Ecosystem Structure and Function Along Urban-Rural Gradients: An Unexploited Opportunity for Ecology." *Ecology* 71 (4): 1232–1237.

[17] The Environmental Protection Agency (EPA) defines a brownfield as "real property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant." http://epa.gov/brownfields/overview/glossary.htm

[18] Westphal, L.M., P.H. Gobster, and M. Gross. 2010. "Models for Renaturing Brownfield Areas." Chapter 19. In *Restoration and History: The Search for a Usable Environmental Past*, edited by M. Hall, 208–217. New York, NY: Routledge.

[19] Whisenant, S. 1999. *Repairing Damaged Wildlands*. Cambridge, UK: Cambridge University Press. (doi: 10.1017/CBO9780511612565)

[20] Hobbs, R.J., and D.A. Norton. 1996. "Towards a Conceptual Framework for Restoration Ecology." *Restoration Ecology* 4 (2): 93–110. (doi: 10.1111/j.1526-100x.1996.tb0012.x)

[21] Shachak, M., J.R. Gosz, S.T.A. Pickett, and A. Perevolotsky. 2004. *Biodiversity in Drylands: Toward a Unified Framework*. New York, NY: Oxford University Press.

[22] Beschta, R.L., and W.J. Ripple. 2012. "The Role of Large Predators in Maintaining Riparian Plant Communities and River Morphology." *Geomorphology* 157–158: 88–98.

[23] Beschta, R.L., and W.J. Ripple. 2010. "Mexican Wolves, Elk, and Aspen in Arizona: Is There a Trophic Cascade?" *Forest Ecology and Management* 260 (5): 915–922.

[24] Oregon State University. 2007. "Trophic Cascades Program." http://www.cof.orst.edu/cascades/index.php

[25] USEPA. 2014. "Green Infrastructure." Office of Water, EPA. Last modified October 27. http://water.epa.gov/infrastructure/greeninfrastructure/index.cfm

[26] CBP-DOI. 2009. Memorandum of Agreement Between U.S. Customs and Border Protection and U.S. Department of the Interior Regarding Natural and Cultural Resource Mitigation Associated with Construction and Maintenance of Border Security Infrastructure along the Border of the United States and Mexico.

[27] Groom, M.J., G.K. Meffe, and C.R. Carroll. 2006. *Principles of Conservation Biology, Third Edition.* Sunderland, MA: Sinauer Associates, 440.

[28] Groom, M.J., G.K. Meffe, and C.R. Carroll. 2006. *Principles of Conservation Biology, Third Edition.* Sunderland, MA: Sinauer Associates, 439.

[29] Omernik, J.M. 2004. "Perspectives on the Nature and Definition of Ecological Regions." *Environmental Management* 34 (1 Suppl.): 27–38. (doi: 10.1007/s00.267-003-5197-2)

[30] Omernik, J.M. and R.G. Bailey. 1997. "Distinguishing Between Watersheds and Ecoregions." *Journal of the American Water Resources Association* 33 (5): 935–949. (doi: 10.1111/j.1752-1688.1997.tb04115.x)

[31] On August 14, 1983, the United States and Mexico signed the United States–Mexico Agreement on Cooperation for the Protection and Improvement of the Environment in the Border Area, better known as the La Paz Agreement. This remains the keystone agreement for bilateral cooperation on environmental protection in the border zone.

[32] Hallett, L.M., S. Diver, M.V. Eitzel, J.J. Olson, B.S. Ramage, H. Sardinas, Z. Statman-Weil, and K.N. Suding. 2013. "Do We Practice What We Preach? Goal Setting for Ecological Restoration." *Restoration Ecology* 21 (3): 312–319. (doi:10.1111/rec.12007)

[33] Ernstson, H., and S. Sörlin. 2013. "Ecosystem Services as Technology of Globalization: On Articulating Values in Urban Nature." *Ecological Economics* 86: 274–284. (doi:10.1016/j.ecolecon.2012.09.012)

[34] McKay, S.K., I. Linkov, J.C. Fischenich, S.J. Miller, and L.J.J. Valverde. 2012. *Ecosystem Restoration Objectives and Metrics*. Vicksburg, MS: U.S. Army Engineer Research, ERDC TN-EMRRP-EBA-16.

[35] Foley, M.M., B.S. Halpern, F. Micheli, M.H. Armsby, M.R. Caldwell, C.M. Crain, R.S. Steneck. 2010. "Guiding Ecological Principles for Marine Spatial Planning." *Marine Policy* 34 (5): 955–966. (doi:10.1016/j.marpol.2010.02.001)

[36] Foley, M.M., M.H. Armsby, E.E. Prahler, M.R. Caldwell, A.L. Erickson, J.N. Kittinger, P.S. Levin. 2013. "Improving Ocean Management Through the Use of Ecological Principles and Integrated Ecosystem Assessments." *Bioscience* 63 (8): 619–631. (doi:10.1525/bio.2013.63.8.5)

[37] Pursuant to § 4180.1 43 CFR Ch. II (10–1–10 Edition). http://www.gpo.gov/fdsys/pkg/CFR-2010-title43-vol2/pdf/CFR-2010-title43-vol2-sec4180-2.pdf

[38] Lucero J., Bureau of Reclamation, personal communication.

[39] USDA. "Ecological Site Descriptions." Accessed November 2014. http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/ecoscience/desc/

[40] Norman, L.M., D.D. Hirsch, and A.W. Ward. 2008. *Proceedings of a USGS Workshop on Facing Tomorrow's Challenges Along the U.S.-Mexico Border—Monitoring, Modeling, and Forecasting Change Within the Arizona-Sonora Transboundary Watersheds: U.S. Geological Survey Circular 1322.* Tucson, AZ: U.S. Geological Survey. http://pubs.usgs.gov/circ/1322

[41] Updike, R.G., E.G. Ellis, W.R. Page, M.J. Parker, J.B. Hestbeck, and W.F. Horak, eds. *2013, United States–Mexican Borderlands—Facing tomorrow's challenges through USGS science: U.S. Geological Survey Circular 1380*. Reston, VA: U.S. Geological Survey.

[42] NOAA National Weather Service. "Advanced Hydrologic Prediction Service." http://water.weather.gov/ahps/partners/nws_partners.php

[43] Just over 2,696 acres (1,091 hectares) are held in trust, whereas the other 876 acres (355 hectares) are held in simple fee.

[44] The Pueblo acquired the 70,360-acre (28,470-hectare) Chilicote Ranch, located in both Jeff Davis and Presidio counties in west Texas. Preceding the 1960s, the ranch was managed primarily for sheep, goat, and cattle production. Since that time, the ranch has run a cow/calf operation, occasionally grazing yearlings. The property has been managed to derive income from mule deer, pronghorn, aoudad, quail hunting and javelina and for predator control of coyote, mountain lions and bobcats. Pens for Big Horn Sheep were installed for an animal re-introduction project funded by the state. State funding is no longer available, so although the pens are still standing, the Project no longer operates.

[45] A steel-framed, polyethylene-covered structure, also called a hoop house, which is used in agriculture to extend the growing season. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/oh/programs/?cid=nrcs144p2_029511

[46] Pellant, M., P. Shaver, D.A. Pyke, and J.E. Herrick. 2005. "Interpreting Indicators of Rangeland Health, Version 4." Denver, CO: U.S. DOI, BLM National Business Center. Technical Reference 1734-6. BLM/WO/ST-00/001+1734/REV05.

[47] CBP-DOI. 2009. Memorandum of Agreement Between U.S. Customs and Border Protection and U.S. Department of the Interior Regarding Natural and Cultural Resource Mitigation Associated with Construction and Maintenance of Border Security Infrastructure along the Border of the United States and Mexico.

[48] Webb, R.H., T.C. Esque, K.E. Nussear, M. Sturm. 2013. "Disruption rates for one vulnerable soil in Organ Pipe Cactus National Monument." *Journal of Arid Environments* 95: 75–83. (doi:10.1016/j.jaridenv.2013.03.016)

[49] Vernal pools are temporary pools of water that provide habitat for distinctive species of plants and animals.

[50] Parrish, J.D., D.P. Braun, and R.S. Unnasch. 2003. "Are We Conserving What We Say We Are? Measuring Ecological Integrity Within Protected Areas." *BioScience* 53 (9): 851–860. (doi: http://dx.doi.org/10.1641/0006-3568(2003)053[0851:AWCWWS])

[51] Unnasch, R.S., D.P. Braun, P.J. Comer, G.E. Eckert. 2008. *The Ecological Integrity Assessment Framework: A Framework for Assessing the Ecological Integrity of Biological and Ecological Resources of the National Park System*. Report to the National Park Service.

[52] Armitage, D., C. Béné, A.T. Charles, D. Johnson, and E.H. Allison. 2012. "The Interplay of Well-being and Resilience in Applying a Social-Ecological Perspective." *Ecology and Society* 17 (4): 15 (http://dx.doi.org/10.5751/ES-04940-170445)

[53] U.S. DOI. 2013. "Desert Landscape Conservation Cooperative Fact Sheet." Last modified December 13, 2013, accessed September 18, 2014. http://www.usbr.gov/dlcc/resources/docs/DLCCfactsheet.pdf

[54] U.S. DOI. 2009. *Addressing the Impacts of Climate Change on America's Water, Land, and Other Natural and Cultural Resources*. Secretarial Order 3289. http://www.fws.gov/home/climatechange/pdf/SecOrder3289.pdf

[55] National Academies. 2014. "Call for Nominations by July 8: Evaluation of the Landscape Conservation Cooperatives." http://nas-sites.org/americasclimatechoices/studies-in-progress/evaluation-of-the-landscape-conservation-cooperatives-call-for-nominations

[56] U.S. DOI, BLM. 2014. *The BLM's Landscape Approach for Managing Public Lands*. Last modified January 31, 2014, accessed October 1, 2014. http://www.blm.gov/wo/st/en/prog/more/Landscape_Approach.html

[57] The NISC was created by EO 13112 in 1999. It is co-chaired by the Secretaries of the Interior, Agriculture, and Commerce. NISC members include the Secretaries of State, Defense, Homeland Security, Treasury, Transportation, Health and Human Services, the U.S. Trade Representative (USTR), as well as the Administrators of the U.S. Environmental Protection Agency, National Aeronautics and Space Administration, and U.S. Agency for International Development.

[58] The National Invasive Species Council. *About NISC*. http://www.invasivespecies.gov/main_nav/mn_about.html

[59] National Advisory Committee on Invasive Species. 2010. *National Strategy on Invasive Species in Mexico: Prevention, Control and Eradication.* Mexico: Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, Comisión Nacional de Áreas Protegidas, Secretaría de Medio Ambiente y Recursos Naturales. http://www.biodiversidad.gob.mx/v_ingles/country/pdf/Invasive_species_Mexico_dec2010.pdf

[60] USEPA. 2012. *Border 2020: U.S.-Mexico Environmental Program*. EPA-160-R-12-001. Washington, D.C.: Office of International and Tribal Affairs. http://www2.epa.gov/sites/production/files/documents/border2020summary.pdf

[61] An excellent overview of these different local, state, and federal agencies and non-governmental districts and other institutions with a role in managing water along the border can be found in the Eighth GNEB report. See www2.epa.gov/sites/production/files/documents/gneb8threport.pdf, pp.4–10. See also the Fifteenth GNEB report http://www2.epa.gov/sites/production/files/documents/english-gneb-15th-report.pdf, pp. 5–15.

[62] Poole, J.M., W.R. Carr, D.M. Price, and J.R. Singhurst. 2007. *Rare Plants of Texas: A Field Guide*. Texas Parks and Wildlife Department, 498–499.

[63] GNEB. 2010. *Thirteenth Report of the Good Neighbor Environmental Board to the President and Congress of the United States,* p. 29. Accessed July 7, 2014. http://www2.epa.gov/sites/production/files/documents/eng_gneb_13th_report_final.pdf

[64] GNEB. 2005. *Water Resources Management on the U.S.-Mexico Border: Eighth Report to the President and the Congress of the United States*, p. 22. Accessed July 7, 2014, http://www2.epa.gov/sites/production/files/documents/gneb8threport.pdf; and GNEB. 2009. *Innovative and Practical Approaches to Solving Border Environmental Problems: Twelfth Report of the Good Neighbor Environmental Board to the President and Congress of the United States*, p. 8. Accessed July 7, 2014, http://www2.epa.gov/sites/production/files/documents/english-gneb-12th-report.pdf

[65] Roosevelt, Theodore. 1906. *Convention between the United States and Mexico. Equitable Distribution of the Waters of the Rio Grande.* Article II. http://www.ibwc.gov/Files/1906Conv.pdf

[66] Truman, Harry S. 1944. *Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande, U.S.-Mexico: Treaty Between the United States of America and Mexico, Signed at Washington, D.C., February 3, 1944, and Protocol Signed at Washington, D.C., November 14, 1944.* Article 3.

[67] The Tranboundary Aquifer Assessment Act (U.S. Public Law 109-448) was signed by the President of the United States on December 22, 2006. Mexico's collaboration in the program was formalized through a Joint Report signed by the Principal Engineers of the IBWC on August 19, 2009. The Joint Report established the Cooperative Framework for U.S.-Mexico coordination and dialogue that has been essential to binational study of these aquifers. Working through the IBWC Cooperative Framework, the U.S. Geological Survey, the University of Arizona, Mexico's National Water Commission (CONAGUA), and the University of Sonora are nearing completion of the *Santa Cruz River Aquifer Binational Report* and the *San Pedro River Aquifer Binational Report*, which will be issued by IBWC later in 2014 in Spanish and English (see wrrc.arizona.edu/TAAP).

[68] Texas sued New Mexico in January 2013 over this issue.

[69] Collier, M., R.H. Webb, and J.C. Schmidt. 1996. *Dams and Rivers: Primer on the Downstream Effects of Dams: U.S. Geological Survey Circular 1126.* Tucson, AZ: U.S. Geological Survey.

[70] AgriLife Extension, Texas A&M System. "Texas Biological Program Continues to Expand, Despite Some Controversies." *Beetle-Mania: Biological Control of Salt Cedar in Texas* 2 (2 Summer 2010) 1–2.

[71] GNEB. 2012. *The Environmental, Economic and Health Status of Water Resources in the U.S.-Mexico Border Region: Fifteenth Good Neighbor Environmental Board Report,* pp. 42–43. www.epa.gov/ocempage/gneb/gneb15threport/English-GNEB-15th-Report.pdf

[72] "Southmost Preserve: Threatened Treasure." YouTube video, posted by The Nature Conservancy, July 7, 2010. www.nature.org/ourinitiatives/regions/northamerica/unitedstates/texas/explore/mammals-ocelot.xml

[73] 2010 U.S. Census. http://www.census.gov/2010census/data/

[74] INEGI (Instituto Nacional de Estadística y Geografía; National Institute of Statistics and Geography). http://www.inegi.org.mx/

[75] San Diego Planning Department. "Urban Forest Management Plan." http://www.sandiego.gov/planning/programs/urbanforest/index.shtml

[76] Tijuana River National Estuarine Research Reserve. "Overview." http://trnerr.org/about/overview/

[77] Environmental Defense Fund. About the Colorado River Basin. http://www.coloradoriverbasin.org/about-the-colorado-river-Basin/

[78] U.S. Bureau of Reclamation. 2011. "Colorado River Basin Water Supply and Demand Study Seeks Input to Help Resolve Projected Future Supply and Demand Imbalances." November 29, accessed September 24, 2014. http://www.usbr.gov/newsroom/newsrelease/detail.cfm?RecordID=38644

[79] U.S. Bureau of Reclamation. 2004. *Lower Colorado River Multi-Species Conservation Program, Volume II: Habitat Conservation Plan*. December 17. http://www.lcrmscp.gov/publications/hcp_volii_dec04.pdf

[80] U.S. Bureau of Reclamation. "Lower Colorado River Multi-Species Conservation Program." Last updated December 20, 2013. http://www.lcrmscp.gov/general_program.html

[81] Minutes are decisions of the IBWC. When approved by both countries, they have the force of treaty.

[82] In its fifteenth report, the GNEB addressed environmental flows and recommended that U.S. federal agencies and IBWC develop metrics and models for environmental flows for use in water planning.

[83] Stotz, N.G. 2000. *Historic Reconstruction of the Ecology of the Rio Grande/Rio Bravo Channel and Floodplain in the Chihuahuan Desert.* Report prepared for the World Wildlife Fund.

[84] Water Policy Review Advisory Commission. 1998. *Water in the West: Challenge for the Next Century*, which found that aquatic ecosystems are under stress from a variety of sources, including federal projects and activities and recommended that federal agencies develop comprehensive plans for aquatic ecosystem restoration, including among their goals the recovery of aquatic species at risk by "developing multispecies habitat conservation programs" (pp. 6–12).

[85] Information from the Texas Parks and Wildlife Department and *Devils River Working Group, Final Report and Recommendations*, January 2012.

[86] GNEB. 2009. *Innovative and Practical Approaches to Solving Border Environmental Problems: Twelfth Good Neighbor Environmental Board Report*, pp. 24–27. Accessed May 3, 2014. http://www.epa.gov/ocempage/gneb/gneb12threport/English-GNEB-12th-Report.pdf

[87] State of California. 2013. *Salton Sea Restoration Act.* California Fish Game Code, Division III, Chapter 13.

[88] Ohmart, R.D. and B.W. Anderson. 1986. "Riparian Habitats." In *Inventory and Monitoring of Wildlife Habitat,* edited by A.Y. Cooperrider, et al., 169–99. Denver, CO: U.S. DOI, BLM.

[89] USGS. "Aridland Water Harvesting Study." Last updated August 7, 2014. http://geography.wr.usgs.gov/science/aridlands/

[90] Norman, L.M., M.L. Villarreal, H.R. Pulliam, R. Minckley, L. Gass, C. Tolle, and M. Coe. 2014. "Remote Sensing Analysis of Riparian Vegetation Response to Desert Marsh Restoration in the Mexican Highlands." *Ecological Engineering* 70C: 241–54. (doi: 10.1016/j.ecoleng.2014.05.012)

[91] Barry, T. 2014. "Transborder Drylands Restoration: Vision and Reality After Three Decades of Innovative Partnerships on the U.S.-Mexico Border." *S.A.P.I.EN.S. Surveys and Perspectives Integrating Environment and Society.* 7 (2). http://sapiens.revues.org/1553

[92] Borderlands Restoration. http://borderlandsrestoration.org/

[93] U.S. FWS. "Southwestern Willow Flycatcher Final Revised Critical Habitat 2013." Last updated December 3, 2013. http://www.fws.gov/southwest/es/arizona/SWWF_revisedCH_2013.htm

[94] Minute 276, "Conveyance, Treatment and Disposal of Sewage from Nogales, Arizona and Nogales, Sonora Exceeding the Capacities Allotted to the United States and Mexico at the Nogales International Sewage Treatment Plant Under Minute 227," dated July 26, 1988, is an agreement of the International Boundary and Water Commission, United States and Mexico, for the expansion of the Nogales International Wastewater Treatment Plant in Arizona, the allotment of treatment plant capacity between the United States and Mexico, and the sharing of associated costs between the two countries.

[95] CBP-DOI. 2009. Memorandum of Agreement Between U.S. Customs and Border Protection and U.S. Department of the Interior Regarding Natural and Cultural Resource Mitigation Associated with Construction and Maintenance of Border Security Infrastructure along the Border of the United States and Mexico.

[96] Special Area Management Plan, Section 304 of the Coastal Zone Management Act of 1972 (Public Law 92-583, 16 U.S.C. 1451-1456).