Chapter 9

Rio Grande
MEXICO
Dallas
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Houston
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Durango
G. of California

Chapter 9

Challenge Theme 7. Information Support for Management of Border Security and Environmental Protection

By Jean W. Parcher and William R. Page

Introduction

Historically, international borders were located far from the major political and economic capitals of their countries and rarely received adequate planning or infrastructure development. Today, as a result of global economics and increased movement of goods between nations, border regions play a much greater role in commerce, tourism, and transportation. For example, Mexico is the second largest destination for United States exports (Woodrow Wilson Center Mexico Institute, 2009). The rapid population and economic growth along the United States–Mexican border, undocumented human border crossings, and the unique natural diversity of resources in the Borderlands present challenges for border security and environmental protection. Assessing risks and implementing sustainable growth policies to protect the environment and quality of life greatly increase in complexity when the issues cross an international border, where social services, environmental regulations, lifestyles, and cultural beliefs are unique for each country. Shared airsheds, water and biological resources, national security issues, and disaster management needs require an integrated binational approach to assess risks and develop binational management strategies.

Border Security and Environmental Protection Issues

Both national security and environmental protection are critical issues along the border. The challenge is to integrate these issues and develop a plan that is beneficial and acceptable to both the United States and Mexico. Frequent consultation and joint decisionmaking between the two countries provide for a more effective solution to security and environmental issues than would separate plans that do not take into account shared concerns and issues. The common objectives that are shared by the entities in charge of securing our border and protecting the environment include protection of critical infrastructure, development of a national incident management system, and use of technology and intelligence—all to be accomplished in ways that sustain a healthy environment (Schoik, 2007).

The extensive border between the United States and Mexico runs through urban sister city areas, Native American tribal lands, national forests, U.S. Department of Defense properties, national parks, and other U.S. Department of Interior lands (see poster, figs. 2–3 to 2–6). Because these Federal lands are in various management jurisdictions and are primarily rural and unpopulated, they create the opportunity for a large volume of illicit cross-border activity. This activity has created significant security challenges to our Nation in protecting and maintaining border integrity, but authorities have responded by securing waterways, preventing undocumented crossings and subterranean tunnel activities, and apprehending illegal drug traffickers in both urban and rural settings.

U.S. Customs and Border Protection Air and Marine group conducting aerial operations with an unmanned aircraft system

Emphasis on national security along our borders greatly increased after the events of September 11, 2001. The United States–Mexican border has 39 ports of entry which facilitate over 300 million legal crossings a year and almost $650 million a day in binational commerce, including critical energy supplies (United States–México Border Health Commission, 2007; U.S. Customs and Border Protection, 2007; U.S. White House, 2007). Illegal crossings and the smuggling of people, drugs, cash, and weapons occur in both directions along the 3,141-kilometer (km) (1,952-mile [mi]) border (figs. 9–1 and 9–2) and result in significant costs related to intelligence and enforcement, loss of life, and adverse effects on the environment. From the mid-1990s to 2006, more than a million illegal immigrants were apprehended and deported each year. Most immigrants are Mexican nationals, and a small percentage of people were from Central America, South America, and Asia (Sapp, 2011). From 1998 to 2005, migrant deaths from illegal border crossings doubled due to a shift in migration routes from urban areas to rural areas. In the past few years in Mexico, violence associated with Mexican drug cartels has resulted in an increase in drug, cash, and weapons smuggling and the deaths of thousands of people in Mexico, many in the border cities of Tijuana, Baja California, and Ciudad Juárez, Chihuahua—as of 2009, cartels caused 12,000 deaths in Mexico (Napolitano, 2009), and the number of deaths continue to grow. The violence has worsened so much that the U.S. Department of Homeland Security and its cooperators continue to strengthen security in order to disrupt the smuggling operations helping to fuel cartel violence in Mexico and prevent its spillover into the United States (U.S. Department of Homeland Security, 2011).

Figure 9–1. Illegal immigrants apprehended near the border.

(Below) Patrolling for opium near the United States–Mexican border near Tijuana, Baja California, 1948

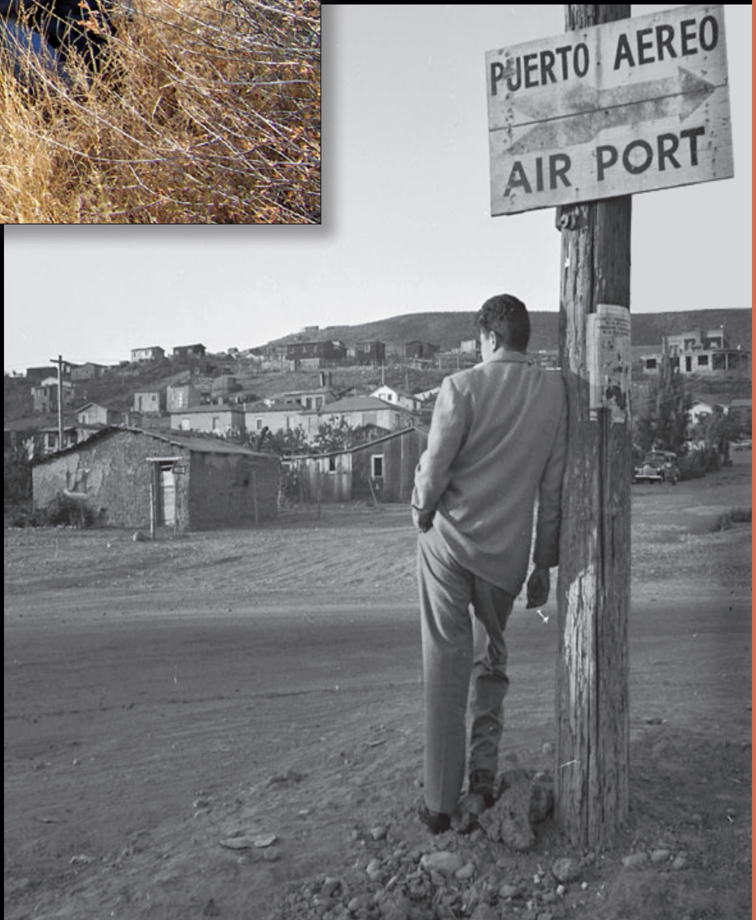
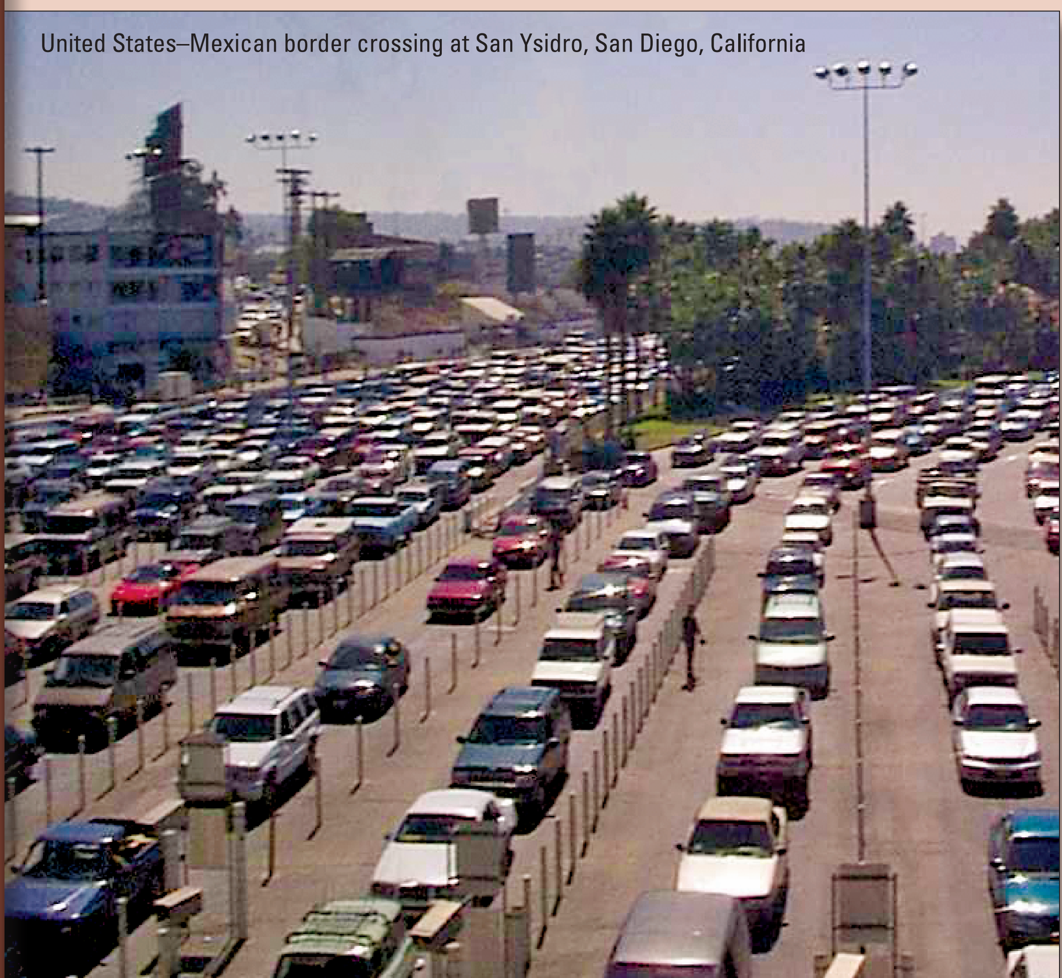


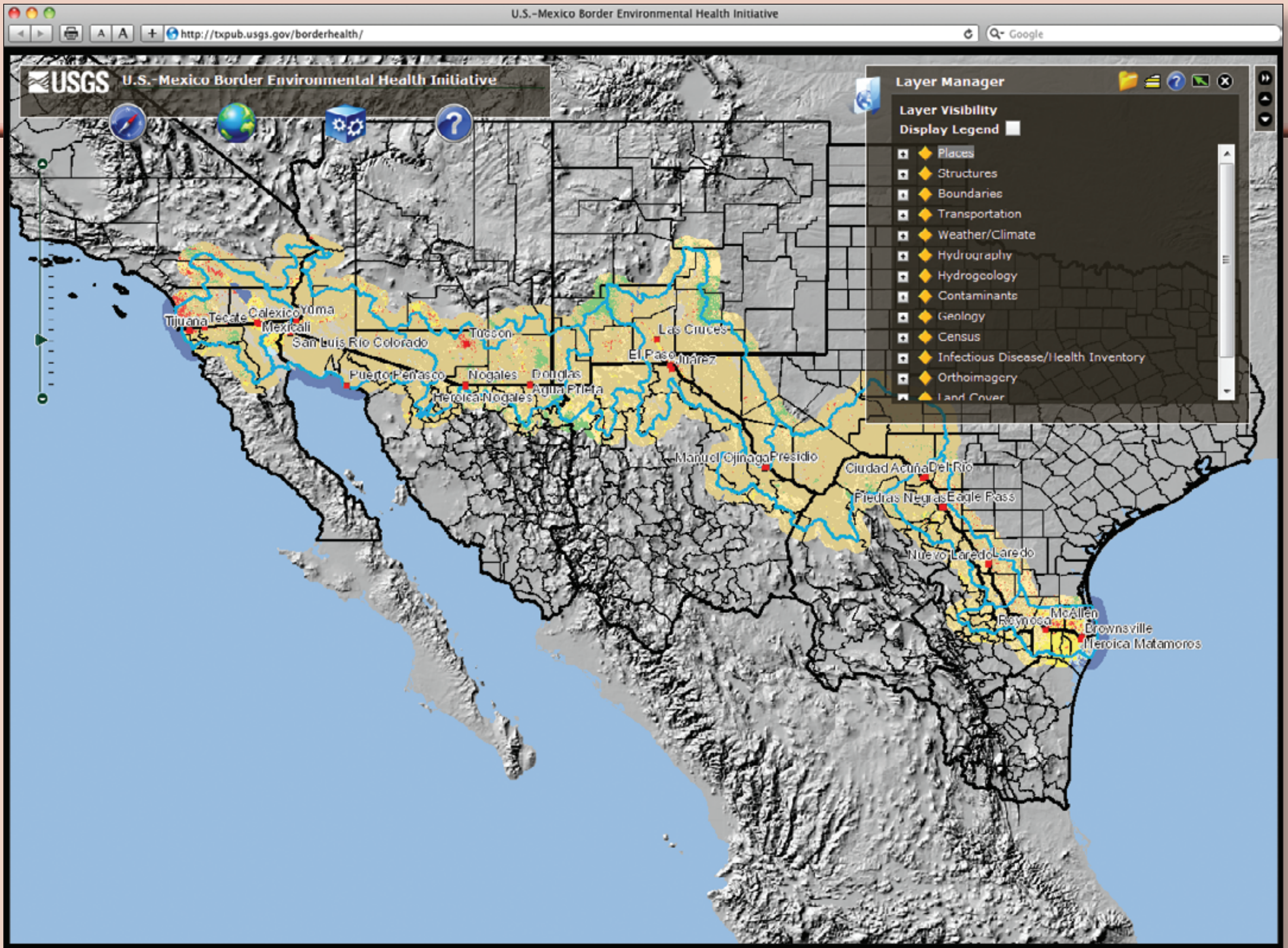
Figure 9–2. Apprehended vehicle loaded with marijuana.

United States–Mexico Border Geographic Information System

Geographic information systems (GIS) and the development of extensive geodatabases have become invaluable tools for addressing a variety of contemporary societal issues and making predictions about the future. The USGS Border Environmental Health Initiative (BEHI; *http://borderhealth.cr.usgs.gov*) United States–Mexico Border Geographic Information System (USMX-GIS) is based on fundamental datasets that are produced and (or) approved by the national geography agency of each country—the U.S. Geological Survey (USGS) and the Instituto Nacional de Estadística y Geografía (INEGI) [National Institute of Statistics and Geography]—and the International Boundary and Water Commission. The data are available at various scales to allow both regional and local analysis (Parcher, 2008). The signing of the USGS and INEGI Project Annex Six, which provides the legal framework for public access to the best available harmonized binational geospatial datasets along the United States–Mexican border, allowed full public access to the numerous transboundary GIS datasets developed by the BEHI project.



United States–Mexican border crossing at San Ysidro, San Diego, California



The United States–Mexico Border Environmental Health Initiative (BEHI) Internet map service user interface. Dataset layers can be selected through the Layer Manager. (*http://txpub.usgs.gov/borderhealth/*)

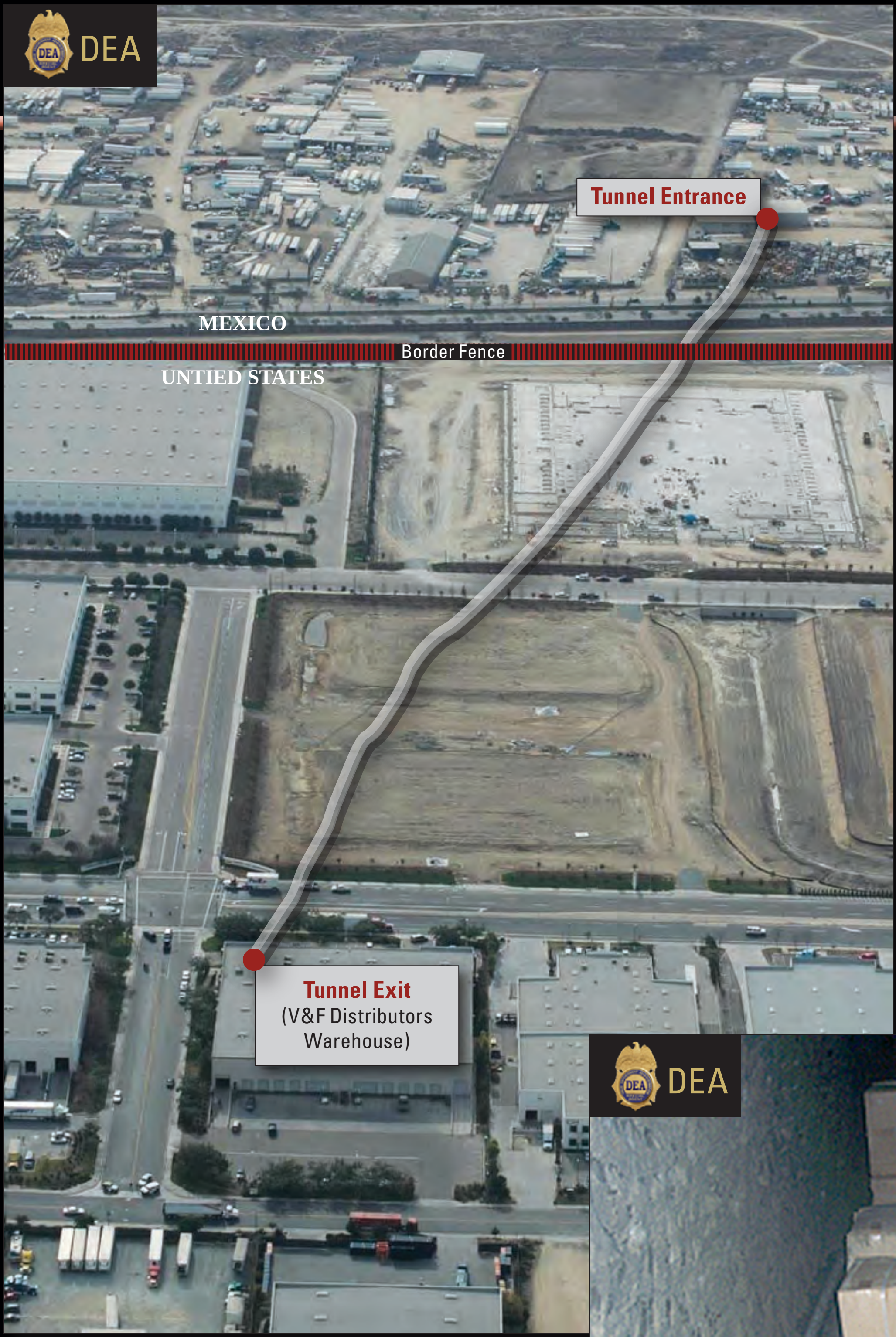
The USMX-GIS extends GIS development to include national level cooperation between various agencies in both countries to provide harmonized geospatial and thematic datasets. These binational harmonized datasets are available in a range of raster products:

- high-resolution digital orthophotographs, digital elevation models, and satellite imagery;
- demographic information—population density, populated areas, transportation, geographic names, hospitals, schools, and international, State, and local government administration boundaries;
- water information—watersheds, hydrographic networks, and water quality data;
- physical features—geologic maps, land use, and land cover; and
- contaminants—in biota, potential sources of contaminants, and soil geochemistry.

These datasets can be viewed in an Internet map service at *http://txpub.usgs gov/borderhealth/* and are available for public download through a file transfer protocol (FTP) Web site at *http://borderhealth.cr.usgs.gov/datalayers.html*.

U.S. Geological Survey Support in Tunnel Detection Technology

Underground tunnels used in illegal smuggling operations are a significant security challenge along the United States–Mexican border, and dozens of these tunnels have been documented, mainly in California and Arizona. Border security agencies rely on the support of USGS geophysicists for the advancement of technology used to detect illegal tunnels along the border. Scientists with geophysical expertise serve on technology assessment teams whose major role is to evaluate different geophysical techniques that can be used for tunnel detection. They collaborate with security agencies to conduct site characterization surveys—the collection of important geophysical data, including electrical measurements, helps to define subsurface soils and rock that can host buried tunnels. The scientists collect samples of tunnel rock and perform laboratory analyses to determine physical properties of these samples, including density, magnetic susceptibility, resistivity, and water content. These characteristics provide important clues in understanding why tunnels are constructed in certain areas and help predict the location of undetected tunnels in other areas along the border. Scientists then contribute to tunnel detection technology reports which summarize their site characterization and evaluation investigations.



tunnels

A U.S. Geological Survey (USGS) scientist collects geophysical data along the United States–Mexican border (facing page). The data collected by the USGS helps border security agencies find smuggling tunnels near the United States–Mexican border, such as this tunnel under Otay Mesa in California (top left). These bales of marijuana (bottom right) were seized from the tunnel by the Drug Enforcement Administration in January 2006.

Terrorism threats on infrastructure and on United States and Mexican citizens are also a concern in the Borderlands and create challenges for securing our shared binational waterways, including the Rio Grande and associated reservoirs and dams (Amistad and Falcon Reservoirs and Dams in Texas and Elephant Butte Reservoir and Dam in New Mexico) and the Gulf Coast and Pacific Coast areas. Heightened terror alerts have been posted in the past for some railways along the border; alerts may also affect other transportation hubs including shipping ports, airports, and truck and bus depots, as well as other infrastructure such as chemical, military, and communication facilities and natural gas and electrical lines that cross the border region.

Two other important security challenges are improving readiness for response to and recovery from disasters—which include not only terrorist attacks but also natural events such as earthquakes, wildfire, landslides, and flooding—and controlling the spread of infectious disease such as avian influenza or the H1N1 virus. For example, the Gulf Coast areas of Tamaulipas and southern Texas are extremely vulnerable to hurricanes and associated flooding, such as Hurricane Beulah in 1967, which caused severe flooding and inundated thousands of acres of agricultural land in the lower Rio Grande valley (see chapter 8). Because of a humid and temperate climate, these areas have also experienced recent outbreaks of dengue fever and are vulnerable to the spread of other vector-borne disease such as the West Nile virus. On the western end of the border, southern California and Baja California, the most heavily populated areas of the Borderlands, have experienced devastating earthquakes and wildfires in recent years, which resulted in loss of life and millions of dollars of damage to infrastructure and property.

A drainpipe on the Mexican side of the border leaves a gap in the fence at Calexico, California, 1979

Special operations training for U.S. Navy and U.S. Air Force personnel at Elephant Butte Reservoir, New Mexico, 1990

Another unfortunate aspect of illegal immigration and other criminal activity for border security authorities to consider is the deleterious effect such activity has on the limited natural resources and fragile wildlife habitat of the Borderlands (Cordova and de la Parra, 2007). For example, in the Buenos Aires National Wildlife Refuge in southern Arizona, illegal immigrants have left behind about 500 tons of trash (fig. 9–3), have abandoned hundreds of vehicles, and have forged more than 2,092 km (1,300 mi) of trails that traverse the land (Swarbick, 2007; Viramontes and Brown, 2008). Border security itself—in the form of border fences and walls constructed by the U.S. Department of Homeland Security (figs. 9–4 and 9–5)—though important to the prevention of illegal activity, can also negatively affect Borderlands ecosystems (Flesch and others, 2010). These physical barriers prevent the natural migration of wildlife and may cause habitat fragmentation, eventually leading to a decline in wildlife populations and possible total species loss. This issue is of particular concern in the many protected lands in the Borderlands, including Big Bend National Park (Texas), the adjacent Reserva de la Biosfera Maderas del Carmen [biosphere reserve] and Área de Protección de Flora y Fauna Cañón de Santa Elena [protected flora and fauna area] in Mexico (Coahuila and Chihuahua), Organ Pipe Cactus National Monument (Arizona), Cabeza Prieta National Wildlife Refuge (Arizona), and San Pedro Riparian National Conservation Area (Arizona). Many of the animals that occupy these lands are uncommon in the first place, partly because they reside at the northern limit of their habitat. Wildlife that may be affected by the construction of border fences include the Mexican black bear (*Ursus americanus eremicus*), Mexican gray wolf (*Canis lupus baileyi*), ocelot (*Leopardus pardalis*), jaguar (*Panthera onca*; already endangered), bobcat (*Lynx rufus*), puma (*Puma concolor*), Sonoran pronghorn (*Antilocapra americana sonoriensis*), bighorn sheep (*Ovis canadensis*), and various reptile and amphibian species. Many border fences are planned to have bright lighting, which may adversely affect bats and migratory bird populations. Other problems associated with border fences include the buildup of sediment and trash along rivers and drainages crossing the border, which can potentially disrupt natural river ecozones such as wetlands and other sensitive habitats.

Sonoran pronghorn (*Antilocapra americana sonoriensis*)

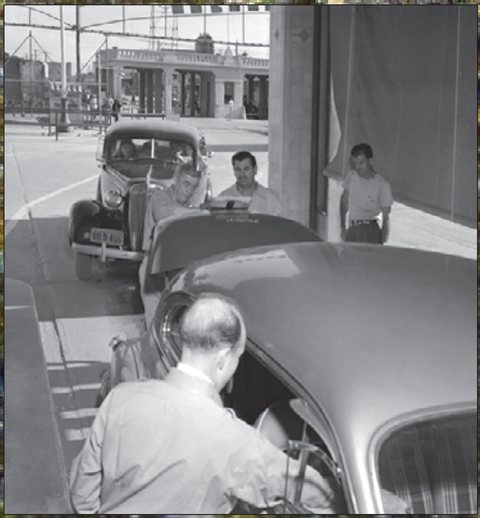
Trash left behind by illegal immigrants

Bighorn sheep (*Ovis canadensis*)

Border Crossings at Sister Cities *Calexico, California*, and *Mexicali, Baja California*

then

Ferry boat crossing near Calexico, California, *1906*



Vehicle inspection at the Calexico-Mexicali border crossing station, *1948*

View of Calexico-Mexicali border crossing station from United States side, *1950*

(Background image) View south into Mexicali, Baja California, from Calexico, California now

Calexico port of entry, 2003

Calexico east port of entry, 2003

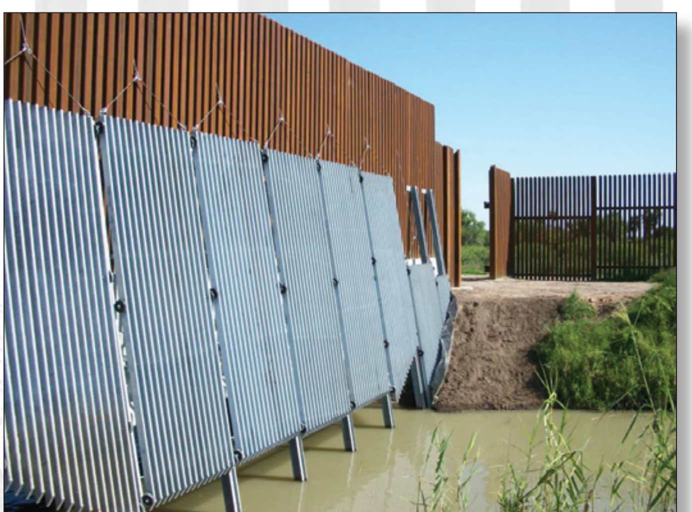
Vehicle inspection at the Calexico-Mexicali border crossing station, 2012

The U.S. Department of the Interior (DOI) manages 18 national parks, 15 wilderness areas, 3 national monuments, and 6 recreation or conservation areas within the Borderlands (see poster, figs. 2–2 to 2–5). Additionally, there are 12 wildlife refuges and 12 tribal entities, some of which span the border. Thus, each DOI bureau with land interests in the area—U.S. Fish and Wildlife Service, National Park Service, Bureau of Land Management, Bureau of Reclamation, and Bureau of Indian Affairs—has land and resource management issues along the border that are tied directly to their bureau mission mandates. The DOI U.S.–Mexico Border Field Coordinating Committee (FCC; *http://www.cerc.usgs.gov/fcc/*) facilitates communication and coordination among all DOI bureaus and consultation with Mexican counterparts through biannual meetings, information sharing, and working groups established to address specific subjects directly related to border security, environmental protection issues including climate change, invasive species, and water availability and quality. By assisting the member bureaus in building partnerships and enlisting volunteers, the FCC advances its objectives of improved communication, coordinated activity, and implementation of the best conservation practices in the Borderlands. Through binational cooperative efforts facilitated by the FCC, scientists in the United States and Mexico share long-term data and technical expertise to recognize and monitor border security activities and the effects of urbanization and agriculture in these preserved lands.

Figure 9–3. Trash left behind by illegal immigrants at Buenos Aires National Wildlife Refuge, Arizona.

Figure 9–4. Fence along the United States–Mexican border at Buenos Aires National Wildlife Refuge, Arizona.

Figure 9–5. Newly constructed fence on the United States–Mexican border near the San Diego–Tijuana sister city area (California–Baja California).



Border fence crossing irrigation canal

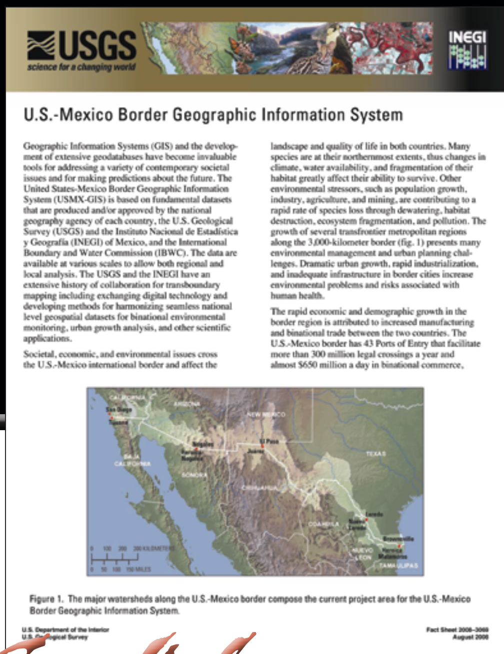
Debris accumulation at a drainage grate

USGS Capabilities

The expertise of the U.S. Geological Survey (USGS) in mapping, modeling, and integrating scientific databases, combined with long-term partnerships with Mexican Federal agencies, provides a strong foundation to address the issues of national security and environmental protection and management. The USGS Border Environmental Health Initiative (BEHI; *http://borderhealth.cr.usgs.gov*) recognized the need for transboundary science datasets based on a geographic information system (GIS) to address myriad Borderlands issues and, as a result, developed the United States–Mexico Border Geographic Information System, an Internet mapping service containing integrated binational, multidisciplinary GIS datasets, many of which are directly applicable to solving border security and environmental issues (Parcher, 2008).

These datasets provide a temporal baseline used to analyze information needed to facilitate joint planning activities related to securing the border, improving readiness for response to and recovery from disasters, and improving sustainable development practices related to natural resource conservation. Some of the BEHI datasets that support border security and environmental management activities include remote sensing data, geology, hydrology, geographic features (such as international and local boundaries), urban areas, named features, transportation and infrastructure, census data, and human health data.

The USGS has expert capabilities in remote sensing technology that can provide valuable tools for monitoring border security, observing the environment from space, and extracting detailed elevation data for improving readiness for natural disasters such as hurricanes and floods. These data are also used in regional and local planning and economic development. The most common remote sensing datasets include Landsat imagery (facing page and fig. 9–6), digital orthophotographs (fig. 9–7), digital elevation models (DEMs; fig. 9–8); and light detection and ranging (LIDAR) imagery (fig. 9–9). The USGS and the International Boundary and Water Commission (IBWC), in cooperation with the Instituto Nacional de Estadística y Geografía (INEGI) [National Institute of Statistics and Geography], have compiled newly revised demarcation maps for the international boundary based on high-resolution remote sensing datasets, including digital orthophotograph imagery. Remote sensing datasets are critical in identifying illegal roads and trail networks associated with illegal immigration and other smuggling operations in rural parts of the border, and satellite imagery and digital orthophotographs are essential in detecting illegal dump sites in the border region that can contain hazardous waste or other toxic materials. Remote sensing, combined with transportation datasets, is also useful in monitoring infrastructure potentially subject to terrorist threats, such as dams and reservoirs, bridges, buildings, transportation, and other features.



U.S.-Mexico Border Geographic Information System

Geographic Information Systems (GIS) and the development of extensive geodatabases have become invaluable tools for addressing a variety of contemporary societal issues and for making predictions about the future. The United States-Mexico Border Geographic Information System (USMX-GIS) is based on fundamental datasets that are produced and/or approved by the national geography agency of each country, the U.S. Geological Survey (USGS) and the Instituto Nacional de Estadística y Geografía (INEGI) of Mexico, and the International Boundary and Water Commission (IBWC). The data are available at various scales to allow both regional and local analysis. The USGS and the INEGI have an extensive history of collaboration for transboundary mapping including exchanging digital technology and developing methods for harmonizing seamless national level geospatial datasets for binational environmental monitoring, urban growth analysis, and other scientific applications.

Societal, economic, and environmental issues cross the U.S.-Mexico international border and affect the landscape and quality of life in both countries. Many species are at their northernmost extents, thus changes in climate, water availability, and fragmentation of their habitat greatly affect their ability to survive. Other environmental stressors, such as population growth, industry, agriculture, and mining, are contributing to a rapid rate of species loss through dewatering, habitat destruction, ecosystem fragmentation, and pollution. The growth of several transfrontier metropolitan regions along the 3,000-kilometer border (fig. 1) presents many environmental management and urban planning challenges. Dramatic urban growth, rapid industrialization, and inadequate infrastructure in border cities increase environmental problems and risks associated with human health.

The rapid economic and demographic growth in the border region is attributed to increased manufacturing and binational trade between the two countries. The U.S.-Mexico border has 43 Ports of Entry that facilitate more than 300 million legal crossings a year and almost $650 million a day in binational commerce.

Figure 1. The major watersheds along the U.S.-Mexico border compose the current project area for the U.S.-Mexico Border Geographic Information System.

U.S. Department of the Interior
U.S. Geological Survey

August 2008

English

Sistema de Información Geográfica de la Frontera entre México y Estados Unidos

Los Sistemas de Información Geográfica (SIG) y el desarrollo de bases de datos geográficas han cobrado gran importancia hoy en día como herramientas invaluables para dirigir una gran cantidad de actividades sociales, así como para hacer predicciones acerca del futuro. El Sistema de Información Geográfica de la frontera México- Estados Unidos (USMX-GIS por sus siglas en Inglés) está basado en grupos de datos fundamentales producidos y aprobados por las agencias geográficas nacionales de cada país, El Servicio Geológico de los Estados Unidos (USGS) y el Instituto Nacional de Estadística y Geografía (INEGI) de México, además de la Comisión Internacional de Límites y Aguas (CILA). Los datos están disponibles en varias escalas para permitir tanto el análisis regional como el local. El USGS y el INEGI cuentan con una larga trayectoria de colaboración en la elaboración de mapas transfronterizos, el intercambio de tecnología y el desarrollo de métodos para armonizar (equiparar, homogeneizar) los niveles geoespaciales de grupos de datos para el monitoreo del medio ambiente, el análisis del crecimiento urbano y otras aplicaciones científicas.

Los asuntos sociales, económicos y del medio ambiente a lo largo de la frontera México–Estados Unidos afectan el panorama y la calidad de vida de ambos países. Muchas especies se encuentran en la extensión norte de dicha frontera y por lo tanto, los cambios en el clima, la disponibilidad de agua y la fragmentación de su hábitat afectan en gran medida su esperanza de sobrevivencia. Otros factores ambientales, tales como el crecimiento de la población, la industria, la agricultura y la minería, contribuyen a la rápida pérdida de estas especies por sequías, destrucción de hábitats, fragmentación de ecosistemas y contaminación. El crecimiento de varias regiones metropolitanas trasfronterizas a lo largo de los 3000 kilómetros de frontera (figura 1) implica muchos retos en materia de administración del medio ambiente y planeación urbana. El dramático crecimiento urbano, la rápida industrialización y una inadecuada infraestructura en las ciudades fronterizas incrementan los problemas ambientales y por lo tanto, los riesgos asociados a la salud humana.

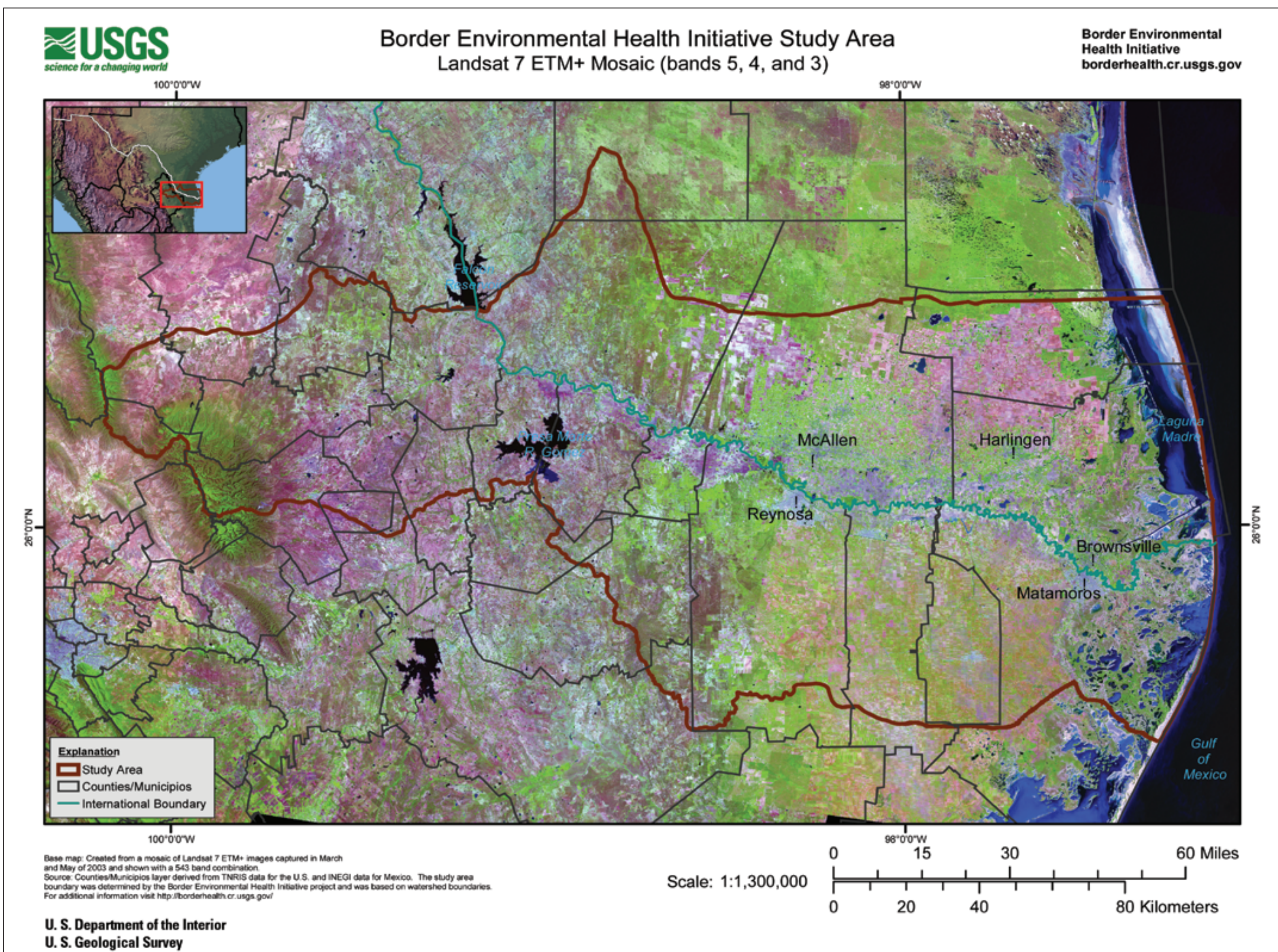
El rápido crecimiento económico y demográfico en las regiones fronterizas es atribuido a las actividades manufactureras y comerciales entre ambos países. Esta frontera cuenta con 43 puertos de entrada que facilitan más de 300 millones de cruces legales de personas al año, además de 650 millones de dólares al día en transacciones comerciales, incluyendo el suministro de energía. En el año de 2007, México se constituyó en el segundo socio de intercambio comercial más grande de los Estados Unidos, después de Canadá. El intercambio comercial entre Estados Unidos y México ha incrementado considerablemente en los últimos

Figura 1. Las principales cuencas hidrográficas a los largo de la frontera entre Estados Unidos y México constituyen el área actual del proyecto Sistemas de Información Geográfica de la frontera entre Estados Unidos y México.

U.S. Department of the Interior

August 2008

Español



Landsat

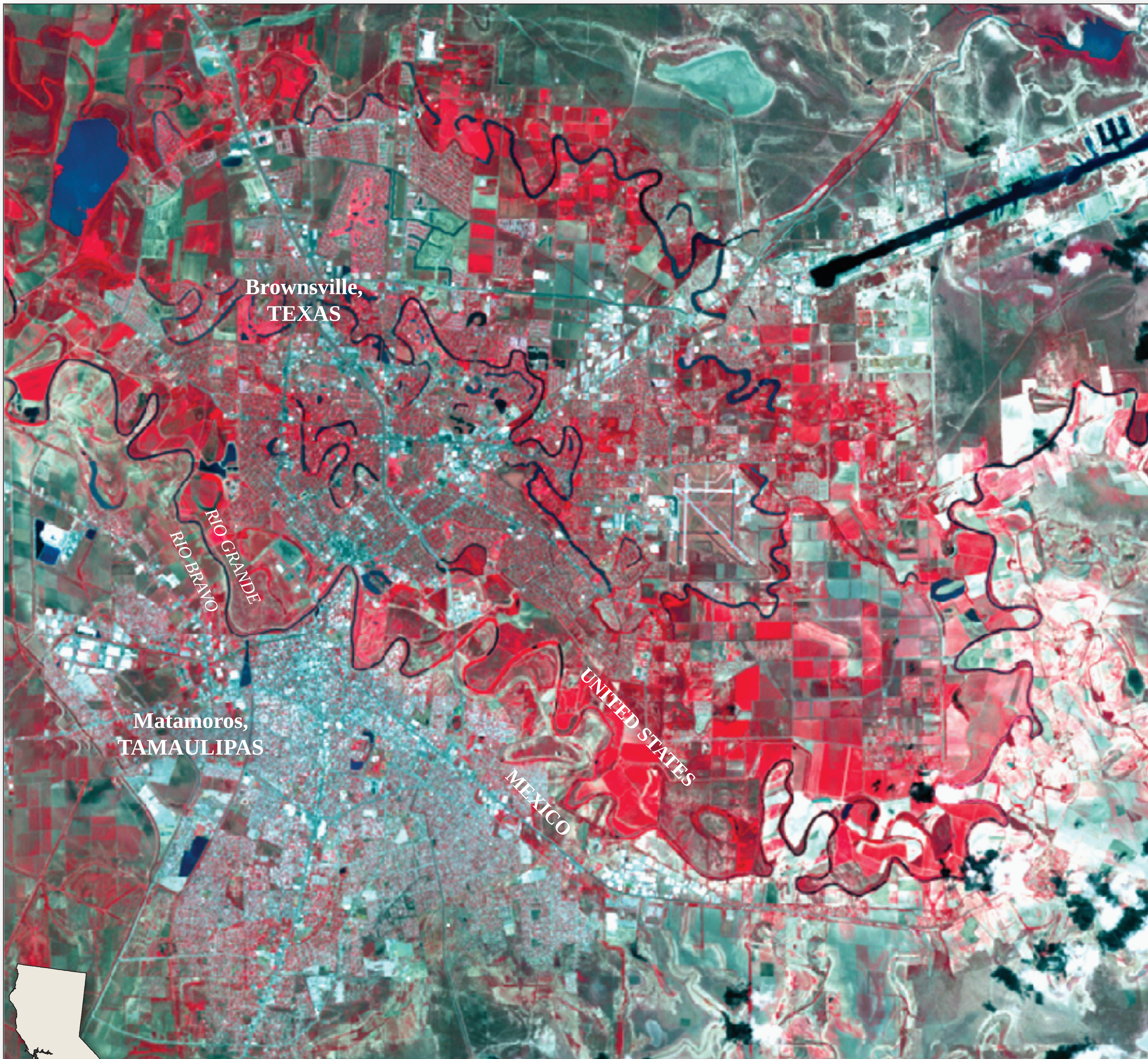


Figure 9–6. Landsat 7 ETM+ multispectral satellite image of the Brownsville-Matamoros sister city area (Texas-Tamaulipas).

digital orthophoto

Figure 9–7. Digital orthophotograph showing the Santa Fe Bridge crossing from El Paso, Texas, to Ciudad Juárez, Chihuahua.

digital elevation model

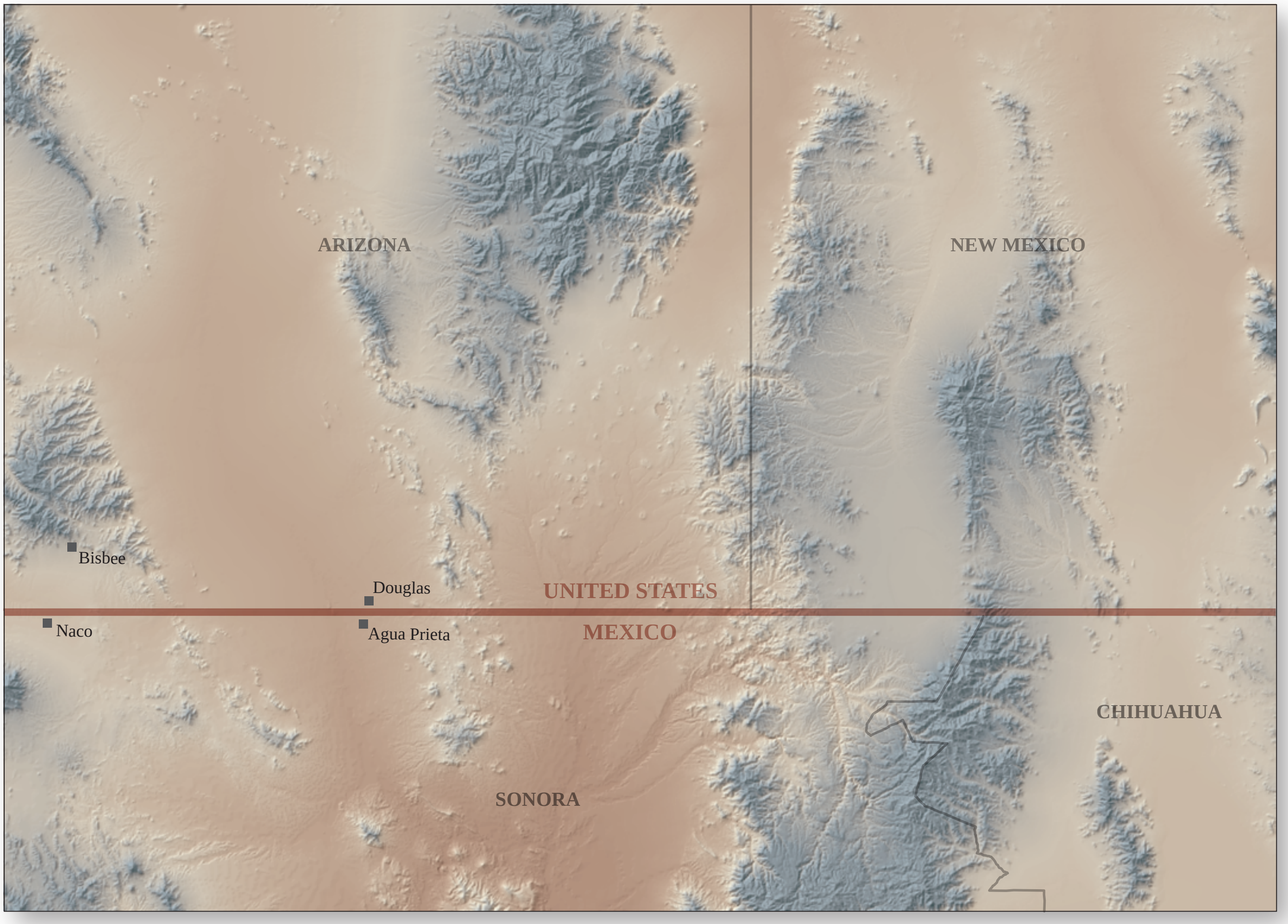
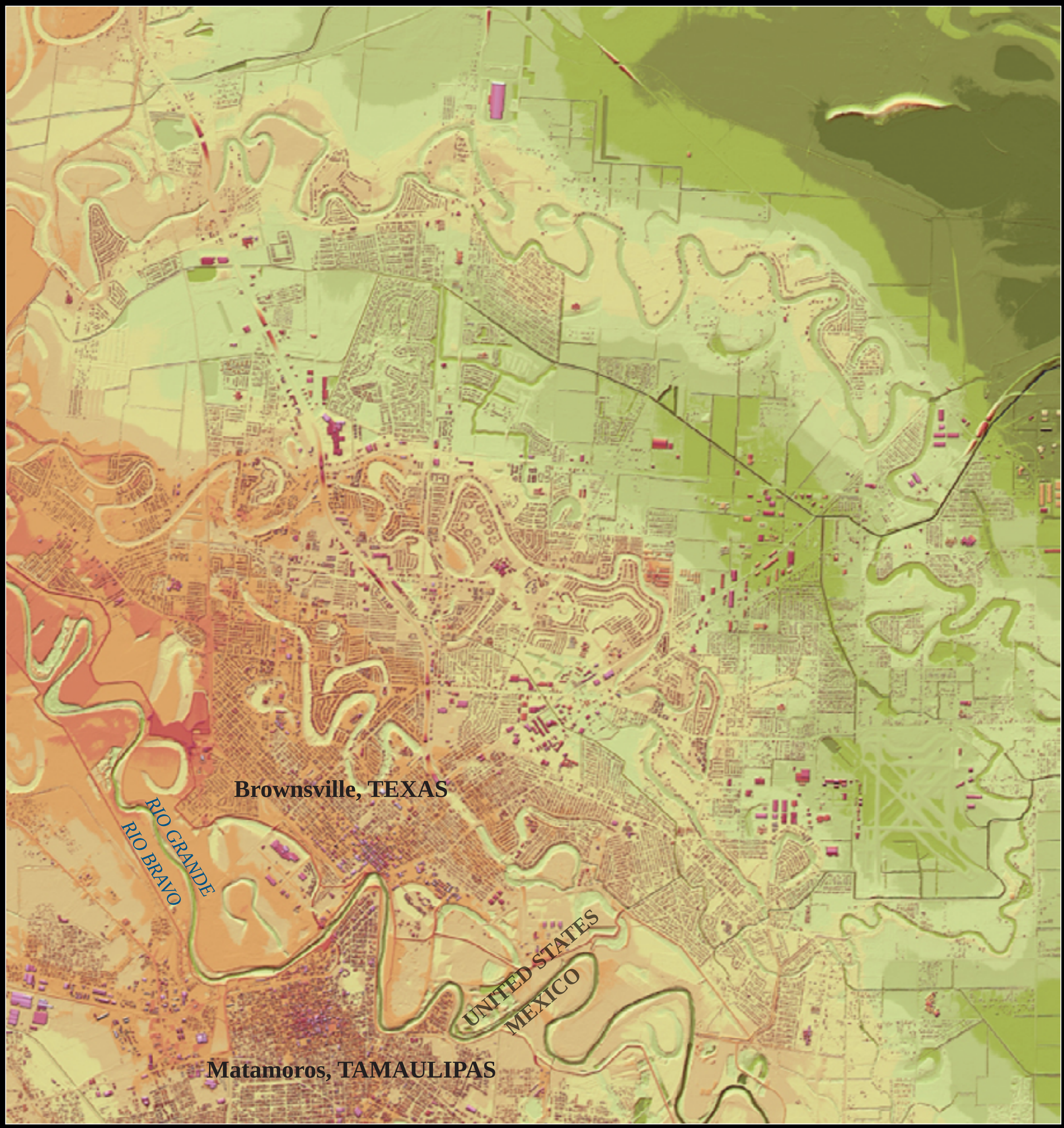


Figure 9–8. Digital elevation model of the area surrounding the Douglas–Agua Prieta sister city area (Arizona-Sonora). Gray colors indicate higher-elevation mountain ranges; tan colors indicate lower-elevation basins.

light detection and ranging



Courtesy of the University of Texas Center for Space Research

Figure 9–9. High-resolution LIDAR elevation model of the Brownsville-Matamoros sister city area (Texas-Tamaulipas). Green colors indicate higher-elevation areas; brown colors indicate lower-elevation areas.

U.S. Border Patrol using alternative transportation—horses (above) and all-terrain vehicles (below)—to patrol difficult terrain along the United States–Mexican border

One of the most common applications of remote sensing techniques used by USGS scientists is the mapping, monitoring, and modeling of natural and human changes in the environment. Remote sensing, in conjunction with land use and land cover datasets, helps us to understand and analyze the effects of these changes on humans, ecosystems, and natural resources so that we may take the appropriate actions in maintaining and preserving the quality of life in the Borderlands. One example of the unique integrated science capabilities of the USGS is the application of assessments of environmental effects to the many fence construction projects proposed in the Borderlands. Biologists with the USGS use remote sensing and other data to map and monitor wildlife ranges and habitats; this research can then be used to study the prevention of species loss and fragmentation, which can occur when border fences break up habitats (see chapter 3). Scientists with the USGS also use remote sensing imagery to map the distribution of and changes in vegetation on which different species depend for their major food sources. The USGS has expertise in researching the biology and ecology of biota, applying and developing environmental indicators, conducting baseline biological indicators, and establishing long-term monitoring in the Borderlands to fully understand the environmental effects potentially caused by border fences and walls.

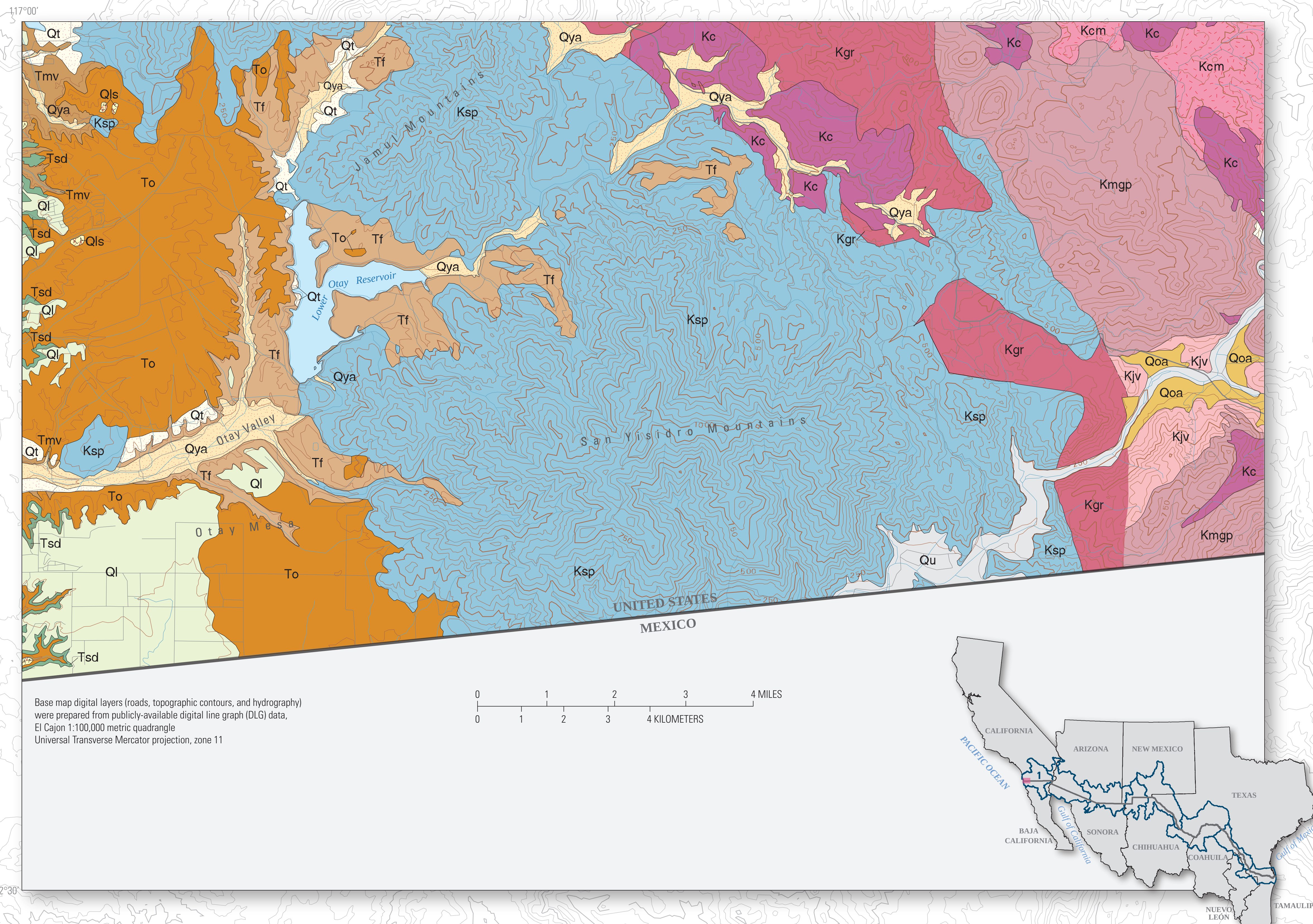
U.S. Army National Guard soldier assisting in border patrol operations near Nogales, Arizona

Light detection and ranging (LIDAR) technology is used to collect a dense network of elevation points used to model the topography of the ground surface. These data are extremely useful in providing information needed to assess risk and vulnerabilities associated with natural disasters and to prepare readiness procedures, especially for hurricane-related flooding in the Gulf Coast areas of Texas and Tamaulipas. For example, figure 9–9 shows LIDAR data from the Brownsville-Matamoras sister city area (Texas-Tamaulipas). The brown end of the color scale indicates areas of lower elevation along the Rio Grande; these areas are more prone to storm surge flooding than the green areas of higher elevation.

The USGS is also at the forefront of researching, analyzing, and integrating geologic and geophysical data that can be directly applied to predicting and detecting the locations of illegal smuggling tunnels crossing beneath the United States–Mexican border. The USGS has collaborated with security organizations—including U.S. Northern Command, the U.S. Army Corps of Engineers, and the U.S. Department of Homeland Security—to advise them on geophysical techniques and help them evaluate techniques that can be used to detect underground tunnels. Geology (rock type) can determine how easy it is to tunnel or excavate in a given area, so it can indicate where illegal tunnels are likely to be found. For example, the USGS geologic map of the Otay Mesa area in southern California (fig. 9–10; cropped from Todd, 2004) shows different rock types and illustrates their influence on potential tunneling. The Otay Formation on the west end of the map (orange geologic unit, labeled To) consists of poorly consolidated sandstone and soft claystone and has high potential for tunneling. The illegal tunnel shown on page 211 was excavated in the Otay Formation. Additionally, Quaternary rocks (yellow and tan units, labeled Qya, Qu, Qls, Qoa, Ql, and Qt) and Tertiary rocks (tan units, labeled Tsd, Tf, and Tmv) are soft and unconsolidated to poorly consolidated and have high tunneling potential. The Santiago Peak volcanics in the central part of the map (blue unit, labeled Ksp) consist of volcanic rocks. Though they are mostly well consolidated (solid and hard), they also contain some units that are poorly consolidated (weak and soft), so these rocks overall have moderate potential for tunneling. The units on the east end of the map (pink and red units, labeled Kc, Kmgp, Kcm, Kjv, and Kgr) are mainly hard granitic rocks. These rocks have low tunneling potential because they are very hard and dense and make tunneling very difficult.

A medallion showing the location of the international border between the United States and Mexico

geologic map



EXPLANATION

El Cajon quadrangle

- Qya — **Young alluvium (Holocene)**—Sand, silt, and gravel in modern streambeds
- Qu — **Alluvium and colluvium, undivided (Holocene and Pleistocene)**—Loose deposits of rock debris at base of slope
- Qls — **Landslide deposits (Quaternary)**—Deposits of earth and rock materials that moved downslope as landslides
- Qoa — **Older alluvium (Holocene and Pleistocene)**—Sand, silt, and gravel in old stream valleys

San Diego Embayment

- Ql — **Lindavista Formation (Pleistocene or Pliocene)**—Reddish-brown sandstone and mixed rocks; contains iron which gives formation characteristic color
- Tsd — **San Diego Formation (Pliocene)**—Marine sandstone and mixed rocks; sandstone is typically fine to medium grained
- Tf — **Fanglomerate (Pliocene and Miocene)**—Fans of boulders that are cemented together
- To — **Otay Formation (Oligocene)**—Sandstone and claystone; light gray and light brown; claystone is waxy, composed almost exclusively of clay

Poway Group

- Tmv — **Mission Valley Formation (Eocene)**—Sandstone; soft and crumbly

Western Colorado Desert

- Qt — **Terrace deposits (Pleistocene)**—Sand, silt, and gravel of stream beds higher than modern streams

Peninsular Ranges Batholith

Western sequence

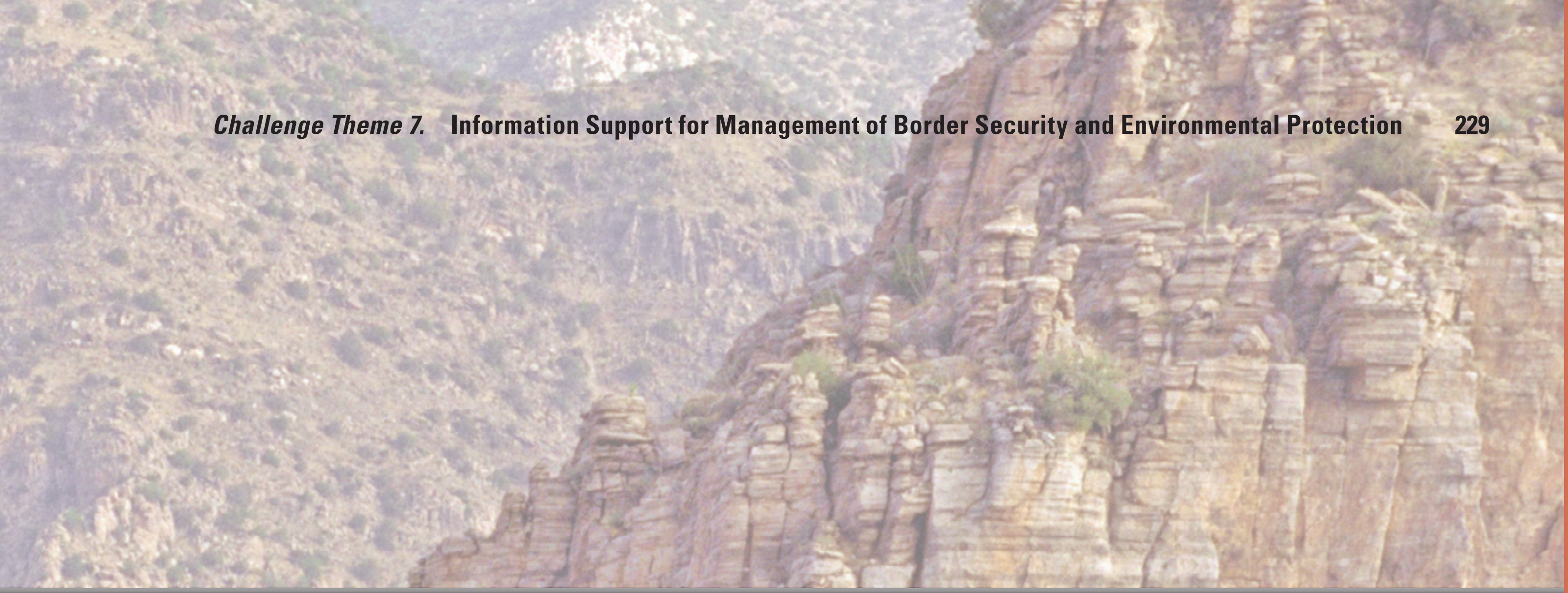
- Kc — **Cuyamaca Gabbro (Early Cretaceous)**—Dark, igneous, coarse grained, hard rocks
- Kmgp — **Monzogranite of Mother Grundy Peak (Early Cretaceous)**—Igneous, medium to very coarse grained, hard rocks
- Kcm — **Corte Madera Monzogranite (Early Cretaceous)**—Granite-like rocks
- Kjv — **Japatul Valley Tonalite (Early Cretaceous)**—Igneous, coarse grained, hard rocks
- Kgr — **Granitoid rocks (Early Cretaceous)**—Granite-like rocks

Prebatholithic and Suprabatholithic rocks

- Ksp — **Santiago Peak Volcanics (Early Cretaceous)**—Hard volcanic rocks and flows

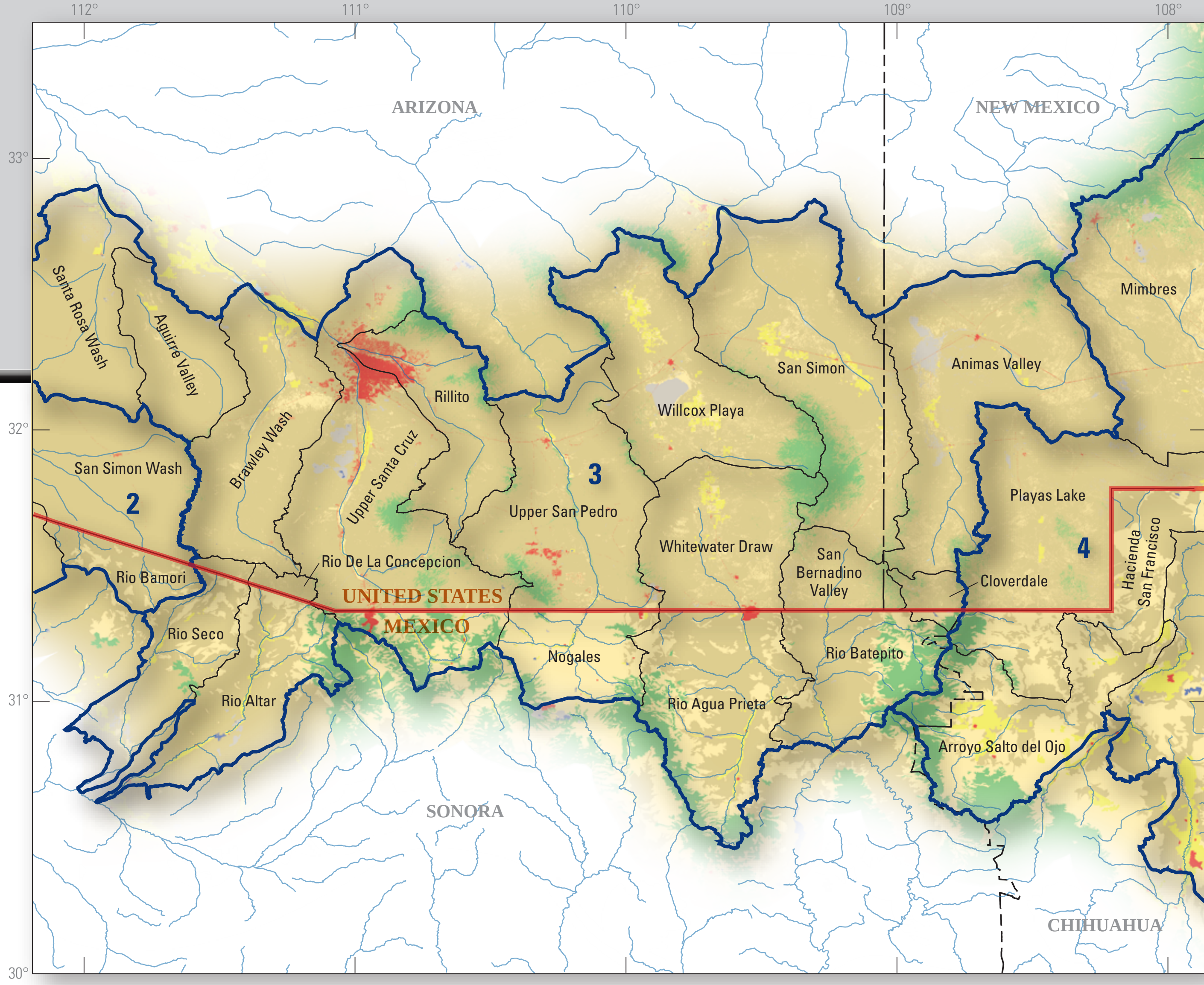
Figure 9–10. Geologic map showing the different rock types of the Otay Mesa area in the California border region north of Baja California. The soft Otay Formation in orange (labeled To) and Quaternary-Tertiary rocks in yellows and tans have the highest potential for tunneling, the Santiago Peak volcanics in blue (labeled Ksp) have moderate tunneling potential, and the hard, dense granitic rocks in pinks and reds have low tunneling potential. The city of Tecate, California, is about 2 miles beyond the east edge of the map. This map shows a part of the southwest corner of the geologic map of the El Cajon 30' x 60' quadrangle; modified from Todd (2004).

Two U.S. Customs and Border Protection Air unit UH-60 Blackhawk helicopters patrolling the airspace over rugged terrain in the American southwest border region



Water is the most critical natural resource on earth and is the lifeblood of communities, economies, and ecosystems, especially in the arid to semiarid Borderlands. The expertise of the USGS in compiling, integrating, and analyzing water-related datasets (see chapter 4) is extremely important in addressing issues such as securing our waterways from terrorist threats and assuring plentiful supplies of safe drinking water for future generations. Securing our waterways and assuring water quality and quantity involve a full understanding of hydrologic systems. Geographers with the USGS and INEGI are collaborating to harmonize a binationally consistent and seamless dataset of watershed boundaries and a hydrographic network of surface-water features for the Borderlands (fig. 9–11). This cooperative effort would provide a consistent framework for program planning, implementation, and reporting of the binational hydrologic systems. To help in assessing safe drinking water supplies, the USGS conducts real-time monitoring of about 7,500 streamgages; the data from these gages are also a critical component of an experimental flash flood and debris flow warning system jointly operated by the USGS, the National Oceanic and Atmospheric Administration, and the National Weather Service. To help assure and assess water quality, the USGS, the IBWC, and the Mexican Comisión Nacional del Agua [National Water Commission] are building a digital warehouse database for water quality in the Borderlands.

Figure 9–11 (facing page). Pilot area for the development of binational watershed boundaries and a networked hydrography for the United States–Mexican border region. The geographic area is along the Arizona and Sonora borders, corresponding with subarea 3. The binational land use and land cover dataset provides the background information.



Land use/land cover data from U.S. Geological Survey National Land Cover Dataset, 1992, and Instituto Nacional de Estadística, Geografía, e Informática Uso de Suelo, Version II

0 25 50 75 100 MILES
0 25 50 75 100 KILOMETERS

EXPLANATION

Land use/land cover

- Developed
- Agriculture
- Forest
- Shrubland
- Water
- Barren
- Grassland/pasture
- Wetlands

3 Subareas of the border region

- **2** Colorado River–Gulf of California
- **3** Mexican Highlands
- **4** San Basilio–Mimbres

Binational watershed boundary

International boundary

The USGS can provide valuable resources in developing databases and analyzing GIS data involving human health issues, such as the potential spread of infectious disease, and in defining and understanding potential connections between impaired environments and human health (see chapter 5). Scientists with the USGS Border Environmental Health Initiative (*http://borderhealth.cr.usgs.gov)* and cooperating agencies are currently analyzing and modeling census, health statistics, water quality, contaminant, and other datasets to better understand and make predictions concerning transboundary human health issues.

In response to natural disasters, the USGS collaborates with other agencies in providing timely science information to emergency response officials and the public to help reduce property damage, injury, and loss of life (see chapter 8). The USGS mobilizes response efforts worldwide during and after natural disasters, providing scientific counsel on recovery and response, such as when USGS used remote sensing techniques to map the extent of flooding and collect coastal impact data following Hurricane Katrina (Farris and others, 2007). More recently, the USGS Multi-Hazards Demonstration Project cooperated with numerous agencies to provide mapping expertise and data collection for the assessment of secondary hazards and damage caused by the 2007 southern California wildfires (see chapter 8, p. 194). The USGS also plays a leading role in monitoring and posting data for major earthquakes and landslides in real time, to provide decisionmakers and the public with important information needed to develop mitigation and loss-reduction strategies and predict where and when these hazards will occur. The USGS is also developing expertise in disaster readiness by analyzing GIS datasets to define levels of risk and vulnerability in disaster-prone areas (see chapter 8, p. 200).

References cited in this chapter are listed in chapter 12.