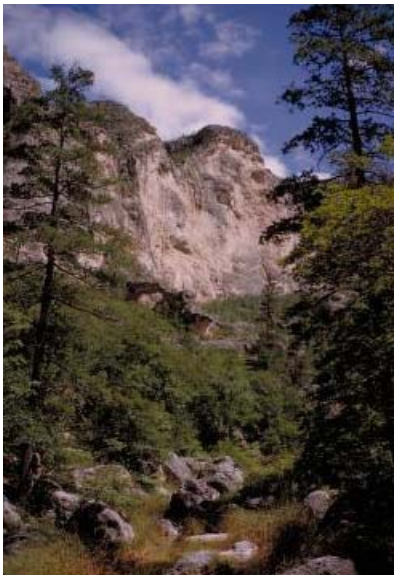
National Park Service
U.S. Department of the Interior

Natural Resource Program Center

Chihuahuan Desert Network Vital Signs Monitoring Plan

Appendices

Natural Resource Report NPS/CHDN/NRR—2010/188



ON THE COVER
Clockwise from upper left to bottom right: Carlsbad Caverns National Park, Guadalupe Mountains National Park, Fort Davis National Historic Site, Big Bend National Park, White Sands National Monument (by Pete Mananen), Amistad National Recreation Area. NPS photos unless otherwise noted.

Chihuahuan Desert Network Vital Signs Monitoring Plan

Appendices

Natural Resource Report NPS/CHDN/NRR—2010/188

National Park Service
Chihuahuan Desert Inventory and Monitoring Network
Genesis C Bldg
New Mexico State University
Las Cruces, NM 88003

April 2010

U.S. Department of the Interior
National Park Service
Natural Resource Program Center
Fort Collins, Colorado

The National Park Service, Natural Resource Program Center publishes a range of reports that address natural resource topics of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate high-priority, current natural resource management information with managerial application. The series targets a general, diverse audience, and may contain NPS policy considerations or address sensitive issues of management applicability.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manne. This report received formal, high-level peer review based on the importance of its content, or its potentially controversial or precedent-setting nature. Peer review was conducted by highly qualified individuals with subject area technical expertise and was overseen by a peer review manager.

Views, statements, findings, conclusions, recommendations, and data in this report are those of the author(s) and do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the National Park Service.

This report is available from the Chihuahuan Desert Network, http://science.nature.nps.gov/im/units/chdn/, and the Natural Resource Publications Management website, http://www.nature.nps.gov/publications/NRPM.

Please cite this publication as:
National Park Service, Chihuahuan Desert Inventory and Monitoring Network. 2010. Chihuahuan Desert Network vital signs monitoring plan. Natural Resource Report NPS/CHDN/NRR—2010/188. National Park Service, Fort Collins, Colorado.

NPS 960/101911, April 2010

Contents

Figures v

Tables..... vii

Appendix A. Summary of Legislation and Other Federal Mandates Relevant to the Vital Signs Monitoring Program..... 1

Appendix B. International Treaties and Conventions Relevant to Chihuahuan Desert Network Border Parks (AMIS, BIBE, RIGR)..... 7

Appendix C. Overview of Chihuahuan Desert Network Parks, Including Resource Management Concerns and Resource Threats 9

Appendix D. Habitats and Vegetation Communities..... 47

Appendix E. Climate Summary for Chihuahuan Desert Network Parks and Additional Areas Within the Region 57

Appendix F. Chihuahuan Desert Water Resources and Water Quality Standards: An Overview..... 61

Appendix G. Vital Signs Scoping Workshop Materials and Results 97

Appendix H. Existing Monitoring Programs Relevant to the Chihuahuan Desert Network 135

Appendix I. Chihuahuan Desert Network Prioritization Workshop Report..... 143

Appendix J. Chihuahuan Desert Network Protocol Development Summaries..... 181

Appendix K. Chihuahuan Desert Network Data Management Plan 213

Appendix L. Charter of the Chihuahuan Desert Network Inventory and Monitoring Program..... 215

Figures

Figure C.1. Map of Amistad National Recreation Area, Texas. 9
Figure C.1. Map of Big Bend National Park, Texas. 13
Figure C.2. Map of Carlsbad Caverns National Park, New Mexico. 19
Figure C.4. Map of Fort Davis National Historic Site, Texas. 27
Figure C.3. Map of Guadalupe Mountains National Park, Texas. 30
Figure C.4. Map of White Sands National Monument, New Mexico. 35

Tables

Table C.1.4. Threatened, endangered, species of concern, and park endemic species, Amistad National Recreation Area. 12
Table C.2.4. Threatened, endangered, species of concern, and park endemic species, Big Bend National Park 16
Table C.3.4. Threatened, endangered and species of concern, Carlsbad Caverns National Park 24
Table C.4.4. Threatened, endangered and species of concern, Fort Davis National Historic Site. 29
Table C.5.4. Threatened, endangered and species of concern, Guadalupe Mountains National Park. 33
Table C.6.4. Threatened, endangered and species of concern, White Sands National Monument 37
Table C.7-1. Numbers of plant and vertebrate species (Spp.) and families (Fam.) in the CHDN. 38
Table C.7-2. Invasive/non-native plants occurring in CHDN park units. Plants are listed in descending order of growth-forms. 39
Table C.7-3. Invasive/non-native animals occurring in CHDN park units. 44
Table F.3-1. Information contained within the EPA STORET database and Baseline Water Quality Data Inventory and Analysis Reports for CHDN parks. 70
Table F.2. Specific park resources and resource threats provided in Phase II Water Resources report (Huff et al. 2006) and from park-vital signs scoping meetings. 71
Table F.4.2.8. Numerical Water Quality Criteria (micrograms per Liter) for Freshwater Aquatic Life. 76
Table F.4.2.9. Texas Numerical Water Quality Criteria (micrograms per Liter) for Human Health 77
Table F.4.3. Dissolved Oxygen Criteria for Aquatic Life Uses. 80
Table F.5. Chronic Criteria, Total Ammonia (mg/L), Fish Early Life Stages Present 85
Table F.6-1. Location of, and information on, selected surface-water monitoring sites within and near Chihuahuan Desert Network park units. 87
Table F.8. Location of and information on selected groundwater monitoring sites within and near Chihuahuan Desert Network. 91
Table H.1. Existing monitoring programs in CHDN parks, organized by NPS Ecological Framework. 135
Table I.1-1. The 97 Vital Signs (Phase I) that made up the database for the VS Prioritization Workshop (Phase II). 145
Table I.1-2. List of Vital Signs Prioritization (Phase II) Workshop participants. 148
Table I.2-1. Vital Signs Prioritization (Phase II) Workshop agenda. 152
Table I.2-2. All CHDN vital signs ranked at the Vital Signs Prioritization Workshop (Phase II). 154
Table I.2-3. CHDN vital signs for the Desert ecosystem ranked at the vital signs prioritization workshop. 160
Table I.2-4. CHDN vital signs for the Foothills ecosystem ranked at the vital signs prioritization workshop. 163
Table I.2-5. CHDN vital signs for the Mountain ecosystem ranked at the vital signs prioritization workshop. 166
Table I.2-6. CHDN vital signs for the Reservoir ecosystem ranked at the vital signs prioritization workshop. 169
Table I.2-7. CHDN vital signs for the River ecosystem ranked at the vital signs prioritization workshop. 171
Table I.2-8. CHDN vital signs for the Caves ecosystem ranked at the vital signs prioritization workshop. 173
Table I.2-9. CHDN vital signs for the Dunes ecosystem ranked at the vital signs prioritization workshop. 175
Table I.3.2. Justification sources for use in the Chihuahuan Desert Network Prioritization Workshop. 178

Appendix A. Summary of Legislation and Other Federal Mandates Relevant to the Vital Signs Monitoring Program

Modified from NPS Inventory & Monitoring Web site,
http://science.nature.nps.gov/im/monitor/ProgramGoals.cfm#LawsPolicy

Legislation	Summary content
National Park Service Organic Act of 1916 (16 USC 1 et seq. [1988], Aug. 25, 1916).	The 1916 National Park Service Organic Act is the core of park service authority and the definitive statement of the purposes of the parks and of the National Park Service mission. The act establishes the purpose of national parks: To conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations.
Wilderness Act of 1964 (16 USC 1131 et seq.)	Establishes the National Wilderness Preservation System. In this act, wilderness is defined by its lack of noticeable human modification or presence; it is a place where the landscape is affected primarily by the forces of nature and where humans are visitors who do not remain. Wilderness Areas are designated by Congress and are composed of existing federal lands that have retained a wilderness character and meet the criteria found in the act. Federal officials are required to manage Wilderness Areas in a manner conducive to retention of their wilderness character and must consider the effect upon wilderness attributes from management activities on adjacent lands.
National Historic Preservation Act of 1966, as amended (16 USC 470 et seq.)	Congressional policy set forth in NHPA includes preserving the historical and cultural foundations of the Nation and preserving irreplaceable examples important to our national heritage to maintain cultural, educational, aesthetic, inspirational, economic, and energy benefits. NHPA established the National Register of Historic Places composed of places and objects significant in American history, architecture, archeology, engineering, and culture. NHPA requires federal agencies take into account the effects of actions on historic (state and federal) properties.
Wild and Scenic Rivers Act of 1968 (P.L. 90-542 as amended) (16 U.S.C. 1271-1287)	Provides for a National Wild and Scenic Rivers System and their administration.

Appendix A. Summary of legislation and other federal mandates relevant to the vital signs monitoring program.

Legislation	Summary content
National Environmental Policy Act of 1969 (42 USC 4321-4370)	The purposes of NEPA include encouraging harmony between [humans] and their environment and promote efforts which will prevent or eliminate damage to the environment and stimulate the health and welfare of [humanity]. NEPA requires a systematic analysis of major federal actions that includes a consideration of all reasonable alternatives as well as an analysis of short-term and long-term, irretrievable, irreversible, and unavoidable impacts. Within NEPA, the environment includes natural, historical, cultural, and human dimensions. Within the NPS emphasis is on minimizing negative impacts and preventing impairment of park resources as described and interpreted in the NPS Organic Act. The results of evaluations conducted under NEPA are presented to the public, federal agencies, and public officials in document format (e.g. EAs and EISs) for consideration prior to taking official action or making official decisions.
General Authorities Act of 1970 (16 USC 1a-11a-8 (1988), 84 Stat. 825, Pub. L. 91-383	The General Authorities Act amends the Organic Act to unite individual parks into the National Park System. The act states that areas of the National Park System, though distinct in character, are united through their inter-related purposes and resources into one national park system as cumulative expressions of a single national heritage; that individually and collectively, these areas derive increased national dignity and recognition of their superb environmental quality through their inclusion jointly with each other in one national park system preserved and managed for the benefit and inspiration of all the people of the United States.
Environmental Quality Improvement Act of 1970 (42 U.S.C. 56-4371)	Directs all Federal agencies, the activities of which may affect the environment, to implement policies established under existing law to protect the environment.
Federal Advisory Committee Act of 1972 (5 USC App. 1—16; PL 92-463)	Creates a formal process for federal agencies to seek advice and assistance from citizens. Any council, panel, conference, task force, or similar group used by federal officials to obtain consensus advice or recommendations on issues or policies fall under the purview of FACA.
Clean Water Act of 1972 (33 USC 1251-1376)	The Clean Water Act, passed in 1972 as amendments to the Federal Water Pollution Control Act, and significantly amended in 1977 and 1987, was designed to restore and maintain the integrity of the nation's water. It furthers the objectives of restoring and maintaining the chemical, physical, and biological integrity of the nation's waters and of eliminating the discharge of pollutants into navigable waters by 1985. Establishes effluent limitation for new and existing industrial discharge into U.S. waters. Authorizes states to substitute their own water quality management plans developed under S208 of the act for federal controls. Provides an enforcement procedure for water pollution abatement. Requires conformance to permit required under S404 for actions that may result in discharge of dredged or fill material into a tributary to, wetland, or associated water source for a navigable river.
Endangered Species Act of 1973, as amended (ESA) (16 USC 1531-1544)	The Endangered Species Act was enacted in 1973 and amended in 1978, 1982 and 1988. It provides for the conservation, protection, restoration, propagation and recovery of species of native fish and wildlife (including plants) that are listed as being threatened with extinction. All entities using federal funding must consult with the Secretary of the Interior (through authority delegated to the US Fish and Wildlife Service) on activities that potentially affect endangered or threatened flora and fauna.

Appendix A. Summary of legislation and other federal mandates relevant to the vital signs monitoring program.

Legislation	Summary content
Migratory Bird Treaty Act of 1974 16 U.S.C. §703-711	On January 10, 2001, the President signed Executive Order 13186, directing Federal agencies to minimize their negative impacts on migratory birds, to enter into an MOU with the U.S. Fish and Wildlife Service, and to carry out certain actions to further the implementation of the Migratory Bird Treaty Act. In addition, the Executive Order calls on Federal agencies to take reasonable steps that include restoring and enhancing habitat, incorporating migratory bird conservation into planning processes, promoting research and information exchange, providing training and visitor education, and developing partnerships beyond agency boundaries. The Migratory Bird Treaty Act (MBTA), signed in 1918 and amended in 1936, 1974 and 1989, is the domestic law that implements the United States' commitment to four international conventions (with Canada, Mexico, Japan and Russia) for the protection of migratory birds. The species protected by the MBTA are listed at 50 CFR § 10.13. In 2000, a Federal Court ruled that Federal agencies, like private citizens, are subject to MBTA regulations regarding take of migratory birds. An MOU between the National Park Service and the U.S. Fish and Wildlife Service is currently being drafted to address this issue, as required by the Executive Order.
Forest and Rangeland Renewable Resources Planning Act of 1974 (16 U.S.C. 36-1642	Mandates that the Secretary of Agriculture inventory and monitor renewable natural resources in National Forests and has been cited as congressional authorization for the inventory and monitoring of natural resources on all federal lands. Whereas this is not specifically directed in the act, it is perhaps indicative of a national will to account for and manage the nation's natural heritage in manner that sustains these resources in perpetuity.
Redwood National Park Act of 1978 (16 USC 79a-79q (1988), 82 Stat. 931, Pub. L. 90-545	This act includes both park-specific and system-wide provisions. This act reasserts system-wide protection standards for the National Park System. This act qualifies the provision that park protection and management "shall not be exercised in derogation of the values and purposes for which these areas have been established" by adding "except as may have been or shall be directed and specifically provided for by Congress." Thus, specific provisions in a parks enabling legislation allow park managers to permit activities such as hunting and grazing.
Clean Air Act (42 USC 7401-7671q, as amended in 1990)	Establishes a nationwide program for the prevention and control of air pollution and establishes National Ambient Air Quality Standards. Under the Prevention of Significant Deterioration provisions, the act requires federal officials responsible for the management of Class I Areas (national parks and wilderness areas) to protect the air quality related values of each area and to consult with permitting authorities regarding possible adverse impacts from new or modified emitting facilities. The act establishes specific programs that provide special protection for air resources and air quality related values associated with NPS units. The EPA has been charged with implementing this act.
Lechuguilla Cave Protection Act, 1993 (PL 103-169)	Asserts that congress finds Lechuguilla Cave and adjacent public lands to have internationally significant scientific, environmental, and other values and should be…protected against…activities presenting threats to the areas.
Government Performance and Results Act (GPRA) of 1993 (31 USC 1115 et seq.4; PL 103-62)	Requires the NPS to set goals (strategic and annual performance plans) and report results (annual performance reports). The NPS Strategic Plan contains four GPRA goal categories: park resources, park visitors, external partnership programs, and organizational effectiveness. In 1997, the NPS published its first GPRA-style strategic plan, focused on measurable outcomes or quantifiable results.

Appendix A. Summary of legislation and other federal mandates relevant to the vital signs monitoring program.

Legislation	Summary content
National Parks Omnibus Management Act, 1998 (P.L. 105-391)	Requires Secretary of Interior to continually improve NPS ability to provide state-of-the-art management, protection, and interpretation of and research on NPS resources... Section 5939 states that the purpose of this legislation is to: (1) More effectively achieve the mission of the National Park Service; (2) Enhance management and protection of national park resources by providing clear authority and direction for the conduct of scientific study in the National Park System and to use the information gathered for management purposes; (3) Ensure appropriate documentation of resource conditions in the National Park System; (4) Encourage others to use the National Park System for study to the benefit of park management as well as broader scientific value, and (5) Encourage the publication and dissemination of information derived from studies in the National Park System.

Executive Orders	Summary content
Off-Road Vehicle Use (Executive Orders 11644 and 11989) of 1977	Executive Order 11644, enacted February 8, 1972, and amended by Executive Order 11989 on May 24, 1977, regulates off-road vehicle use. If the enabling legislation allows the use of off-road vehicles, NPS is required to designate specific areas for off-road vehicle use. These areas must be located to minimize damage to soil, watershed, vegetation, or other resources (Section (3)(a)(1)). If it is determined that such use is adverse to resources, the NPS is to immediately close such areas or trails until the impacts have been corrected.
Floodplain Management (Executive Order 11988) of 1977	This Order 11988 was enacted May 24, 1977. It requires all federal agencies to “reduce the risk of flood loss, … minimize the impacts of floods on human safety, health and welfare, and … restore and preserve the natural and beneficial values served by flood plains.” E. O. 11988 is implemented in the National Park Service through the Floodplain Management Guidelines (http://www.nature.nps.gov/rm77/floodplain.cfm). “It is the policy of the National Park Service to 1) Protect and preserve the natural resources and functions of floodplains; 2) Avoid the long- and short-term environmental effects associated with the occupancy and modification of floodplains; and 3) Avoid direct and indirect support of floodplain development and actions that could adversely affect the natural resources and functions of floodplains or increase flood risks…”
Protection of Wetlands (Executive Order 11990) of 1977	Executive Order 11990 was enacted May 24, 1977. It requires all federal agencies to minimize the destruction, loss, or degradation of wetlands, and preserve and enhance the natural and beneficial values of wetlands. Unless no practical alternative exists, federal agencies must avoid any activities that have the potential to adversely affect wetland ecosystem integrity. NPS guidance pertaining to this Executive Order is stated in Floodplain and Wetland Protection Guidelines (http://www.epa.gov/wetlands/regs/eo11990.html).
Invasive Species (Executive Order 13112) of 1999	This executive order was signed into law on February 3, 1999, to prevent the introduction of invasive species and provide for their control and to minimize the economic, ecological, and human health impacts that invasive species cause. Among other things, this Executive Order established the National Invasive Species Council and required the preparation of a National Invasive Species Management Plan to recommend specific, performance-oriented goals and objectives and specific measures of success for Federal agency efforts concerning invasive species.

Appendix A. Summary of legislation and other federal mandates relevant to the vital signs monitoring program.

Executive Orders	Summary content
Protection of Migratory Birds (Executive Order 13186) of 2001	This order provides additional protection for migratory birds, such that Federal agencies should "design migratory bird habitat and population conservation principles, measures, and practices, into agency plans and planning processes (natural resource, land management, and environmental quality planning, including, but not limited to, forest and rangeland planning, coastal management planning, watershed planning, etc.) as practicable, and coordinate with other agencies and nonfederal partners in planning efforts."

NPS policy/Guidance	Summary content
NPS Management Policies-2001 (NPS Directives System)	This is the basic NPS service-wide policy document. It is the highest of three levels of guidance documents in the NPS Directives System. The Directives System is designed to provide NPS management and staff with clear and continuously updated information on NPS policy and required and/or recommended actions, as well as any other information that will help them manage parks and programs effectively.
NPS Directors Orders	Second level of NPS Directives System. Directors Orders serve a vehicle to clarify or supplement Management Policies to meet the needs of NPS managers. Relevant Directors Orders: DO-2.1 Resource Management Planning DO-12 Environmental Impact Assessment DO-14 Resource Damage Assessment & Restoration DO-24 Museum Collections Management DO-41 Wilderness Preservation & Management DO-47 Sound Preservation & Noise Management DO-77 Natural Resource Protection
NPS Handbooks and Reference Manuals	This is the third tier in the NPS Directives System. These documents are issued by Associate Directors and provide NPS field employees with a compilation of legal references, operating policies, standards, procedures, general information, recommendations, and examples to assist them in carrying out Management Policies and Director's Orders. Level 3 documents may not impose any new service-wide requirements, unless the Director has specifically authorized them to do so. Relevant Handbooks and Reference Manuals: NPS-75 Natural Resources Inventory & Monitoring NPS-77 Natural Resources Management Guidelines NPS Guide to Fed. Advisory Committee Act Web site: Monitoring Natural Resources in our National Parks, http://science.nature.nps.gov/im/monitor

Enabling legislation	Summary content
Amistad National Recreational Area (AMIS) (P.L. 101-628)	Amistad National Recreation Area was established on November 28, 1990 following the construction of Amistad Dam along the Rio Grande. Its purpose is to "…provide for public outdoor recreation use and enjoyment of the lands and waters associated with the United States portion of the reservoir known as Lake Amistad, located on the boundary between the United States and Mexico; and protect the scenic, scientific, cultural, and other values contributing to the public enjoyment of such lands and waters…"
Big Bend National Park (BIBE) (49 Stat. 393)	Big Bend National Park was established on June 20, 1935 "…for the use of the public for recreational park purposes…within the boundaries to be determined…within the area of approximately 1.5 million ac…"

Appendix A. Summary of legislation and other federal mandates relevant to the vital signs monitoring program.

Enabling legislation	Summary content
Carlsbad Caverns National Park (CAVE) (1679 Stat. 1929)	Carlsbad Caverns National Monument was created on October 25, 1923 "…a limestone cavern…of extraordinary proportions and of unusual beauty and variety of natural decoration…beyond the spacious chambers that have been explored, other vast chambers of unknown character and dimensions exist…." This park unit was elevated to Park status in 1930.
Fort Davis National Historic Site (FODA) (75 Stat. 488)	Fort Davis National Historic Site was established on September 8, 1961 "…for the purpose of establishing a national historic site…set aside as a public national memorial to commemorate the historic role played by the fort in the opening of the West…"
Guadalupe Mountains National Park (GUMO) (P.L.89-667 80 Stat. 920)	Guadalupe Mountains National Park was established on October 15, 1966 "…in order to preserve in public ownership an area…possessing outstanding geological values together with scenic and other natural values of great significance…"
Rio Grande Wild and Scenic River (RIGR) (P.L. 95-625 sec. 702)	Rio Grande Wild and Scenic River was officially established on November 10, 1978, through the addition of the Wild and Scenic Rivers Act of 1968. This segment of the river "…is to protect water quality and to preserve in a free-flowing condition certain rivers with outstandingly remarkable natural, cultural, or recreational values for the enjoyment of present and future generations…the United States side of the river and such plan shall include, but not be limited to, the establishment of a detailed boundary which shall include an average of not more than 160 ac per mile…."
White Sands National Monument (WHSA) (47 Stat 2551)	White Sands National Monument was established on January 18, 1933 to "…preserve the white sand and additional features of scenic, scientific, and educational interest…."

Appendix B. International Treaties and Conventions Relevant to Chihuahuan Desert Network Border Parks (AMIS, BIBE, RIGR)

from: http://www.ibwc.state.gov

Treaty or Convention	Significance
Treaty of February 2, 1848	Established the United States–Mexico Boundary.
Treaty of December 30, 1853	Established the United States-Mexico Boundary as it exists today.
Convention of November 12, 1884	Established the rules for location of the boundary when meandering rivers transferred tracts of land from the one bank of the river to the other.
Convention of March 1, 1889	Established the International Boundary Commission (IBC) to apply the rules in the 1884 Convention and was modified by the Banco Convention of March 20, 1905 to retain the Rio Grande and Colorado River as the international boundary.
Treaty of February 3, 1944	Water treaty for "Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande." Distributed the waters in the international section of the Rio Grande from Fort Quitman, Texas to the Gulf of Mexico. Changed the name of the IBC to the International Boundary and Water Commission (IBWC), and entrusted the IBWC to give preferential attention to the solution of all border sanitation problems.
Treaty of November 23, 1970	Resolved all pending boundary differences. Provides procedures designed to avoid the loss and gain of territory by either country incident to future changes in the river.

Appendix C. Overview of Chihuahuan Desert Network Parks, Including Resource Management Concerns and Resource Threats

The CHDN includes seven NPS units in New Mexico and Texas. The parks vary in size from almost 200 ha (500 ac) at Fort Davis National Historic Site (NHS) to over 300,000 ha (800,000 ac) at Big Bend National Park. Six of the seven CHDN park units are located in the Northern Chihuahuan Subregion of the Chihuahuan Desert Ecoregion. Amistad National Recreation Area is situated primarily within the Tamaulipan Thornscrub (Mezquital) Ecoregion of southern Texas and northeastern Mexico. This Appendix provides a general description of the features and resources of each CHDN park, along with a brief summary of each park's primary management concerns, threats, and species of special concern. The information on management concerns and threats was generated through review of park general management plans, interviews, and literature provided by park personnel. Most of these park units operate with limited budgets and few staff, and are not able to provide personnel and funds for many of the natural resource concerns they face. The resources available at the network level will greatly increase their capacity to meet increasingly complex resource management issues.

C.1 Amistad National Recreation Area (AMIS)

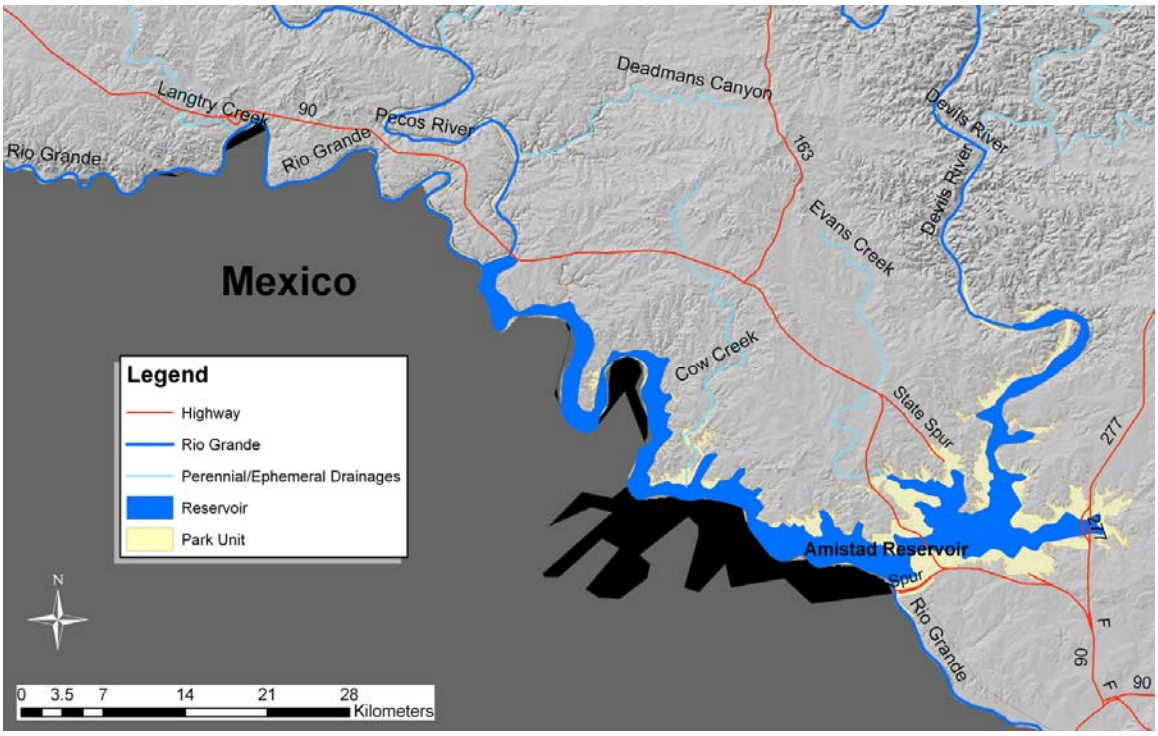


Figure C.1. Map of Amistad National Recreation Area, Texas.

C.1.1 General description

Size: Amistad National Recreation Area (NRA) encompasses 23,195 ha (57,292 ac) of land. When the reservoir water level is at its conservation elevation of 340 m (1117 ft), then there is (17,820 ac) of land in this NRA. The Amistad NRA includes more than 864 km (540 miles) of park boundary on the US side, and extends 118 km (74 miles) up the Rio Grande, 22 km (14 miles) up the Pecos River, and 38 km (24 miles) up the Devils River.

Location: Amistad NRA is located along the Rio Grande in southwest Texas, approximately 10 km (6 miles) northwest of Del Rio, Texas, and approximately 256 km (160 miles) west of San Antonio, Texas. Park headquarters are located on the north edge of Del Rio, but the recreation area may be accessed from points along U.S. Highway 90 and U.S. Highway 277/377. Amistad is located in Val Verde County, Texas.

Adjacent Lands: Amistad NRA is primarily surrounded by private lands. Seminole Canyon State Historic Park is in close proximity. The country of Mexico borders the park on the south and shares administration of the lake with the park.

Elevation: The elevation of the Amistad dam is 349 m (1,145 ft).

Park History: Among the Chihuahuan Desert Network (CHDN) parks, Amistad National Recreation Area (NRA) is unique in that it is the only park unit that includes a reservoir. Amistad NRA was established as part of a cooperative effort with Mexico to develop a combination of recreation, flood control, water storage, and power generation facilities. The stated intent was to "provide for public outdoor recreation use and enjoyment of the lands and waters associated with the United States portion of the reservoir known as Lake Amistad", and to "protect the scenic, scientific, cultural, and other values contributing to the public enjoyment of such lands and waters". The dam was completed in 1969 at a site on the Rio Grande just downstream from its convergence with the Devils River, and the reservoir was filled the following year. The international boundary with Mexico lies underwater along the historic bed of the Rio Grande.

Amistad NRA lies in a region characterized by one of the densest concentrations of prehistoric American Indian rock art and artifacts in the New World. Several sites (including Panther and Parida Caves) are preserved at Amistad NRA and are accessible to visitors by boat when water levels permit. Other recreational uses of the area include boating, swimming, fishing, and camping.

Physical and Natural Characteristics: elevation within the NRA range from 282 to 364 m (925 to 1194 ft). This NRA is located at the convergence of three ecoregional provinces: Chihuahuan Desert, Edward's Plateau and Tamaulipan Thornscrub. The area is also situated at the southern limit of the Edwards Plateau where it terminates at the Balcones Escarpment. The escarpment developed along a region of Late Cretaceous and Cenozoic fault-lines; today it separates the resistant Cretaceous limestone of the elevated plateau and northeastern Texas Hill Country from the lower elevation sediments of the southern Coastal Plain. Soils are thin, and the steep slopes and relatively impermeable bedrock increase the potential for erosion. The geography of Amistad NRA consists primarily of low hills and valleys near the dam, with steep-walled limestone canyons up to 60 m (~ 200 ft) in height occurring upstream.

Current inventories show that Amistad NRA has 691 plant species from 106 families (Table C.7-1). Vertebrate taxa include 39 species of fish, 49 herps, 54 mammals, and 182 species of birds.

Commonly associated plants include guajillo, lotebush, mesquite, guayacan, Texas prickly pear, paloverde, goatbush, yucca, sotol, desert yaupon, catclaw acacia, kidneywood, allthorn, curly mesquite,

Texas grama, hairy tridens, slim tridens, and two-leaved senna. Stands of whitethorn acacia and other acacias also dominate this system. Limestone substrates appear important for at least these species.

The climate at Amistad NRA is arid, with an average of 46 centimeters (18 in) of annual precipitation, the majority of which occurs from April through October. Summers are hot and humid, with average temperatures in the mid 30s °C (90s °F) and winters are dry and mild, with average temperatures in the teens °C (60s °F).

C.1.2 Resource management concerns

Effects of Reservoir Fluctuation: Water levels in the reservoir are in continuous fluctuation, which has created large expanses of disturbed land that are alternately exposed and inundated. Beginning in 1993, southwest Texas experienced a prolonged drought. Demands from downstream users and low inflows into the reservoir resulted in a decrease in water volume to an historic low of 322 m (1,058 ft) in August of 1998, which was 18 m (59 ft) below the conservation level of 340 m (1,117 ft). Although the reservoir level has recovered to some degree, it has not been at conservation level since 1993. As a result, terrestrial plants and animals are now colonizing the formerly inundated areas.

Density, Distribution, and Effects of Exotic Plants and Animals: A number of common exotic plants are found at Amistad NRA. Tamarisk is found in many locations in the park (Table C.7-2), and is particularly common in the inundation zone of the reservoir. Other exotic species have been confirmed in the canyon bottoms and other microhabitats. Introduced and escaped, non-native fish are also an issue for this NRA (Table C.7-3). More detailed information on the presence of exotic plants is required to understand the effects of continued low reservoir levels on the surrounding natural resources.

Livestock Grazing: The meandering boundary of Amistad NRA has proven difficult to manage, and much of the park is affected by unmanaged grazing of livestock. As Amistad NRA has no complete plant list, the presence/absence of sensitive species and the effects of grazing are not well understood.

Land-Use Conversion: Housing development is occurring at 18 locations, occupying 89 km (55 miles), along the boundary of Amistad NRA. Disturbance of the land along this boundary accelerates the encroachment of exotic plant species into the recreation area.

Water Resources: Amistad National Recreation Area – Receives surface flows from all surrounding lands and three significant rivers.

C.1.3 Threats

- Deposition from atmospheric pollution,
- Sedimentation pollutants or contaminants from Rio Grande inflow,
- Sedimentation pollutants or contaminants from Devils and Pecos River inflow,
- Runoff from Mexican sources to the Rio Grande,
- Runoff from US sources, including adjacent ranches, exterior to the park,
- Hydrocarbons from US and Mexican watercraft,
- Possible fecal matter and debris from undocumented aliens in transit,
- Possible debris and fecal matter from US and Mexican watercraft,
- Hydrocarbons and debris from US and Mexican boat launch sites,
- Camping area runoff.

Table C.1.4. Threatened, endangered, species of concern, and park endemic species, Amistad National Recreation Area.

Type	Scientific name	Common name	Status
Plants	*Ancistrocactus tobuschii*	Tobusch fishhook cactus	FE, TxE
	Styrax platanifolius ssp. *texanus*	Texas snowbells	FE, TxE
Fish	*Dionda diaboli*	Devils River minnow	FT, TxT
	Cycleptus elongatus	blue sucker	TxT
	Cyprinella proserpina	proserpine shiner	TxT
	Cyprinidon eximius	Conchos pupfish	TxT
	Etheostoma grahami	Rio Grande darter	TxT
	Scaphirhynchus platorynchus	shovelnose sturgeon	TxT
	Hybognathus amarus	Rio Grande silvery minnow	FE
	Notropis simus simus	Rio Grande bluntnose shiner	TxTE
	Gambusia senilis	blotched gambusia	TxTE
Reptiles	*Drymarchon melanurus erebennus*	Texas indigo snake	TxT
	Gopherus berlandieri	Berlandier's tortoise	TxT
	Phrynosoma cornutum	Texas horned lizard	TxT
Birds	*Sterna antillarum athaloassos*	interior least tern	FE, TxE
	Vireo atricapillus	black-capped vireo	FE, TxE
	Pelecanus occidentalis	brown pelican	FE, TxE
	Plegadis chihi	white-faced ibis	TxT
	Haliaeetus leucocephalus	bald eagle	FT, TxT
	Falco peregrinus anatum	peregrine falcon	TxE
Mammals	*Ursus americanus*	black bear	TxT

FE = Federal Endangered; TxE = State Endangered; TE = Federal Threatened; TxT = State Threatened

C.2 Big Bend National Park (BIBE)

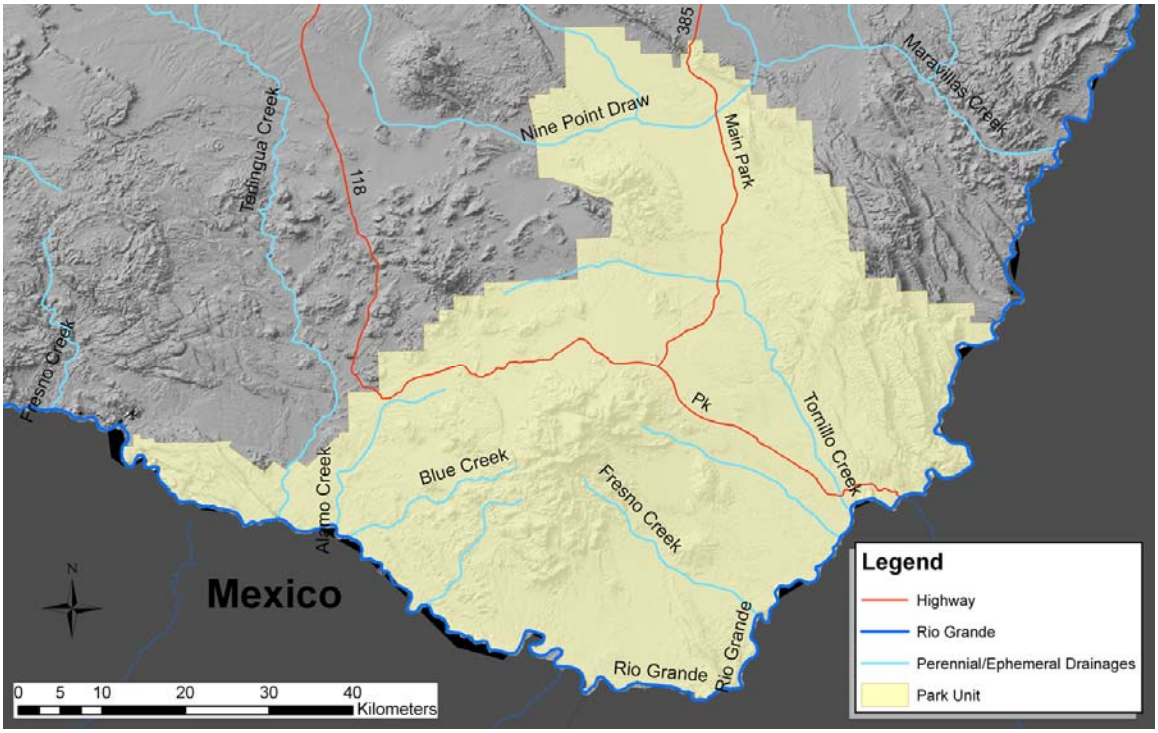


Figure C.1. Map of Big Bend National Park, Texas.

C.2.1 General description

Size: 324,641 ha (801,863 ac)

Location: Big Bend National Park (NP) is located along the U.S. border within the bend of the Rio Grande in southwestern Texas. The park is accessible from State Highway 118 approximately 128 km (80 miles) south of Alpine, Texas, or from U.S. Highway 385, 64 km (40 miles) south of Marathon, Texas. Park headquarters is located at the junction of these two highways, in the northern foothills of the Chisos Mountains. Big Bend NP is located in Brewster County, Texas.

Adjacent Lands: Big Bend NP shares much of its boundary with Mexico. In the United States much of the adjacent land is private with some state lands. Neighbors to the park, either adjacent or in close proximately, include Big Bend Ranch State Park, Black Gap State Wildlife Management Area, State of Texas General Land Office, and the Nature Conservancy.

Elevation: Park elevations range from 548 m (1,800 ft) at the Rio Grande to 2,377 m (7,800 ft) atop Emory Peak in the Chisos Mountains. Overall change in elevation is approximately 1,829 m (6,000 ft).

Park History: The state of Texas established Big Bend State Park in 1933, which was comprised of approximately 64,750 ha (160,000 ac) of state-owned school section and tax forfeit properties. In 1935, President Franklin D. Roosevelt signed a bill authorizing establishment of a national park on the site. In 1944 the state presented a deed for approximately 283,300 ha (700,000 ac) to the President, and Big Bend National Park was dedicated on June 12, 1944.

Big Bend NP currently encompasses the largest protected area representative of the Chihuahuan Desert, and is classified as a U.S. Biosphere Reserve. It includes 216,070 ha (533,900 ac) of recommended Wilderness and administers the 305-kilometer (190-mile) Rio Grande Wild and Scenic River.

Physical and Natural Characteristics: During the Cretaceous Period (65-145 million years ago) much of West Texas was part of a shallow inland sea. Gradual accumulation of sediment and marine animal skeletons resulted in the formation of extensive layers of limestone, sandstone, and shale. By the Early Tertiary Period (50 million years ago) the sea had receded and the land was covered by extensive forests and wetlands. Basin and Range faulting action along converging fault lines formed the Appalachian Mountains to the east, the Rocky Mountains to the northwest, and the Sierra Madre range to the south, and also displaced large sections of the old seabed. The resulting cliffs and canyons continued to be shaped by erosion, while subsequent volcanic activity created the Chisos Mountains and other igneous features.

As recently as 10,000 years ago cooler and moister conditions prevailed in the Big Bend region, but climatic change gradually resulted in hotter, dryer conditions and Big Bend NP now lies near the northern edge of the Chihuahuan Desert. The relative youth of the desert combines with the dramatic topographic relief of the park to produce tremendous biological diversity. In addition to the many desert-adapted plants and animals found in the lower elevations of the park, the "sky islands" of the higher elevations retain species with origins in the cooler and moister climate of the last Ice Age.

Big Bend National Park has the greatest species richness of all CHDN park units. This pattern is likely due to the large area, greater range of elevation, diversity of landforms and habitats. Current inventories show that 1,321 plant species from 114 families (Table C.7-1). Vertebrate taxa include 37 species of fish, 70 species of herps, 81 species of mammals, and 410 species of birds.

The climate is arid, with average annual precipitation ranging from 25 centimeters (10 in) in the lower desert to 46 centimeters (18 in) in the Chisos Mountains. More than half of the annual precipitation occurs from July to early October. Temperatures regularly exceed 38 °C (100 °F) from June through August, but freezing temperatures are not uncommon from November to mid-March as cold air moves southward into the park from the Great Plains. Snow falls occasionally in the Chisos Mountains and rarely at the lower elevations.

C.2.2 Resource management concerns

Aquatic and Riparian Species Loss Due to Degradation of the Rio Grande: Historically, the Rio Grande supported aquatic and riparian communities unique to the arid Chihuahuan Desert ecosystem. However, modern human impacts have severely degraded the river's potential to sustain these native plant and animal assemblages. Much of the river has been diverted upstream for agricultural, urban, and industrial purposes. Impoundments alter natural flood and flow cycles, contaminants have altered water chemistry, and exotic species invasions have disrupted native species dominance. Research indicates that at least seven fish species and one amphibian species have been extirpated from the river in recent history. Effective management of the riparian communities of Big Bend NP requires baseline data on the current status of the at-risk plant and animal species, and consistent monitoring efforts so that status changes may be noted and addressed.

Disruption of Ecosystem Structure by Exotic Plant and Animal Species: A host of invasive non-native plant and animal species threaten native communities and species throughout the park. Tamarisk, Buffelgrass, Giant Reed, Bermudagrass, Johnsongrass, and a variety of other exotic plants are displacing native species park wide. Feral hogs, Nutria (*Myocaster coypus*), Barbary Sheep (*Ammotragus lervia*), trespassing livestock, non-native fish species, and other exotic vertebrates continue to disrupt native ecosystems (Tables C.7-2 and C.7-3). Further research is needed on the distribution and invasiveness of

exotics, and their impact upon native plant and animal habitats, if managers are to effectively monitor and control them.

Protection of Isolated or Rare Species and Habitats of Mountains and Desert Springs: A significant part of the park's diversity is represented by isolated populations of plants and vertebrates that are found in the Chisos Mountains and in many of the desert springs distributed across the park. These species are threatened by local impacts such as fire, human disturbance, disruption of migration routes and movement corridors, and exotic species encroachment. In addition, broad-scale issues such as the potential for minor climatic shifts (such as drought) and atmospheric deposition of airborne contaminants may affect these species. Managers need inventories of species associated with imperiled vegetation communities, as well as isolated species and their habitats. This will improve understanding of the nature and sources of threats and increase the ability of managers to monitor population status changes.

Continued Grassland and Riparian Degradation Resulting from Pre-Park Land Use Practices: Formerly extensive desert grasslands and shrub lands that protected soils, retained moisture, and supported diverse plant and animal communities were damaged by pre-park agricultural practices. Thin, fragile soils began eroding when grazing, plowing, development, and hydrologic alteration for water catchments reduced vegetative cover. Irreparable loss of fragile topsoil and the slow rate of soil development have resulted in continued degradation despite current land protection policies within park boundaries. Reduced soil cover diminishes organic soil structure and moisture retention. Consequently, when intensive thunderstorms increase runoff, back-cutting and downstream erosion are escalated. Increased erosion, in turn, further threatens surviving grass and shrublands. Vegetative reproduction becomes compromised or limited by more disturbance-tolerant, invasive, and exotic species. The ultimate decrease in diversity of native grasses and shrubs magnifies fragmentation and decline of associated vertebrate populations. Managers need to understand existing conditions and the potential for remediation. Implementation of a long-term monitoring program that quantifies and tracks changes in grass and shrubland-associated plants and animals will help provide this understanding.

Vegetation Shifts Due To Climate Change: The potential for climate change to create large-scale shifts in vegetation associations in the park's Chihuahuan desert communities is immense. Many plant and animal communities are relic, unique, geographically isolated, or exist on the margin of their range. Although climate change models are not widely agreed upon, the potential is significant for indirect consequences (such as wildfire or drought) to accelerate desertification and loss of plant and animal diversity. Managers need monitoring programs that identify early signs of climate-related species declines, and provide data with which to model and characterize future risk.

Water resources: Big Bend National Park – Receives flow from two major rivers (Rio Grande and Rio Conchos) and several smaller US and Mexican tributaries (Terlingua Creek, Alamito Creek, Arroyo de Fortino). Some of the tributaries are intermittent but contribute a significant amount of sediment loading to the Rio Grande. The Rio Conchos is the only major contributor to the flow of the Rio Grande above Big Bend NP. The cities of El Paso and Juarez ordinarily take all of the Rio Grande. Irrigation return flow and occasional rainfall runoff provides some flow to the river, but the flow reaching Big Bend NP is due in large part to the contributions from the Rio Conchos.

C.2.3 Threats

- Deposition from atmospheric pollution,
- Sedimentation, pollutants or contaminants from Rio Grande inflow,
- Waste water effluent discharges from Presidio and Ojinaga,
- Permitted wastewater discharge to tributary Terlingua Creek,
- Mexican livestock in and adjacent to the Rio Grande,
- Runoff from in-park concessions and camping areas,

- Fecal matter during flooding of restroom facilities at Santa Elena Canyon,
- Several contaminants possibly released in potential Rio Grande Village flooding,
- Runoff and infiltration from all Panther Junction park facilities,
- Runoff and infiltration from gasoline station west of Panther Junction,
- Runoff and infiltration from all Chisos Basin concessionaire and park facilities,
- Fecal matter from dispersed camping and hiking activities, especially along the Rio Grande and its tributaries,
- Camping debris and fecal matter near springs and seeps,
- Possible fecal matter and debris from undocumented aliens in transit,
- Vandalism by aggressive pothunters and others in and around springs and seeps,
- Hydrocarbons and debris from River Road users.

C.2.4 Species of special concern

Table C.2.4. Threatened, endangered, species of concern, and park endemic species, Big Bend National Park

Type	Scientific name	Common name	Status
Plants/ Cacti	*Coryphantha ramillosa*	wiskerbrush pincushion cactus	FT
	Coryphantha chaffeyi	Chaffey's pincushion cactus	Tnh
	Echinocereus chisoensis	Chisos hedgehog cactus	FT Tnh (endemic)
	Coryphantha dasyacantha	desert pincushion cactus	Tnh
	Coryphantha duncanii	Duncan's pincushion cactus	Tnh
	Opuntia azurea var. aureispina	golden-spined prickly pear	Tnh
	Echinomastus mariposensis	mariposa cactus	FT, Tnh
	Opuntia imbricata var. argentea	Big Bend cholla	Tnh
	Coryphantha sneedii var. albicolumnaria	silverlace cactus	Tnh
Succulents	*Agave glomeruliflora*	Chisos agave	Tnh
Orchids	*Hexalectris revoluta*	Chisos root coral	Tnh
	Hexalectris nitida	Glass Mountain coral root	Tnh
	Hexalectris warnockii	Texas purple spike	Tnh
Trees	*Ostrya virginiana var. chisosensis*	Chisos hophornbeam	Tnh
	Quercus tardifolia	Chisos Mountain oak	Tnh
	Quercus graciliformis	slender oak	Tnh
Shrubs	*Brongniartia minutifolia*	little-leaf greentwig	Tnh
	Batesimalva violacea	purple gay mallow	Tnh
	Leptopus phyllanthoides	Trans-Pecos maidenbush	Tnh
Forbs	*Bonamia ovalifolia*	bigpod bonamia	Tnh
	Lechea mensalis	Chisos Mountain pinweed	Tnh
	Streptanthus cutleri	Cutler's twistflower	Tnh
	Aquilegia longissima	long-spur columbine	Tnh

Appendix C. Overview of Chihuahuan Desert Network Parks, cont.

Type	Scientific name	Common name	Status
	Nectouxia formosa	puckering nightshade	Tnh
	Chamaesyce golondrina	swallow spurge	Tnh
	Castilleja elongata	tall-stemmed paintbrush	C, Tnh
	Chamaesyce chaetocalyx var. triligulata	three-tongue spurge	Tnh
Grasses	*Festuca ligulata*	Guadalupe fescue	C, Tnh
Mussels	Cyrtonaias tampicoensis	Tampico pearly mussel	FE
	Popenaias popeii	Texas hornshell	FE
Fish	*Gambusia gaigei*	Big Bend mosquitofish	FE, TxE, AFS
	Hybognathus amarus	Rio Grande silvery minnow	FE, AFS, (extirpated – reintroduced 2008)
	Acipenser oxyrhynchus	Atlantic sturgeon	AFS
	Scaphirhynchus platorynchus	shovelnose sturgeon	TxT, (extirpated)
	Campostoma ornatum	Mexican stoneroller	TxT, AFS
	Notropis chihuahua	Chihuahua shiner	TxT
	Notropis jemezanus	Rio Grande shiner	TxT
	Cycleptus elongatus	blue sucker	TxT, AFS
	Atractosteus spatula	alligator gar	(extirpated)
	Lepisosteus osseus	American eel	rare
	Cyprinella lutrensis blairi	Blair's red shiner	(extirpated)
	Notropis orca	phantom shiner	TxE, AFS, (extirpated)
	Notropis simus simus	bluntnose shiner	TxE, AFS, (extirpated)
	Moxostoma congestum	gray redhorse	AFS
Amphibians	*Bufo woodhouseii*	southwestern Woodhouse's toad	(may be extirpated)
Reptiles	*Trachemys gaigeae*	Big Bend slider	SC
	Phrynosoma cornutum	Texas horned lizard	TxT
	Tantilla cucullata	Trans-Pecos black-headed snake	TxT
	Trimorphodon biscutatus	Texas lyresnake	TxT
	Coleonyx brevis	Texas banded gecko	BE
	Coleonyx reticulatus	reticulated (or Big Bend) gecko	BE
	Cophosaurus texanus texanus	greater earless lizard	BE
	Aspidoscelis marmorata	marbled whiptail	BE
Mammals	*Leptonycteris nivalis*	Mexican long-nosed bat	FE, TxE
	Euderma maculatum	spotted bat	TxT
	Ursus americanus	black bear	TxT
	Nasua narica	white-nosed coati	TxT
	Canis lupus	gray wolf	FE, TxE, (extirpated)

Appendix C. Overview of Chihuahuan Desert Network Parks, cont.

Type	Scientific name	Common name	Status
	Ovis canadensis texiana	desert bighorn sheep	(subspecies extinct-TxRS)
Birds	*Vireo atricapillus*	black-capped vireo	FE, TxE
	Falco peregrinus	peregrine falcon	TxE
	Buteogallus anthracinus	common blackhawk	TxT
	Buteo nitida	gray hawk	TxT
	Buteo albonotatus	zone-tailed hawk	TxT

FE = Federally Endangered; FT = Federally Threatened; C = Candidate for Federal Listing;
TxE = Tex. State Endangered ; TxT = Tex. State Threatened; Tnh = Texas Natural Heritage Program Listed;
TxRS=Tex. Restoration Species; AFS=American Fisheries Society Listed; BE=Big Bend endemic

C.3 Carlsbad Caverns National Park (CAVE)

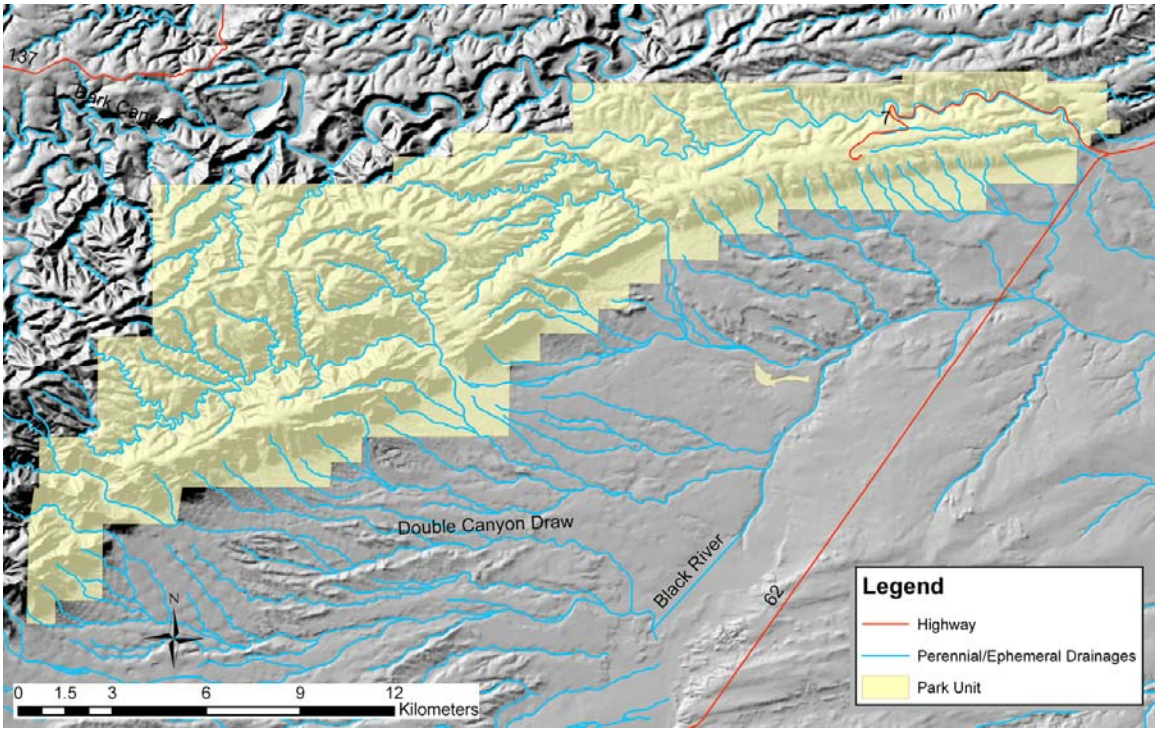


Figure C.2. Map of Carlsbad Caverns National Park, New Mexico.

C.3.1 General description

Size: 18,934 ha (46,766 ac); 71% is wilderness (13,443 ha; 33,203 ac).

Location: Carlsbad Caverns National Park (NP) is located in Eddy County in southeastern New Mexico, about 32 km (20 miles) southwest of Carlsbad, New Mexico, and 240 km (150 miles) east of El Paso, Texas. The main park entrance near White's City is accessible from U.S. Highway 62-180.

Adjacent Lands: This park shares boundaries with private land and public lands managed by the US Forest Service (Lincoln National Forest), Bureau of Land Management, and the New Mexico State Lands Office. Land use is a mix of cattle ranching, oil and gas development, and irrigated agriculture.

Elevation: The elevation in the park ranges from 1,096 m (3,595 ft) in the desert lowlands to 1,987 m (6,520 ft) atop the Capitan Reef. The total relief is 891 m (2,925 ft).

Park History: President Calvin Coolidge established Carlsbad Cave National Monument on October 25, 1923 (Presidential Proclamation No. 1679), under the provisions of the Antiquities Act (34 Stat. 225; June 8, 1906), to protect scenic Carlsbad Cave. Additional public lands were withdrawn by executive order on April 2, 1924 (No. 3984) and May 3, 1928 (No. 4870) for consideration for future national park status. On May 14, 1930, Congress established Carlsbad Caverns National Park (46 Stat. 279). The park was enlarged by executive order on June 17, 1930 (No. 5370), 1933, and 1939. In 1963 boundary adjustments were authorized to acquire Rattlesnake Springs (77 Stat. 818) and in 1978, Congress designated 71% of the park's surface area as Wilderness. Carlsbad Caverns NP was designated a World Heritage Site in 1995, for the protection of "physical and biological formations and groups which are of universal world-wide value and interest."

Physical Characteristics: Carlsbad NP lies in the Guadalupe Mountains, near the northern end of the Capitan Reef geologic formation. The reef was formed approximately 250 million years ago at the margin of a Permian ocean basin. The sea receded late in the Permian era, covering the reef with layers of sediment. Approximately 26 million years ago, Basin and Range faulting action in the Guadalupe Block lifted parts of the reef from its original position, forming the mountains visible today. Erosion in the Guadalupe range has exposed much of the formerly buried reef, making the mountains a premier location for geological research.

Carlsbad Caverns NP preserves more than 90 known caves. Early speleogenesis of the cave systems inside the Guadalupe range may have occurred as early as the Permian era. Initial cave formation was probably caused by carbonic acid filtering through fissures in the reef. However, the presence of gypsum deposits in many of the cave systems has led geologists to believe that sulfuric acid played a role in cave formation during the uplift of the range. They speculate that the salt water that had filled the Capitan Reef was gradually displaced by incoming freshwater. Salt brine rich in hydrogen sulfide subsequently seeped upward from deposits deep under the reef. The hydrogen sulfide then combined with oxygen and freshwater to form sulfuric acid, and migrated throughout the reef. Uplift gradually lifted the upper-level caves clear of the water, and caves formed in lower regions of the reef.

Carlsbad Caverns NP lies in the northern reaches of the Chihuahuan Desert ecosystem, where desert-scrub and grassland plant communities dominate. Small pockets of coniferous woodland are found at higher elevations in the western third of the park.

Current network inventories indicate that Carlsbad Caverns NP is home to 929 plant species from 95 families (Table C.7-1). Vertebrates include 5 species of fish, 51 species of herps, 68 species of mammals and 359 species of birds.

The above ground climate of Carlsbad Caverns NP is arid, and characterized by warm summers and mild winters. In the summer, average highs are in the 30s °C (90s °F). In the winter the average highs range from 10 - 20 °C (50 - 60 °F). Average annual precipitation is approximately 37 centimeters (14.5 in) at 4,400 ft elevation, with over 80% occurring in May – October. Rainfall is highly variable and localized. Subterranean climates are cooler and much less variable.

C.3.2 Resource management concerns

The Guadalupe Mountains – Carlsbad Escarpment is rated as a highest priority terrestrial site for conservation by the World Wildlife Fund (Dinerstein et al. 2000). The Pecos River, including associated spring-fed tributaries such as Rattlesnake Springs, is similarly rated as the highest priority for conservation among freshwater sites. Freshwater riparian areas are the most threatened resource in the Chihuahuan Desert. Riparian communities at Rattlesnake Springs and adjacent non-park lands are magnified in importance due to the rarity of similar habitat in the region, and the diversity of plant and animal life found there, including migratory birds. Seeps and springs, as well as seasonally flooded playas and arroyos, are also sites of interest as they are an important resource for wildlife in a largely arid climate. The high-elevation western escarpment, featuring deep incised canyons, relict ponderosa pine forest, maple stringers, and juniper-piñon mesas, has received scant attention in most previous biological inventories. Among well-visited park areas, Walnut Canyon is of management interest due to the presence of rare taxa (e.g., Coryphantha sneedii var. leei, Lampropeltis alterna, etc.) and high visitor use.

Generally speaking, specific management issues at Carlsbad Caverns National Park mirror broader threats to biodiversity that have been identified in the northern Chihuahuan Desert (e.g., Dinerstein et al. 2000). The following are management concerns at Carlsbad Caverns National Park.

Water Management: Surface flow from Rattlesnake Springs supports 1,000 m (3,281 ft) of stream course with riparian woodlands and marsh ecosystems. The rarity of riparian corridors magnifies the importance of Rattlesnake Springs for the preservation of regional biological diversity. However, groundwater pumping for irrigated agriculture outside of the park has the potential to draw down spring flow at Rattlesnake Springs. Currently, approximately half of the surface flow is diverted towards neighboring Washington Ranch, or for irrigation of cottonwood galleries and orchards at Rattlesnake Springs. The dewatering of the natural drainage ensures that the stream course cannot connect downstream with the Black River, and creates a parallel aquatic community in the concrete-lined ditches that deliver water to Washington Ranch. Maintenance of the ditches disrupts the artificial community, where native Rio Grande leopard frogs (*Rana berlandieri*) and green-throated darters (*Etheostoma lepidum*) have become established. The concrete ditches establish an aquatic link to ponds at Washington Ranch, and may provide a corridor for the dispersal of non-native wildlife such as bullfrogs (*Rana catesbeiana*) and largemouth bass (*Micropterus salmoides*) although desired natives such as the western river cooter (*Pseudemys gorzugi*) may also employ this corridor. The natural stream course may have once reached the Black River, at least occasionally, providing a corridor for many aquatic organisms that reside there. If so, Rattlesnake Springs would have served as a refuge for aquatic species in the Pecos River drainage that are now imperiled due to extensive water diversion.

Livestock Grazing: Livestock use outside the park boundary (and infrequent episodes of trespass grazing) degrades the landscape. Historic grazing by sheep and goats has likewise altered vegetation communities inside the park boundary. Soil erosion, replacement of grasslands by shrub lands, altered fire regimes, and habitat change isolate relatively undisturbed communities from other like habitats. Current land management practices outside the park boundary include the use of herbicides to kill shrubs, and predator control against coyotes (*Canis latrans*) and cougars (*Puma concolor*). Grazing may also alter the density and distribution of native wildlife (e.g., favoring cowbirds (*Molothrus* spp.) and allow the spread of non-native plants.

Oil and Gas Development: Plans for developing leases on state and private lands adjacent to the park, including sections between the main body of the park and Rattlesnake Springs, pose risks to air and water quality, and degrade the surrounding land by road and well pad construction, and habitat loss. Noise and nighttime light pollution are also increased by such activities. Disturbance may be expected to favor the spread of non-native plants.

Exotic Species: Barbary sheep (*Ammotragus lervia*) are established in the park. Feral goats are also occasionally noted. Non-native plants, especially Russian olive (*Elaegnus angustifolia*) and johnsongrass (*Sorghum halapense*), are now major components of the vegetation at Rattlesnake Springs. These species may suppress the cottonwood-willow riparian woodlands and native grasses that occur there. Other non-native plants that have potential to spread in disturbed areas include Malta starthistle (*Centaurea melitensis*), common horehound (*Marrubium vulgare*), and tree-of-heaven (*Ailanthus altissima*). See Tables C.7-2 and C.7-3 for other species of non-native plants and animals that occur in this park.

Illegal Hunting and Poaching: The illegal collection of reptiles and cacti, as well as, rocks, paleontological resources, and cultural artifacts, probably occur in and outside the park. In addition to legal sport and depredation hunts for cougar in New Mexico, illegal trapping and hunting likely persists outside of the park boundary. Cougar hunting is currently unregulated in Texas.

Aircraft Overflights: Occasional military aircraft flyovers have the potential to disturb wildlife and impact wilderness values.

Human Population/Recreation Use: More than 500,000 people visit the park every year, and most of them tour Carlsbad Cavern. Visitor impacts in the cave include the introduction of lint, trash and food into the cave environment. Vandalism and theft of speleothems are also well-documented problems. The

accommodation of visitors in the cave has led to significant modifications to the cave environment, including systems of trails, electric lights, elevators, restrooms, a cafeteria, and gift shop. These impacts may affect the climate in the cave, pollute cave pools, permit the growth of algae and photosynthetic plants, and alter nutrient cycles and the distribution of cave invertebrates. On the surface, visitor impacts are concentrated in Walnut Canyon. Most visitors arrive at the park by automobile, via the 2-lane highway from White's City. The nighttime speed limit has been lowered to 30 mph (daytime limit is 40 mph) to help prevent the loss of wildlife on the road. Automotive pollutants along the highway and in parking areas above Carlsbad Cavern may be harmful, particularly to the cave environment. Primitive roads and trails designed for visitor access are in poor condition, causing erosion of gravel and soil outside the bed into areas containing native plants and wildlife.

Lack of Baseline Inventories: Park managers recognize that improved knowledge of the presence, abundance, and distribution of plants and wildlife is vital to informed decision-making in the areas of fire management, visitor use, and others. The results of such research can assist in the stewardship of park resources, and contribute to the knowledge of broader subjects in ecology such as climate change, migration, and evolution. Research needs for various park taxa include:

I. Amphibians. The lack of any park-wide survey for amphibians is identified as a serious deficiency in resource knowledge and park management. Native amphibians are of special interest due to general declines throughout the southwest, the potential negative impact of non-native bullfrog (*Rana catesbeiana*) on local populations, and the susceptibility of anurans to wildlife diseases and environmental contaminants. One instance of deformity has been noted in an adult bullfrog from Rattlesnake Springs, collected in 2000. The native riparian habitat and system of irrigation ditches and ponds at Rattlesnake Springs and the adjoining Washington Ranch and Black River are host to native Rio Grande leopard frog (*R. berlandieri*) as well as non-native bullfrog populations. The degree of competition between these frogs is unknown. Water management by the park and other landowners (i.e., surface water diversions for irrigation and groundwater pumping) alter the available habitat for these and other species. The park needs to develop a consistent plan for bullfrog management, monitoring of bullfrog and leopard frog populations, and recommendations for irrigation practices that take into account the habitat preferences of native species. Cricket frogs (*Acris crepitans*) were formerly collected at Rattlesnake Springs (Kansas University Museum of Natural History 13420-60), but have not been noted in recent years. Cricket frogs may still occur in flooded grassland habitat at nearby Blue Spring (7.5 km E of White's City). Investigation of this site may shed light on the apparent extirpation of cricket frogs from Rattlesnake Springs, and possibly provide a model for habitat restoration and a source for eventual reintroduction. Several species of amphibians are possible for the park, including eastern barking frogs (*Eleutherodactylus augusti*) which have been noted in the plains a short distance from the park in July 2000 (Chosa Draw, 6.8 km E of Rattlesnake Spring), Woodhouse's toad (*B. woodhousii*), plains leopard frogs (*R. blari*), and plains spadefoot toad (*Spea bombifrons*).

II. Reptiles. Although 49 species of reptiles have been noted for the park, many of these are not verified through specimens or adequate voucher photographs. There is a special interest in having a thorough assessment of riparian-associated species that are known from the nearby Black River, and which may occur at Rattlesnake Springs, including, snapping turtle (*Chelydra serpentina*), painted turtle (*Chrysemys picta*), spiny softshell (*Trionyx spiniferus*), western ribbon snake (*Thamnophis proximus diabolicus*), and blotched water snake (*Nerodia erythrogaster transversa*). Gray-banded kingsnake (*Lampropeltis alterna*) is of particular interest to the park. This species is notoriously difficult to document through standard pitfall trap methods, and is highly sought by reptile collectors. Illegal collection of this and other colorful species likely occurs at Carlsbad Caverns National Park. Several species of reptiles are listed as threatened or endangered by various agencies. These are western river cooter (*Pseudemys gorzugi*, NM state threatened), Texas horned lizard (*Phrynosoma cornutum*, USFS Region 3 sensitive), gray-banded kingsnake (NM state endangered), common kingsnake (*Lampropeltis getula splendida*, USFS Region 3

sensitive), blotched water snake (NM state endangered), western ribbon snake (not known from park; NM state threatened), mottled rock rattlesnake (*Crotalus lepidus lepidus*, NM state threatened), and desert massasauga (*Sistrurus catenatus edwardsi*, not known from park; USFS Region 3 sensitive).

III. Plants. Key management needs at Carlsbad Caverns National Park are an understanding of the distribution of vegetation communities, the response of these communities and rare species to fire, the control of non-native plants, and inventory and monitoring for state and federally listed species. The park has contracted with the New Mexico Natural Heritage Program (NMNHP) to conduct a survey of park vegetation and classify the vegetation communities. The vegetation map will be completed in early 2002. Protection of the federally threatened Lee's pincushion cactus (*Coryphantha sneedii* var. *leei*) is a focus of park management, as the species is restricted in range to the park and immediate surroundings. The park has conducted surveys for Lee's pincushion cactus, monitored some populations to determine mortality from fire events, and contracted a study of the morphometric properties of C. s. var. leei and related species. The presence and population densities of C. s. var. leei and other rare plants are poorly understood for the park. The park needs a rare plant survey to document the distributions of these species and describe the habitats and conditions in which they are found.

IV. Birds. Birds of special concern include riparian obligate species, particularly the state threatened Bell's vireo (*Vireo bellii*) and yellow-billed cuckoo (*Coccyzus americanus occidentalis*, USFS Region 3 species of concern). The federally endangered southwestern willow flycatcher (*Empidonax traillii extimus*) is an observed migrant at Rattlesnake Springs, and may eventually find suitable habitat for nesting there. Brood parasitism by brown-headed cowbirds (*Molothrus ater*) has a negative effect on nesting success in Bell's vireo at Rattlesnake Springs, and may affect species in other habitats as well. The park may also provide habitat for the federally threatened Mexican spotted owl (*Strix occidentalis lucida*), and the state threatened peregrine falcon (*Falco peregrinus anatum*), gray vireo (*Vireo vicinior*), and varied bunting (*Passerina versicolor*). Cave swallows (*Hirundo fulva*) reach their northern range limit at the park, and are of interest to ornithologists and the general public. The distribution and abundance of upland breeding and wintering birds are poorly understood at Carlsbad Caverns.

V. Fish. The park needs to implement monitoring for green-throat darters (*Etheostoma lepidum*, New Mexico state-threatened species) and roundnose minnows (*Dionda episcopa*) in various habitats at Rattlesnake Springs (e.g., spring pond, irrigation ditches, natural stream channel, etc.). Cleaning and repair of concrete irrigation ditches are especially problematic, as the removal of aquatic vegetation and interruption of water flow destroys habitat for the greet-throat darters. Green sunfish (*Lepomis cyanellus*) are native to the area but possibly introduced to the pond area at the springs. Largemouth bass (*Micropterus salmoides*) have also been introduced to the pond habitat. The park needs to assess the need for management of these larger species, and determine the suitability of this habitat for other native fishes that may have once been present (e.g., *Gambusia nobilis*).

VI. Mammals. Carlsbad Caverns National Park has lost some native mammals, including the extinct Merriam's elk (*Cervus elaphus merriamii*), and extirpated desert bighorn sheep (*Ovis canadensis*). Although there are no confirmed park records, prairie dogs (*Cynomys ludovicianus*), gray wolf (*Canis lupus*) and other species may have been historically present. The park contains many bat species that are listed as sensitive by the state of New Mexico or the BLM, including cave myotis (*Myotis velifer*), fringed myotis (*M. thysanodes*), long-legged myotis (*M. volans*), eastern red bat (*Lasiurus borealis*), and Townsend's big-eared bat (*Corynorhinus townsendii*). The status of these and other bat species, particularly the colony of Mexican free-tailed bats (*Tadarida brasiliensis mexicana*) that reside in Carlsbad Cavern, are of keen public and management interest at the park. Many other mammal species are listed as sensitive by the state of New Mexico, notably the spotted skunk (*Spilogale gracilis*), which has not been seen in the park in several decades. Park management of cougar (*Puma concolor*) and mule deer (*Odocoileus hemionus*) has often been controversial with various publics. The park has committed to

monitoring populations of cougar and mule deer in a 1986 Mountain Lion Management Plan and Environmental Assessment. Non-native Barbary sheep (*Ammotragus lervia*) are established in the park. Removal of Barbary sheep and restoration of native desert bighorn sheep are goals for park management. Data on the distribution and abundance of park mammals, including verification of all known collected specimens (n = 1,186) at seven institutions was published in 2002 by the University of Nebraska State Museum.

Water Resources: Receives no significant surface flows from surrounding lands.

C.3.3 Threats

- Deposition from atmospheric pollution,
- Runoff and infiltration to caves from all headquarters area park facilities.
- Oil and gas drilling in the catchment for Rattlesnake Springs has the potential to cause irreparable damage to these springs. During high flow, there has been trace amounts of toluene detected, indicating that some of the adjacent, subsurface water courses have been contaminated and can spill over into the underground channel that feeds Rattlesnake Springs. Grazing and agriculture within the Rattlesnake Springs catchment also poses a threat to the water from high nitrates and phosphates.

C.3.4 Species of special concern

Table C.3.4. Threatened, endangered and species of concern, Carlsbad Caverns National Park.

Type	Scientific name	Common name	Status
Plants	*Amsonia tharpii*	feltleaf bluestar	NM-E
	Aquilegia chrysantha var. *chaplinei*	Chapline's columbine	NM-T
	Astragalus gypsodes	gypsum milkvetch	NM-T
	Chaetopappa hersheyi	mat leastdaisy	SOC, NM-T
	Chrysothamnus nauseosus var. *texensis*	Guadalupe rabbitbrush	SOC, NM-T
	Coryphantha scheeri var. *scheeri*	long-tubercled coryphantha	NM-E
	Coryphantha sneedii var. *leei*	Lee's pincushion cactus	FT
	Coryphantha sneedii var. *sneedii*	Sneed's pincushion cactus	FE
	Echinocereus fendleri var. *kuenzleri*	Kuenzler's hedgehog cactus	FE
	Eriogonum gypsophilum	gypsum buckwheat	FT
	Escobaria guadalupensis	Guadalupe pincushion cactus	SOC, NM-T
	Hedeoma apiculatum	McKittrick pennyroyal	NM-T
	Hexalectris nitida	shining coral root orchid	SOC, NM-E
	Justicia wrightii	Wright's justicia	NM-T
	Nama xylopodum	yellowseed nama	NMRPTC-R
	Penstemon cardinalis ssp. *regalis*	cardinal penstemon	NM-T
	Perityle quinqueflora	five-flowered rock daisy	NM-T

Appendix C. Overview of Chihuahuan Desert Network Parks, cont.

Type	Scientific name	Common name	Status
	Polygala rimulicola var. *rimulicola*	Guadalupe milkwort	NM-T
	Proboscidea sabulosa	sanddune unicorn-plant	NM-T
	Pseudocymopterus longiradiatus	Trans-Pecos false mountain parsley	NM-T
	Salvia summa	mountain sage	NM-T
	Selaginella pilifera	resurrection plant	NM-T
	Sibara grisea	gray sibara	NM-T
	Sophora gypsophila var. *guadalupensis*	Guadalupe smooth aster	NM-T
	Achnatherum curvifolium	curl-leaf needlegrass	NMRPTC-R
	Streptanthus sparsiflorus	few-flowered jewelflower	NM-T
	Valeriana texana	Texas valerian	NM-T
Fish	*Etheostoma lepidum*	greenthroat darter	NM-T
Reptiles	*Pseudemys gorzugi*	Rio Grande cooter	NM-T, FS
	Phrynosoma cornutum	Texas horned lizard	SOC, FS, BLM
	Phrynosoma hernandesi	greater short-horned lizard	TX-T
	Lampropeltis alterna	gray-banded kingsnake	NM-E
	Lampropeltis getula splendida	desert kingsnake	FS
	Nerodia erythrogaster transversa	blotched watersnake	NM-E, FS
	Thamnophis proximus diabolicus	arid land ribbonsnake	NM-T, FS
	Crotalus lepidus lepidus	mottled rock rattlesnake	NM-T, FS
	Sistrurus catenatus edwardsii	desert massasauga	FS
Mammals	*Myotis ciliolabrum melanorhinus*	western small-footed myotis	SOC, NM-S, BLM
	Myotis yumanensis yumanensis	Yuma Myotis	SOC, NM-S, BLM
	Myotis velifer	cave myotis	SOC, NM-S, BLM, FS
	Myotis volans interior	long-legged myotis	SOC, NM-S, BLM
	Myotis thysanodes thysanodes	fringed myotis	SOC, NM-S, BLM
	Lasiurus borealis	eastern red bat	NM-S, FS
	Corynorhinus townsendii pallescens	pale Townsend's big-eared bat	SOC, NM-S, BLM, FS
	Nyctinomops macrotis	big free-tailed bat	SOC, NM-S, BLM
	Neotamias canipes canipes	gray-footed chipmunk	SOC, BLM
	Thomomys bottae guadalupensis	Guadalupe pocket gopher	*SOC, NM-S, BLM, FS*
	Chaetodipus nelsoni canescens	Nelson's pocket mouse	*NM-S*
	Bassariscus astutus	ringtail	NM-S, FS
	Spilogale gracilis	western spotted skunk	NM-S
	Conepatus mesoleucus	white-backed hog-nosed skunk	NM-S
Birds	*Butorides virescens*	green heron	FS
	Falco peregrinus anatum	peregrine falcon	NM-T, FS
	Buteo regalis	ferruginous hawk	SOC, FS, BLM

Appendix C. Overview of Chihuahuan Desert Network Parks, cont.

Type	Scientific name	Common name	Status
	Buteo swainsoni	Swainson's Hawk	FS
	Buteo albonotatus	zone-tailed hawk	FS
	Athene cunicularia hypugea	western burrowing owl	SOC, BLM
	Otus flammeolus	flammulated owl	*FS*
	Micrathene whitneyi whitneyi	elf owl	FS
	Strix occidentalis lucida	Mexican spotted owl	FT, NM-S, FS
	Coccyzus americanus occidentalis	yellow-billed cuckoo	FS
	Ceryle alcyon	belted kingfisher	FS
	Lanius ludovicianus	loggerhead shrike	SOC, BLM
	Empidonax traillii extimus	southwestern willow flycatcher	FE, NM-E, FS
	Vireo bellii	Bell's vireo	NM-T, FS
	Vireo vicinior	gray vireo	*NM-T, FS*
	Dumetella carolinensis ruficrissa	gray catbird	FS
	Anthus spragueii	Sprague's pipit	*FS*
	Setophaga ruticilla tricolora	American redstart	FS
	Ammodramus bairdii	Baird's sparrow	SOC, NM-T, FS, BLM
	Calcarius mccownii	McCown's longspur	FS
	Passerina versicolor	varied bunting	NM-T, FS

FT = Federally Threatened; NM-T = New Mexico State Threatened; FE = Federally Endangered
NM-S = New Mexico Sensitive; SOC = Federal Species of Concern; C = Candidate for Federal Listing;
FS = Forest Service Region 3 Sensitive; TX-T = State of Texas Threatened;
BLM = Bureau of Land Management Sensitive; NMRPTC-R = New Mexico Rare Plant Technical Council Rare

C.4 Fort Davis National Historic Site (FODA)

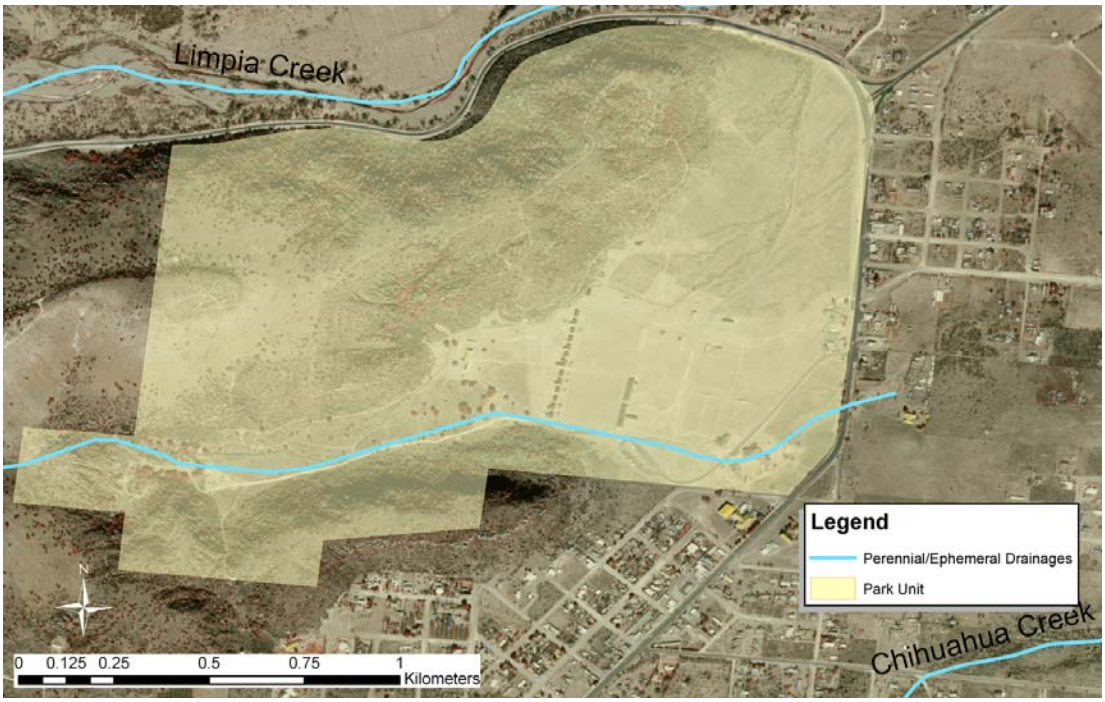


Figure C.4. Map of Fort Davis National Historic Site, Texas.

C.4.1 General description

Size: (192 ha) 474 ac

Location: Fort Davis National Historic Site (NHS) is located at the southeast edge of the Davis Mountains in the Trans-Pecos region of West Texas on the northern edge of Fort Davis, Texas in Jeff Davis County. It may be reached via State Highways 118 and 17, approximately 328 km (205 miles) southeast of El Paso, Texas, and 248 km (155 miles) southwest of Odessa, Texas. The site is bordered to the northwest by Davis Mountain State Park and by private land on the other sides.

Adjacent Lands: Fort Davis NHS is bordered to the northwest by Davis Mountains State Park and by private land on the other sides. The Nature Conservancy is a neighbor in close proximity, as is the McDonald Observatory and the Chihuahuan Desert Research Institute.

Elevation: The elevation at Fort Davis NHS ranges from approximately 1,487 m (4,880 ft) at the fort to approximately 1,591 m (5,220 ft) in the Davis Mountains. Overall change in elevation is approximately 104 m (340 ft).

Park History: Fort Davis NHS was authorized on September 8, 1961 and established on July 4, 1963. In its presently preserved condition, this site symbolizes the era of westward migration and the essence of the late 19th century U. S. Army. The park preserves 110 historic buildings, ruins, and foundations and the landscape associated with two forts (active from 1854-1862 and 1867-1891).

Physical Characteristics: Fort Davis NHS is situated at the eastern side of the rugged Davis Mountains, which were formed by volcanic eruptions that occurred during the Tertiary geologic period, which began

approximately 65 million years ago. The historic site is located adjacent to Davis Mountains State Park, which covers 1,096 ha (2,709 ac).

The entrance area, or foreground, of the site features the Chihuahuan Desert grassland community common to the Davis Mountains, and provides visitors with their first view of the fort. It also contains a spring and associated historic grove of cottonwood trees. The historic core provides the visitor with opportunities to view Fort Davis' historic buildings, ruins, foundations, parade ground, and cultural landscape, and to learn about the history of the fort. The fort is located in the middle of an alluvial floodplain and natural drainages run through the site. Historic ditches and dikes are maintained for flood control. Behind the main fort area rise the volcanic cliff walls of Hospital Canyon and a rugged steep escarpment running north/south that forms the prominent backdrop view from the lower elevations. Mixed vegetative cover is found throughout this zone, where desert-scrubland intermixes with cacti and pinyon-juniper woodland. This scenic backdrop ensures that the fort maintains its late 19th century appearance.

Current inventories or expected distributions (of mammals) indicate that Fort Davis NHS is home to 368 species of plants from 74 families (Table C.7-1). This NHS is much smaller than all other CHDN park units. No fish are found within the boundaries of Fort Davis, NHS. However, a number of other vertebrate taxa occur (or in the case of mammals, are expected to occur) here, including 31 species of herps, 15 species of mammals, and 119 species of birds.

The climate of the Davis Mountains is arid, as is typical of the northern Chihuahuan Desert, with annual rainfall averaging 48 centimeters (19 in). The elevation of the site results in relatively mild temperatures, but extremes of more than 35 °C (95 °F) during the summer are common. Winter temperatures may reach below - 6 °C (20 °F).

C.4.2 Resource management concerns

The primary resource concern is maintaining the historic landscape, viewshed, and sounds both inside the park and on private and State of Texas lands bordering the park. The intent is when visitors enter the park they should be able to look and listen in all directions and feel they are on an active military post in the mid to late 19th century. Most of the park's viewshed is protected by natural barriers, however adjacent private land to the northeast could be developed and impact the viewshed. Noise pollution is a minor problem from aircraft overflights, passing traffic on the highway, and vehicles idling in the parking lot.

The General Management Plan was completed and signed in November 2002. It breaks the park down into three Resource Opportunity Areas (ROAs) - Foreground, Historic Core, and Natural Backdrop.

The Foreground: This area is generally left in a natural state except for irrigation and mowing in the cottonwood grove and mowing in the area adjacent to the cavalry stables foundation.

The Historic Core: This is the most heavily impacted area in the park, due to both visitor use and maintenance activities to maintain the cultural landscape. The parade ground and areas adjacent to the buildings and foundations are mowed annually. The interiors and outer perimeters of the foundations are cleared of weeds and grasses and the historic drainage ditch is cleared of vegetation annually. Also, the trees and shrubs along Officers' Row are irrigated and gravel pathways and roads are maintained.

The Natural Backdrop: The area behind the fort contains the bulk of the hiking and natural viewing opportunities at the site, and is maintained in its natural state. Maintenance activities are generally limited to yearly repair of the hiking trails.

Lack of Baseline Data: Cultural resources have been the main focus throughout the park's existence with minimal attention being given to natural resources management. Natural resources generally have been managed with the goal of maintaining the historic late 19th century landscape of the fort. Current information is available for the vascular plants, so the priority for the inventory program is inventory of the vertebrate taxa. Through inventory and monitoring, the park will learn more about what exist and be able to compare it to what existed in the late 19th century, and be able to incorporate the information into management of the historic landscape. Such information could also be used on a regional basis and shared with neighbors such as Davis Mountains State Park and the Chihuahuan Desert Research Institute.

Water Resources: Receives surface flows from adjacent Davis Mountains State Park

C.4.3 Threats

- Deposition from atmospheric pollution,
- Groundwater infiltration from adjacent urban sources,
- Groundwater infiltration from park facilities,
- Flood inflows to Hospital Canyon Arroyo.

C.4.4 Species of special concern

The following list was compiled by Davis Mountains State Park (DMSP). Although the flora and fauna were identified on DMSP land, they very likely could be located at Fort Davis NHS also since the resources are the same.

Table C.4.4. Threatened, endangered and species of concern, Fort Davis National Historic Site.

Type	Scientific name	Common name	Status
Plants	*Allolepis texana*	Texas false saltgrass	SOC
	Croton suaveolens	scented croton	SOC
	Coryphantha dasyacantha var. *dasyacantha*	dense Cory cactus	SOC
	Astragalus mollissimus var. *marcidus*	withered locoweed	SOC
Reptiles	*Phrynosoma cornutum*	Texas horned lizard	FT
	Tantilla cucullata	Trans-Pecos black-headed snake	FT
Mammals	*Thomomys bottae limpiae*	Limpia Botta's pocket gopher	SOC
Birds	*Buteo regalis*	ferruginous hawk	SOC
	Charadrius montanus	mountain plover	SOC
	Lanius ludovicianus	loggerhead shrike	SOC
	Strix occidentalis lucida	Mexican spotted owl	SOC
	Empidonax traillii extimus	southwestern willow flycatcher	FE
	Haliaeetus leucocephalus	bald eagle	FT
	Buteo albonotatus	zone-tailed hawk	FT
	Buteo anthracinus	common black-hawk	FT
	Buteo nitidus	gray hawk	FT
	Falco peregrinus	peregrine falcon	FT

SOC = Species of Concern; FE = Federally Endangered; FT = Federally Threatened

C.5 Guadalupe Mountains National Park (GUMO)

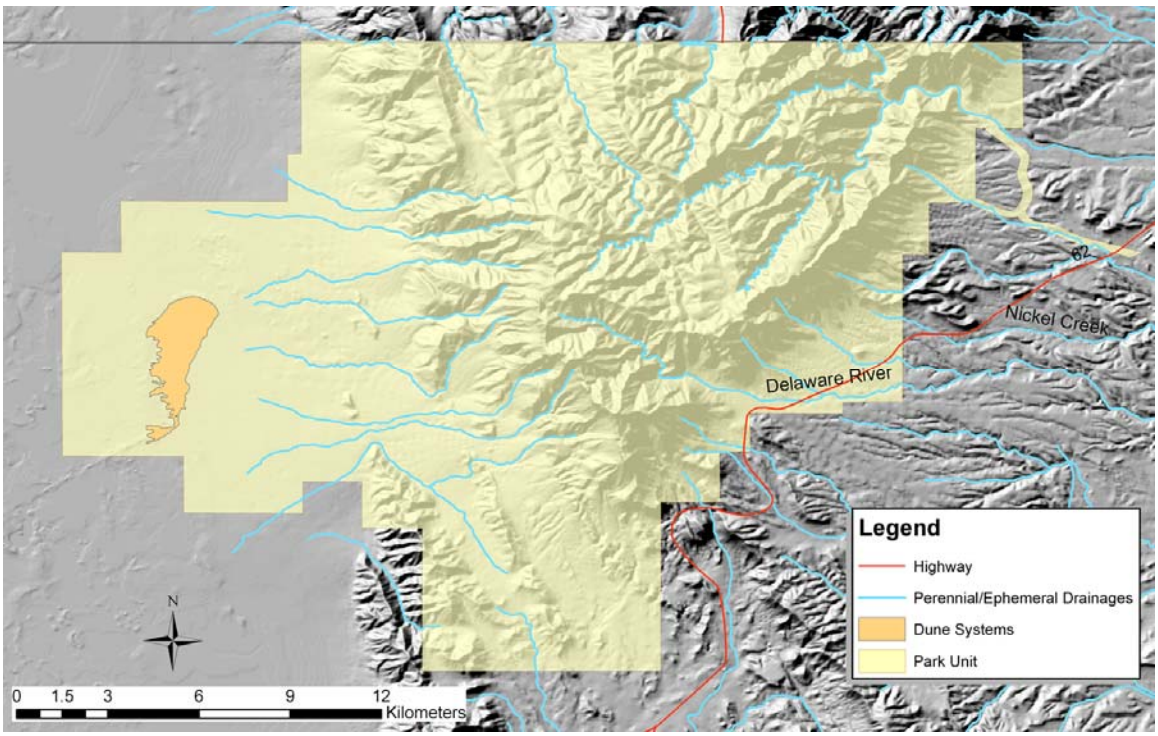


Figure C.3. Map of Guadalupe Mountains National Park, Texas.

C.5.1 General description

Size: 34,986 ha (86,416 ac)

Location: Guadalupe Mountains National Park (NP) is located in the Trans-Pecos region of west Texas just south of the Texas/New Mexico border. The park is approximately 177 km (110 miles) east of El Paso, Texas, and 88 km (55 miles) southwest of Carlsbad, New Mexico. Three main entrances to the park, as well as the park headquarters, may be accessed from U.S. Highway 62/80. A fourth entrance, through Dog Canyon, may be accessed by taking U.S. Highway 285 north from Carlsbad for 19 km (12 miles), then turning west on New Mexico Highway 137 and following it 93 km (58 miles) into the canyon. The west side of the park may be accessed through Dell City, Texas. Guadalupe Mountains NP is located in Culberson and Hudspeth Counties, Texas.

Adjacent Lands: Most of the lands surrounding Guadalupe Mountains NP are private lands in the state of Texas. The only public land is owned by the General Land Office or the Texas Department of Transportation for the highway. The park lies on the state line with New Mexico. In New Mexico adjacent land owners include private lands, State of New Mexico Public Lands, Federal Bureau of Land Management lands in two BLM Resource Areas—Carlsbad and Las Cruces, and U.S. Forest Service lands on the Guadalupe Ranger District of the Lincoln National Forest.

Elevation: The elevation at Guadalupe Mountains NP ranges from approximately 1,204 m (3,624 ft) on the alkali flats to 2,584 m (8,749 ft) atop Guadalupe Peak, which is the highest point in Texas. Total elevation change is 1,480 m (4,855 ft).

Park History: Geologist Dr. G.G. Shumard described the fossil reef in 1855 while accompanying an expedition looking for artesian water. When petroleum was discovered in the Permian Basin in the 1920s, further studies of the Guadalupe Range were undertaken. Geologist Wallace Pratt studied the Guadalupe Mountains extensively and in the 1960s, and donated more than 2,020 ha (5,000 ac) of his property in McKittrick Canyon to be used in the creation of the park.

The park was created by an Act of Congress in 1966 and formally established in 1972. From its establishment in 1972 until 1987, Guadalupe Mountains NP was administered jointly with Carlsbad Caverns NP from headquarters in Carlsbad, New Mexico. During this period, a manager lived at the park and oversaw day-to-day operations. Since October of 1987, Guadalupe Mountains NP has had a resident superintendent, and management of the two parks has been separate except for shared administrative services.

Today, the park preserves the world's most significant fossilized reef outcrops of Permian-age limestone, as well as the associated Chihuahuan Desert and mountain forest ecosystems. Approximately half of the park (18,968 ha [46,850 ac]) is designated as Wilderness area.

Physical Characteristics: Guadalupe Mountains NP is located in the southern portion of the Guadalupe Mountains near the western edge of the Capitan Reef geologic formation. The reef was formed approximately 250 million years ago at the margin of a Permian ocean basin, and was later covered with layers of sediment as the sea receded. Beginning approximately 26 million years ago, Basin and Range faulting action and subsequent erosion exposed parts of the reef. The Western Escarpment of the reef was lifted approximately 3 km (2 miles) above its original position, and is most visible today at the dramatic El Capitan rock face.

During cooler, moister climatic conditions about 15,000 years ago, coniferous forest covered much of the area around the park, and remnants of this forest survive today at higher elevations in the Guadalupe Mountains. The mountains contain a number of deep, sheer-sided canyons, distinguished by high levels of biodiversity. The most notable of the canyons is McKittrick Canyon (often described as "the most beautiful spot in Texas"), which contains the park's only perennial stream, McKittrick Creek. The creek, as well as a number of springs, seeps, and ephemeral washes, support riparian plant communities.

The westernmost portion of the park encompasses several square miles of the alkali flats that dominate the valley west of the mountains. These flats began forming about 7 million years ago when faulting created a basin valley with no drainage outlets. As water entered the basin, broad shallow lakes were created, and evaporation and sedimentation resulted in a concentration of salts on the valley floor. Today, wind has eroded sections of the flats, piling quartz and gypsum sand dunes up against the western foothills of the Guadalupe Mountains. The mountain foothills and surrounding plains are characterized by Chihuahuan Desert vegetation, including specialized desert scrub communities found in the salt flat and dune areas.

The wide range of elevations, diverse landforms and associated habitats in this park unit provide for a great variety of plants and animals. According to current inventories, there are 985 plant species from 99 families found in Guadalupe Mountains National Park (Table C.7-1). Vertebrate taxa include 3 species of fish, 53 species of herps, 70 species of mammals, and 240 species of birds.

Winter temperatures at the park reach average highs of 13 °C (56 °F) and lows of 1 °C (33 °F), with average precipitation of less than 3 centimeters (1 inch). Snowfalls may linger for long periods in the high country. High winds are common during the spring months. The summers bring afternoon thunderstorms that may cause flash-flooding and intense lightning. The average summer precipitation is approximately 7

centimeters (3 in) and average temperatures range from highs around 30 °C (80s °F) to lows in the mid-teens °C (60s °F). Autumn ushers in milder weather, cold nights, and the occasional rainfall.

C.5.2 Resource management concerns

Baseline Inventories: Park managers would like to establish baseline inventory information for vascular plants and vertebrates present on cultural landscape sites that are scheduled for potential restoration, as well as in areas of potential disturbance from routine maintenance activities and future road, trail and park facility development. Obtaining knowledge of the presence or absence of exotic, pioneer, listed, and sensitive species would aid managers in prioritizing and planning construction and restoration projects. In addition to establishing inventory and/or collection sites at target locations, researchers could revisit sites established in the 1970s; duplication of vertebrate and plant collection protocols at these would be a first step in examining changes in species composition over time. Finally, baseline inventories of the vegetation near trails and camp pads would help to assess the level of soil compaction, and the effects of trampling, on vegetation composition in areas of heavy visitor use.

Environmental Effects: Park managers are interested in the environmental effects of fire and air pollutants. Inventories of vegetation and vertebrates in areas recently affected by wild-land or prescribed fire could be compared with historic species lists and baseline data from 1970s to help identify changes in community composition, and dendro-chronological research in the higher elevations forests would also help refine fire management strategies. Establishment of sample plots of sulfate-sensitive vegetation would allow long-term monitoring of the effects of increasing levels of airborne sulfates.

Riparian Areas: Research is required to investigate the impact of exotic fish species on native amphibian populations. An inventory of the vegetation and vertebrate species at seeps and springs throughout the park and measurements of current water levels are also desirable. Comparison of current data with past records may help managers to determine whether any changes in the riparian community structure are correlated with changes in the historic water levels.

Community Dynamics: In higher elevations of the park, a complete inventory of forest species is needed, as well as research to determine relationships between forest composition and species of concern such as the Mexican spotted owl (*Strix occidentalis lucida*). Inventories of vegetation and vertebrates are also need on lands recently acquired by the park and in the northwest quadrant of the park, which is difficult to access. Comparison inventories conducted on adjacent land may help determine the rate of grazing recovery, and how such vegetative recover affects populations of birds and small mammals. Particular attention is to be given to species of concern such as the ferruginous hawk (*Buteo regalis*) and loggerhead shrike (*Lanius ludovicanus*).

Taxa/Species-Specific Research: Park managers are interested in supporting various research projects relating to specific species or taxa, including the following:

An analysis of potential forage in areas deemed appropriate for prairie dog and pronghorn restoration.

An inventory of areas suspected to provide suitable habitat for Montezuma quail (*Cyrtonyx montezumae*) and Merriam's turkey (*Meleagris gallopavo*) to assess the success of past reintroduction projects.

Research on the ecology of exotic Barbary Sheep, in particular, their affect on vegetation composition (particularly at upper elevation seep and spring communities), their role in the dispersal of exotic plant species, and how their impact differs from that of native ungulates.

Re-visitation of established pellet transects to assess current sizes of elk (*Cervus elaphus*) and mule deer (*Odocoileus hemionus*) herds. Additionally, analysis of forage available to native ungulates may help managers determine appropriate herd sizes and management strategies.

Inventory carnivores in front and backcountry areas of the park through the use of bait stations, cameras and hair snares, and identify key habitat components of carnivores such as black bears (*Ursus americanus*), mountain lions (*Puma concolor*), bobcats (*Lynx rufus*), coyotes (*Canis latrans*), and gray fox (*Urocyon cineoargenteus*).

Inventory breeding birds and assess the impact of cowbird parasitism on their reproductive success.

Inventory fall and spring migrant birds to assess which areas are important for forage and shelter during migration.

Analysis of the relationship between winter-resident birds, the distribution of mistletoe in oak woodlands, oak mortality rate, and establishment of receptor fuels for fire in developed zones of the park.

Water Resources: The park in large part receives no significant surface flows from surrounding lands. However, the Salt Basin dune field in the park is hydrologically connected to Basin ground waters.

C.5.3 Threats

- Deposition from atmospheric pollution,
- Runoff and infiltration from park facility areas,
- Runoff from US 62-180 through park,
- Camping area runoff,
- Hiker fecal matter from trail through McKittrick Canyon,
- Possible groundwater changes from water development in the Salt Basin.

C.5.4 Species of special concern

Table C.5.4. Threatened, endangered and species of concern, Guadalupe Mountains National Park.

Type	Scientific name	Common name	Status
Invertebrates	*Cincindela politula petrophila*	Guadalupe Mountains tiger beetle	SOC
Plants	*Aquilegia chrysantha* var. *chaplinei*	Chapline's columbine	GE
	Chaetopappa hersheyi	mat leastdaisy	SOC
	Ericameria nauseosa var. *texensis*	Guadalupe rabbitbrush	SOC
	Escobaria guadalupensis	Guadalupe pincushion cactus	SOC
	Festuca ligulata	Guadalupe fescue	C
	Hedeoma apiculatum	McKittrick pennyroyal	ST
	Hexalectris revoluta	Chisos coral-root	SOC
	Lepidospartum burgessii	gypsum scalebroom	SOC
	Lesquerella valida	scaly bladderpod	GE
	Nama xylopodum	yellowseed nama	GE
	Penstemon cardinalis regalis	cardinal penstemon	GE
	Perityle quinqueflora	five-flowered rock daisy	GE

Appendix C. Overview of Chihuahuan Desert Network Parks, cont.

Type	Scientific name	Common name	Status
	Pinaropappus parvus	dwarf rock lettuce	GE
	Polygala rimulicola var. *rimulicola*	milkwort	GE
	Salvia summa	mountain sage	GE
	Selinocarpus lanceolatus	gypsum monopod	SOC
	Senecio warnockii	Warnock's groundsel	GE
	Sophora gypsophila var. *guadalupensis*	Guadalupe mountain laurel	GE
	Streptanthus sparsiflorus	few-flowered jewelflower	SOC
	Symphoricarpos guadalupensis	McKittrick snowberry	SOC
	Valeriana texana	Texas valerian	GE
	Viola guadalupensis	Guadalupe Mountains violet	SOC
Reptiles	*Phrynosoma cornutum*	Texas horned lizard	ST, SOC
	Phrynosoma hernandesi	Hernandez's short-horned lizard	ST
Mammals	*Thomomys umbrinus guadalupensis*	Guadalupe southern pocket gopher	SOC
	Cynomys ludovicianus	black-tailed prairie dog	SOC*
	Ursus americanus	black bear	ST
Birds	*Asturina nitida*	gray hawk	ST
	Athene cunicularia hypugea	western burrowing owl	SOC
	Buteo regalis	ferruginous hawk	SOC
	Buteo albonotatus	zone-tailed hawk	ST
	Buteogallus anthracinus	common black-hawk	ST
	Cyrtonyx montezumae	Montezuma quail	SOC*
	Falco peregrinus	peregrine falcon	SE
	Lanius ludovicanus	loggerhead shrike	SOC
	Meleagris gallopavo	wild turkey	SOC*
	Strix occidentalis lucida	Mexican spotted owl	FT, ST

FT = Federally Threatened; FE = Federally Endangered; C = Candidate for Federal Listing
SE = State Endangered; SOC = Federal Species of Concern; GE = Guadalupe Mountains endemic species
SOC* = Guadalupe SOC – re-introduction species

C.6 White Sands National Monument (WHSA)

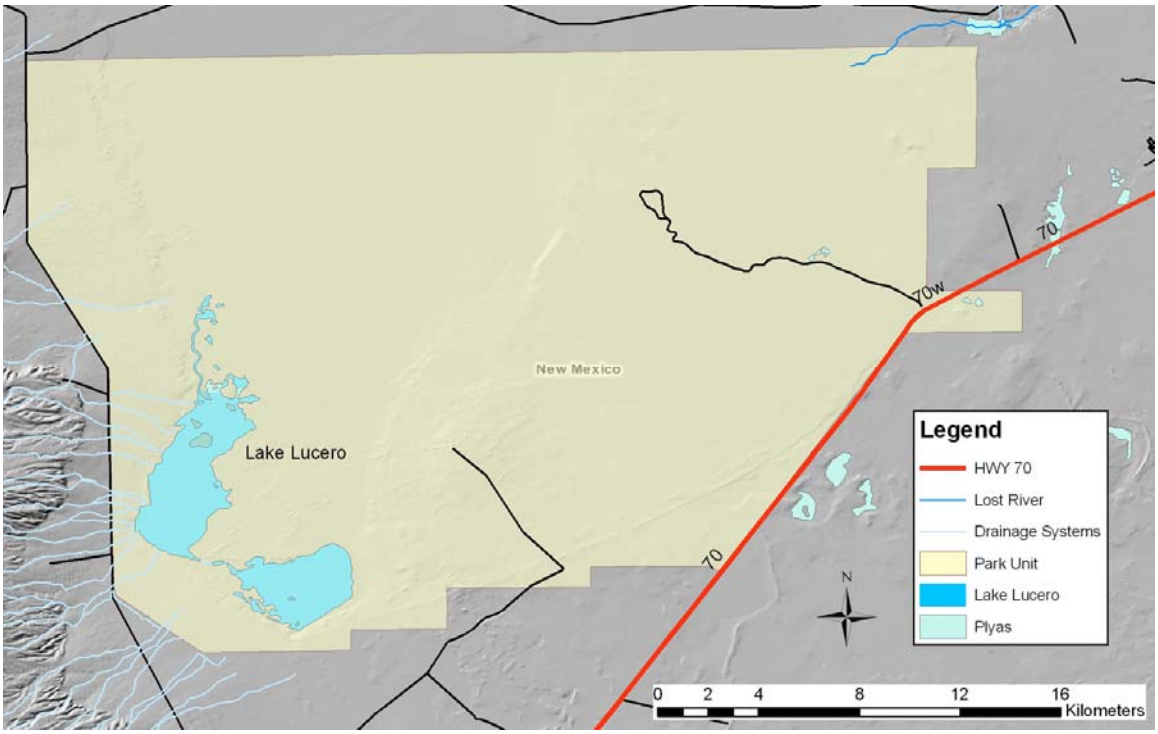


Figure C.4. Map of White Sands National Monument, New Mexico.

C.6.1 General description

Size: 58,191 ha (143,733 ac)

Location: White Sands National Monument (NM) is located in south-central New Mexico, about 24 km (15 miles) southwest of Alamogordo, New Mexico, and 83 km (52 miles) northeast of Las Cruces, New Mexico. The main park entrance and park headquarters are accessible from U.S. Highway 70. White Sands NM is located in Otero and Donna Anna Counties, New Mexico.

Adjacent Lands: White Sands National Monument is surrounded by military land, White Sands Missile Range. Its closest neighbor is Holloman Air Force Base.

Elevation: The elevation within the monument ranges from 1,186 m (3,891 ft) at Lake Lucero to 1,254 m (4,114 ft) in the foothills of the San Andreas Mountains on the west side of the monument. Total elevation change is 68 m (223 ft).

Park History: White Sands National Monument was established in 1933 by President Herbert Hoover, acting under the authority of the "Antiquities Act of 1906". It currently preserves more than half of the world's largest gypsum sand dune field.

Physical Characteristics: The Tularosa Basin extends 240 km (150 miles) north to south, and up to 96 km (60 miles) east to west. The basin represents the easternmost extent of the Basin and Range geologic province. Originally, the San Andres Mountains to the west and the Sacramento Mountains to the east

were connected by the rock that comprises the floor of the Tularosa Basin. Beginning approximately 29 million years ago, pressure from inside the earth caused the crust over the basin to thin and stretch. Simultaneous faulting action caused the mountain ranges to rise as the basin dropped creating the landscape that is seen today.

There are no outlets for the few perennial streams that flow into the Tularosa Basin. The surrounding mountain ranges are drained by ephemeral streams, which primarily flow during periods of heavy precipitation. During cooler, wetter Pleistocene times the western half of the basin contained shallow Lake Otero, which dried up as the climate became more arid. Today, the lowest point of the basin, Lake Lucero, will contain a few in of water only in rare wet seasons. However, the groundwater table lies close to the surface of the Tularosa Basin, creating high levels of humidity. Evaporation results in the formation of calcium sulfate, calcium bicarbonate, calcium magnesium bicarbonate, and sodium chloride deposits throughout the basin. Calcium sulfate (which forms selenite crystals when evaporated) is primarily derived from rainwater dissolving exposed gypsum rich formations exposed on the San Andres Mountains, washing down to the valley floor, evaporating, and re-precipitating the calcium sulfate. Gypsum remains in the basin because of the lack of surface drainage leaving the basin. White Sands NM encompasses a major portion of this dune field; the rest of the field is contained in military land north of the monument.

Gypsum content and mobility of dune soils can limit existence or productivity to plant life. Current inventories show 265 plant species from 51 families (Table C.7-1). The number of species is less than one would expect after accounting for the size of this park unit. Vertebrates in White Sands National Monument include 1 species of fish, 31 species of herps, 38 species of mammals, and 184 species of birds. Some of these species have adapted pale or light phases of coloration.

The climate is arid and subject to rapidly changing weather conditions. The average annual precipitation of approximately 20 centimeters (8 in) falls primarily during summer thunderstorms. Summer temperatures average 35 °C (95 °F). Winter temperatures are typically mild but may drop below -18 °C (0 °F). Snowfall is infrequent but occasionally heavy. The prevailing southwesterly wind is a dominant climatic factor here, especially from March through May, when gale-force windstorms may last for days. This is the time of the greatest dune movement, when living conditions for dune animal and plant communities become extremely harsh.

C.6.2 Resource management concerns

Amphibians: Amphibians are the taxon of greatest concern at White Sands NM. They are the least known and observed of local vertebrates, due to habitat preferences for inaccessible areas and to long periods of seasonal dormancy. Generalized local loss of interdunal wetland ecosystems may be affecting amphibian populations on the monument. Between the 1980s and early 1990s, staff observations indicated drying and loss of isolated wetland areas along the base of the dune field, in inter-dunal valleys, and at an artificial pond (now almost dry). There is no obvious cause of drying, such as prolonged drought or pumping of groundwater outside the monument. Riparian plants, such as cattails (*Typha* spp.) and willows, are still visible in these areas but appear dead and exhibit no signs of re-growth. Loss of mesic vascular plant species due to riparian degradation is also of concern. It is unknown if local amphibian populations are also being affected by any of the variety of factors affecting amphibians elsewhere in the U.S. To the extent made possible by multi-park inventory and monitoring, the NPS should be involved in studying this very vulnerable group of animals.

Lack of Baseline Data: White Sands NM is lacking current baseline information concerning the status of site-specific floral and faunal species. Of particular interest is data relating to the composition, structure, and boundaries of the monument's plant communities, and the presence, distribution, and population trends of amphibians and reptiles (herps), small and medium-sized mammals, and birds. Establishment of

consistent and repeatable inventory and monitoring protocols would allow managers to monitor changes in floral and faunal populations, resulting from natural or man-made environmental effects.

White Sands Pupfish: Prior to 1996, the Lost River, a small perennial stream, flowed into the monument and provided habitat for the White Sands Pupfish. The pupfish is state listed endangered, and is protected by an interagency management team and conservation plan, supported by U.S. Fish and Wildlife Service, New Mexico Department of Game and Fish, Army White Sands Missile Range, Holloman Air Force Base, and White Sands National Monument. Under current conditions, a sand dune 300 m upstream of the monument boundary recently shifted and blocked water of the Lost River from flowing into the monument. This may change in the future, in which case pupfish habitat will again occur in the monument.

Mammal Status Unknown, Extirpation Possible: Porcupines were common and conspicuous in cottonwoods in the housing area and dunefield until 1995, and then precipitously disappeared. Since 1995, no porcupine or sign have been sighted by park staff members. Ringtails were common in and near headquarters buildings in the 1980s. None have been reported since about 1990. Other mammal species may have declined, however baseline data is so sketchy that no change of status is known.

Water Resources: Receives surface and groundwater flows from surrounding lands.

C.6.3 Threats

- Deposition from atmospheric pollution,
- Runoff from surrounding military facilities, including range Road 7,
- Groundwater transport into park from surrounding military facilities,
- Infiltration from park headquarters area facilities,
- A park concern is the ecological impact of possible drop of the water table from basin groundwater resource development.
- Isolated cottonwood stands occur at a number of dune field locations. Their presence implies perennial ground water of rather high quality. Precipitation catching clay lenses or local higher quality, subsurface flows have been suggested as reasons for their persistence. This lack of understanding leads, therefore, to no known threats to these subsurface resources, but it suggests a need for better understanding the matter.

C.6.4 Species of special concern

Table C.6.4. Threatened, endangered and species of concern, White Sands National Monument.

Type	Scientific name	Common name	Status
Plants	*Argemone pleiacantha extimus*	Sacramento prickly poppy	FE
	Coryphantha sneedii sneedii	Sneed pincushion cactus	FE
	Peniocereus greggii	night blooming cereus	SE
	Opuntia arenaria	dune prickly pear	SE
Arachnids	*Cibolancris parviceps arida*	locustid spider	WCS
Insects	*Ammobaenites phrixocnemoides arenicolus*	White Sands camel cricket	WCS
	Daihinoides hastiferum larvale	camel cricket	WCS
Fish	*Cyprinodon tularosa*	White Sands pupfish	ST
Amphibians	*Scaphiopus couchii*	spadefoot toad	WCS

Appendix C. Overview of Chihuahuan Desert Network Parks, cont.

Type	Scientific name	Common name	Status
Reptiles	*Phrynosoma cornutum*	Texas horned lizard	
	Holbrookia maculata ruthveni	bleached earless lizard	WCS
	Sceloporus cowlesi	southwestern fence lizard	WCS
	Aspidoscelis inornata	little striped whiptail	WCS
Mammals	*Neotoma micropus leucophaea*	White Sands woodrat	
	Perognathus flavescens apachii	Apache pocket mouse	WCS
Birds	*Haliaeetus leucocephalus*	bald eagle	FT
	Sterna antillarum	interior least tern	FE
	Falco femoralis septentrionalis	northern Aplomado falcon	FE
	Empidonax trailii extimus	southwestern willow flycatcher	FE
	Athene cunicularia hypugea	western burrowing owl	
	Buteo regalis	ferruginous hawk	
	Charadrius alexandrinus nivosus	western snowy plover (interior)	
	Ammodramus bairdii	Baird's sparrow	
	Childonias niger	black tern	
	Numenius americanus	long-billed curlew	
	Lanius ludovicianus	loggerhead shrike	

WCS=White Colored Species; FT = Federally Threatened; FE = Federally Endangered;
ST = State Threatened; SE = State Endangered

C.7 Network species lists

Table C.7-1. Numbers of plant and vertebrate species (Spp.) and families (Fam.) in the CHDN.

CHDN	Plants		Fish		Amphibians		Reptiles		Mammals*		Birds	
Park Unit	Spp.	Fam.	Spp.	Fam.	Spp.	Fam.	Spp.	Fam.	Spp.	Fam.	Spp.	Fam.
AMIS	701	106	39	15	9	6	40	13	54	23	244	50
BIBE	1,361	114	41	13	12	6	59	15	80	24	412	56
CAVE	942	95	5	4	8	3	43	10	68	19	362	52
FODA	368	74	0	0	5	5	26	9	15	11	119	37
GUMO	1,017	99	3	2	9	4	44	10	68	19	240	47
WHSA	300	51	1	1	7	3	28	7	38	17	184	48

FODA mammal count represents what is likely present; no inventory has been conducted.
Data are from the CHDN park-inventory database (list generated 12 April 2010). Numbers include non-native species listed in Tables C.7-2 and C.7-3.

Table C.7-2. Invasive/non-native plants occurring in CHDN park units. Plants are listed in descending order of growth-forms.

Scientific name	Common name	Park					
		AMIS	BIBE/RIGR	CAVE	FODA	GUMO	WHSA
Trees							
Tamarix spp.	saltcedar	X	X	X			X
Elaeagnus angustifolia	Russian olive			X			
Ulmus pumila	Siberian elm		X	X		X	
Ailanthus altissima	tree of heaven			X			
Populus nigra	Lombardy poplar			X			
Salix X sepulcralis	weeping willow			X			
Vitex agnus-castus	vitex	X					
Melia azederach	China berry	X					
Nicotiana glauca	tobacco tree	X	X				
Morus spp.	mulberry	X	X	X			
Sapium sebiferum	Chinese tallow	X					
Caesalpinia gilliesii	bird of paradise		X			X	
Ficus carica	common fig, edible fig		X				
Malus pumila	Paradise apple			X			
Malus sylbestris	European crabapple			X			
Prunus armeniaca	apricot			X			
Prunus domestica	European plum			X			
Ziziphus mauritiana	Indian jujube				X		
Aquatic-Associated							
Arundo donax	African/Giant reed	X	X				
Hydrilla verticillata	hydrilla	X					
	golden algae (blooms)	X	X				
Forbs							
Peganum harmala	African rue			X		X	X
Acroptilon repens	Russian knapweed						X
Salsola tragus	Russian thistle	X				X	X
Centaurea melitensis	Malta starthistle		X	X	X	X	X
Centaurea solstitialis	yellow starthistle	X					
Verbascum Thapsus	wooly mullein	X		X		X	
Ricinus communis	castor beans	X				X	
Marrubium vulgare	white horehound	X	X	X	X	X	
Onopordum acanthium	Scotch thistle			X			

Appendix C. Overview of Chihuahuan Desert Network Parks, cont.

Scientific name	Common name	Park					
		AMIS	BIBE/RIGR	CAVE	FODA	GUMO	WHSA
Kochia scoparia	kochia			X		X	
Convolvulus arvensis	bindweed	X		X		X	
Sisymbrium altissimum	tumble mustard			X			
Sisymbrium irio	London rocket	X	X	X	X	X	X
Amaranthus albus	amaranth (pigweed)					X	X
Ambrosia spp.	common ragweed						X
Lactuca serriola	prickly lettuce	X		X			
Tribulus terrestris	puncturevine (goathead)		X	X	X	X	
Lamium amplexicaule	common henbit deadnettle			X			
Mentha spicata	spearmint		X	X		X	
Erodium cicutarium	filaree (Crane's bill)	X		X	X	X	
Melilotus albus	white sweetclover		X	X		X	
Meliotus indicus	yellow sweetclover	X	X	X			
Rorippa nasturtium-aquaticum	watercress			X		X	
Plantago major	broadleaf plantain			X		X	
Ciclospermum leptophyllum	marsh parsley	X					
Torilis arvensis	hedge parsley	X					
Carduus tenuiflorus	plumeless thistle	X					
Pseudognaphalium luteoalbum	winged cudweed	X					
Sonchus oleraceus	sow thistle	X	X	X		X	
Medicago arabica	spotted burclover	X					
Anagallis arvensis	pimpernel	X					
Calibrachoa parviflora	seaside petunia	X					
Daturia inoxia	pricklyburr	X					
Asparagus officinalis	asparagus		X	X			
Cerastium glomeratum	sticky chickweed		X				
Chenopodium album	lambsquarters		X		X		
Chenopodium ambrosioides	Mexican tea		X				
Chenopodium murale	nettle-leaf goosefoot		X				
Ciclospermum leptophyllum	fir-leaved celery		X				
Corispermum nitidum	neat bug seed		X			X	
Eruca sativa	arrugula, rocket		X				
Medicago polymorpha	toothed bur-clover		X				
Medicago sativa	alfalfa		X			X	
Melilotus officinalis	yellow sweet-clover		X			X	
Nerium oleander	oleander		X				
Parkinsonia aculeata	Jerusalem thorn		X				

Appendix C. Overview of Chihuahuan Desert Network Parks, cont.

Scientific name	Common name	Park					
		AMIS	BIBE/RIGR	CAVE	FODA	GUMO	WHSA
Petunia parviflora	wild petunia		X				
Physalis philadelphica	Mexican groundcherry		X				
Polygonum convolvulus	climbing buckwheat		X				
Polygonum lapathifolium	curlytop knotweed		X				
Rumex crispus	narrowleaf dock				X		
Salsola kali	Russian thistle		X	X			X
Solanum sisymbriifolium	sticky nightshade		X				
Sonchus asper	prickly sowthistle		X	X		X	
Sanvitalia procumbens	Mexican creeping zinnia		X				
Taraxacum officinale	dandelion			X	X	X	
Descurainia sophia	tansymustard			X		X	
Thlaspi arvense	field pennycress			X			
Portulaca oleracea	purslane			X			
Euphorbia davidii	David's spurge			X			
Medicago lupulina	black medic clover			X		X	
Oxalis corniculata	creeping oxalis			X			
Verbena hastata	blue verbena, vervain			X			
Plantago lanceolata	lanceleaf plaintain			X		X	
Tragopogon dubius	salsify, goat's beard				X	X	
Medicago minima	burr-clover				X		
Ipomoea purpurea	morning glory				X		
Diplotaxis tenuifolia	slimleaf wallrocket						X
Bassia hyssopifolia	smotherweed						X
Linaria dalmatica	dalmatian toadflax						X
Ammi visnaga	bishop's seed					X	
Apium graveolens	wild celery					X	
Salsola collina	spineless Russian thistle					X	
Silene gallica	forked catchfly					X	
Tragopogon porrifolius	oyster-root					X	
Xanthium spinosum	spiny cocklebur					X	
Pennisetum ciliare	buffelgrass	X	X				
Eragrostis lehmanniana	Lehman's love grass	X	X	X			
Sorghum halapense	Johnsongrass	X	X	X	X	X	
Bothriochloa ischaemum	King Ranch bluestem	X	X				
Cynodon dactylon	Bermuda grass	X	X	X	X	X	
Panicum coloratum	kleingrass			X			
	sandbur			X		X	

Appendix C. Overview of Chihuahuan Desert Network Parks, cont.

Scientific name	Common name	Park					
		AMIS	BIBE/RIGR	CAVE	FODA	GUMO	WHSA
Digitaria sangiunalis	crabgrass			X	X		
Avena fatua	wild oat	X		X		X	
Bromus catharticus	rescuegrass	X		X		X	
Bromus japonicus	Japanese brome			X		X	
Bromus rubens	red brome			X			
Echinochloa crus-galli	barnyard grass		X	X	X	X	
Eleusine indica	goosegrass			X			
Eragrostis cilianensis	stinkgrass	X	X	X		X	
Poa annua	annual bluegrass			X		X	
Polypogon spp.	rabbitfoot grass	X	X	X		X	
Dichanthium annulatum	Kleberg bluestem	X					
Echinochloa colona	jungle rice grass	X	X	X			
Eragrostis barrelieri	Mediterranean lovegrass	X	X	X			
Hemarthria altissima	African jointgrass	X	X			X	
Lolium perenne	perennial rye grass	X					
Panicum antidotale	blue panic grass	X	X				
Paspalum dilatatum	Dallas grass	X	X			X	
Paspalum urvillei	vasey grass	X					
Setaria pumila	yellow bristlegrass	X			X		
Polygonum persicaria	lady's thumb	X	X				
Chloris virgata	feather finger grass	X					X
Agrostis semiverticillata	bentgrass, waterbent		X				
Agrostis stolonifera	creeping bentgrass		X				
Bromus tectorum	cheat grass		X			X	
Carex planostachys	cedar sedge		X				
Cyperus esculentus	chufa, yellow nutgrass		X				
Digitaria ciliaris	southern crabgrass		X				
Digitaria sanguinalis	large crabgrass		X				
Juncus bufonius	toad rush		X				
Oplismenus hirtellus	bristle basketgrass		X				
Panicum lanuginosum	panic grass		X				
Setaria adhaerens	burr bristlegrass		X				
Setaria viridis	bottle grass, green foxtail		X			X	
Sorghum bicolor	broomcorn, sorghum		X				
Tragus berteronianus	spiked burr grass		X			X	
Hordeum marinum	seaside barley			X			
Pennisetum glauca	yellow foxtail				X		

Appendix C. Overview of Chihuahuan Desert Network Parks, cont.

Scientific name	Common name	Park					
		AMIS	BIBE/RIGR	CAVE	FODA	GUMO	WHSA
Eragrostis pectinacea	spreading lovegrass					X	
Panicum miliaceum	broomcorn millet						
Pseudoroegneria spicata	bluebunch wheatgrass					X	
Pennisetum glaucum	yellow bristlegrass					X	
Triticum aestivum	wheat					X	

Table C.7-3. Invasive/non-native animals occurring in CHDN park units.

Scientific name	Common name	Park					
		AMIS	BIBE/RIGR	CAVE	FODA	GUMO	WHSA
Mammals							
Ovis aries	Mouflon sheep				X		
Ammotragus lervia	Barbary (Aoudad) sheep	X	X	X	X	X	
Oryx leucoryx	oryx (gemsbock)						X
Myocastor coypus	Nutria	X	X				
Sciurus niger	Eastern foxtail squirrel			X			
Cervus canadensis	wapiti elk		X	X		X	
Felis catus	feral house cats	X		X			
Sus scrofa	feral hogs	X	X			X	
Mus musculus	house mouse	X					
	trespass livestock	X	X	X	X	X	
Birds							
Sturnus vulgaris	European starling	X	X	X	X		X
Passer domesticus	house sparrow	X	X	X	X	X	X
Phasianus colchicus	common pheasant			X			
Columba livia	rock dove (pigeon)	X	X	X		X	X
Streptopelia decaocto	Eurasian collared-dove	X	X	X	X	X	X
Amphibians/Reptiles							
Trachemys scripta elegans	red-eared slider	X	X				
Rana catesbeiana	bullfrog		X	X		X	
Gopherus berlandieri	Berlandier's tortoise		X				
Hyla cinerea	green tree frog		X				
Anolis carolinensis	green anole		X				
Hemidactylus turcicus	Mediterranean gecko	X	X				
Fish							
Oncorhynchus mykiss	rainbow trout					X	
Lepomis cyanellus	green sunfish			X		X	
Lepomis auritus	redbreast sunfish	X				X	
Micropterus dolomieu	smallmouth bass	X					
Morone chrysops	white bass	X	X				
Morone saxatilis	striped bass	X					

Menidia beryllina	inland silverside		X		
Dorosoma petenense	threadfin shad		X		
Cyprinella venusta	blacktail shiner		X		
Fundulus zebrinus	Plains killifish		X		
Oreochromis aureus	blue tilapia	X	X		
Lepomis microlophus	redear sunfish	X	X		
Cyprinus carpio	common carp	X	X		
Gambusia affinis	mosquitofish			X	
Micropterus salmoides	large-mouth bass			X	
Invertebrates					
Corbicula fluminea	Asian clam	X	X		
Solenopsis invicta	imported red fire ants	X	X		
Apis mellifera	Africanized honey bees	X	X	X	X
Apis spp.	European honey bees			X	

C.8 Literature Cited

Dinerstein E., D. Olson, J. Atchley, C. Loucks, S. Contreras-Balderas, R. Abell, E. Indigo, E. Enkerlin, C. E. William, and G. Castelleja. 2000. Ecoregion-based conservation in the Chihuahuan Desert: A biological assessment. World Wildlife Fund, Washington D.C. http://www.worldwildlife.org/what/wherewework/chihuahuandesert/WWFBinaryitem2757.pdf. Last accessed February 18, 2010.

Appendix D. Habitats and Vegetation Communities

Plants and their assemblages form the foundation level of function in terrestrial ecosystems. Accordingly, one can understand a great deal about the nature of resources in a given region or subregion by knowing the types and members of plant assemblages. The types of plants found in an area will be the consequence of many biotic and abiotic factors, such as climate, geology, soil conditions, historical plant distributions, and competition among species. In addition, the types and names for plant assemblages often vary by objectives and procedures of a classification system, and the interpretations of those producing the classifications. In this appendix, we repeat a classification of terrestrial plant assemblages for the Chihuahuan Desert Ecoregion offered by Dinerstein et al. (2000) and used by Pronatura Noreste et al. (2004) for planning a conservation strategy of this ecoregion. This classification system uses the 'Habitat Type' as the primary category for describing a common assemblage of plants occurring in this ecoregion. The habitat types were also delineated to emphasize identification of areas that may support high diversity of biota. In addition, Wood et al. (1999), Dick-Peddie (1993), Brown (1994), and NMDGF (2005) were used to describe the habitat types listed here. The Dinerstein et al. (2000) classification system was referenced here because it provided a standard description of plant resources for the Chihuahuan Desert that was developed to aid conservation of biodiversity. Other classifications of plant communities found in the Chihuahuan Desert Network include (Brown 1994; NRCS 1997; Brown et al. 1998; Barbour and Billings 2000). These other classification systems have been standardized for larger geographic units, such as North America, United States, or the American Southwest and may provide better surrogates for understanding terrestrial plant production or community ecology.

D.1 Desert Scrub and Woodlands

D.1.1 Larrea desert scrub

The Creosotebush Alliance is widely distributed throughout the Chihuahuan Desert. There are numerous associations with this habitat type (Muldavin et al. 2000). Since most of the park units within the network have not have detailed vegetation mapping, only a broad description will be provided. This alliance is most commonly found on gravelly alluvial fans. However, it also extends onto the fine-soiled, alluvial plains of basin bottoms, onto surrounding foothill slopes, and into the uplands via drainages. No particular aspects are dominant and slopes tend to be gentle to moderate. In the last 150 years there has been an expansion of creosotebush on shallow, sandy and gravelly calcareous soils, as well as, fine silty and clayey soils on alluvial flats and plains (Buffington and Herbel 1965, Stein and Ludwig 1979). Some of this expansion may be due to removal of grass vegetation. Removal of grass opens up non-competitive microsites where creosotebush seedlings can become established (Montana et al. 1995). The mature shrubs exploit subsurface water sources, so they do not compete with grasses, but changes in soil characteristics that accompany the removal of grasses may gradually exclude grasses in some areas (Schlesinger et al. 1990). There is evidence, however, that creosotebush inhibits its own and other shrub species' roots, which may provide an additional competitive advantage to the creosotebush during the early growing stages (Marshall and Callaway 1991). Areas dominated by creosotebush have increased by about 2000% since 1858 (Buffington and Herbel 1965). As creosotebush is extremely poor forage for both wildlife and livestock, this increase has probably had substantial negative impacts on wildlife and range condition (Stubbendieck et al. 1992). Long-term disturbances that remove vegetation and change soil characteristics will promote shrub dominance. *Larrea* desert scrub is found in all of the CHDN parks, except Amistad NRA.

D.1.2 Mixed desert scrub

This is another habitat type which covers a number of alliances.

Chihuahuan Desert Scrubland:

Chihuahuan Succulent Desert Scrub –

This ecological system is found in the Chihuahuan Desert on colluvial slopes, upper bajadas, sideslopes, ridges, canyons, hills and mesas. Sites are hot and dry. Gravel and rock are often abundant on the ground surface. The vegetation is characterized by the relatively high cover of succulent species such as *Agave lechuguilla, Euphorbia antisyphilitica, Fouquieria splendens, Ferocactus* spp., *Opuntia engelmannii, Opuntia imbricata, Opuntia spinosior, Yucca baccata,* and many others. Perennial grass cover is generally low. The abundance of succulents is diagnostic of this desert scrub system, but desert shrubs are usually present. This system does not include desert grasslands or shrub-steppe with a strong cacti component.

Chihuahuan Mixed Desert and Thorn Scrub –

This is a widespread Chihuahuan Desert land cover type. This cover type includes the mixed desert scrub in the foothill transition zone above, sometimes extending up to the lower montane woodlands. Vegetation is mixed with thornscrub and other desert scrub such as *Agave lechuguilla, Aloysia wrightii, Fouquieria splendens, Dasylirion leiophyllum, Flourensia cernua, Leucophyllum minus, Mimosa aculeaticarpa var. biuncifera, Mortonia scabrella, Opuntia engelmannii, Parthenium incanum, Prosopis glandulosa, and Tiquilia greggii*. Stands of *Acacia constricta, Acacia neovernicosa or Acacia greggii* dominated thornscrub are included in this system, and limestone substrates appear important for at least these species. Grasses such as *Dasyochloa pulchella, Bouteloua curtipendula, Bouteloua eriopoda, Bouteloua ramosa, Muhlenbergia porteri* and *Pleuraphis mutica* may be common, but generally have lower cover than shrubs.

Tamaulipan Thornscrub Alliances:

A mixture of these two alliances are found within Amistad NRA.

South Texas Plains Scrubland -

The South Texas Plains brushland consists of woody plants mostly less than nine ft tall which are dominant and grow as closely spaced individuals, clusters or closed canopied stands (greater than 10% canopy cover). Typically there are continuous, impenetrable shrubs covering over 75% of the ground (McMahan et al. 1984). This scrubland is also known as the *ceniza-blackbrush-creosote* association which is normally found on the slopes of the Rio Grande basin, Stockton Plateau and South Texas plains which occur from Val Verde County, in the city of Langtry, to Zapata County near San Ygnacio (McMahan et al. 1984, Diamond 1993). This community typically grows on shallow soils (Diamond 1993). Commonly associated plants include guajillo, lotebush, mesquite, guayacan, Texas prickly pear, paloverde, goatbush, yucca, sotol, desert yaupon, catclaw acacia, kidneywood, allthorn, curly mesquite, Texas grama, hairy tridens, slim tridens, pink pappusgrass and two-leaved senna (McMahan et al. 1984). This community is common and widespread.

Edward's Plateau Scrubland -

Within the Edwards Plateau Ecoregion, this association is found along the Rio Grande Valley to each side of the Pecos and Devil's rivers. This community typically grows on shallow soils (Diamond 1993). Commonly associated plants include guajillo, lotebush, mesquite, guayacan, Texas prickly pear, paloverde, goatbush, yucca, sotol, desert yaupon, catclaw acacia, kidneywood, jessamine, curly mesquite, Texas grama, hairy tridens, slim tridens, pink pappusgrass and two-leaved senna (McMahan et al. 1984).

D.1.3 Yucca woodland

Commonly associated plants include catclaw acacia, whitethorn acacia, sotol, cholla cactus, Torrey yucca, palmella, brickellbush, mesquite, javelina bush, beargrass, black grama, chino grama, fluffgrass, broom snakeweed and jimmyweed (McMahan et al. 1984). This association prefers soils which are shallow and rocky, occurring at elevations below 4,500 ft. On sandy soils at lower elevations, the lower layers are dominated by grasses. The primary grasses associated with these yucca woodlands are black or blue grama (*Bouteloua eriopoda, B. gracilis*), galleta (*Hilaria jamesii*), and mesa dropseed (*Sporobolus flexuosus*). This habitat can be found around Carlsbad Caverns NP and north of White Sands NM.

D.1.4 Izotal (Dasylirion-Yucca-Agave)

Sotol (*Dasylirion leiophyllum*) or yucca species (*Yucca thompsoniana, Y. faxonia, Y. elata*) are the most common dominants with skeletonleaf goldeneye (*Viguiera stenoloba*) occurring in the understory. Lechuguilla (*Agave lechuguilla*) may also be very prevalent, and may co-dominant on some sites. This system is common in mid-elevations at Carlsbad Caverns NP. The grass layer typically consists of sideoats or black grama (*Bouteloua curtipendula, B. eriopoda*), but purple and sixweeks threeawns (*Aristida purpurea, A. adscensionis*) dominant in grazed areas.

D.1.5 Mesquite scrub

Chihuahuan Mesquite Upland Scrub

This ecological system occurs as upland shrublands that are concentrated in the extensive grassland-shrubland transition in foothills and piedmont in the Chihuahuan Desert. It extends into the Sky Island region to the west and the Edwards Plateau to the east. Substrates are typically derived from alluvium, often gravelly without a well-developed argillic or calcic soil horizon that would limit infiltration and storage of winter precipitation in deeper soil layers. *Prosopis* spp. and other deeprooted shrubs exploit this deep soil moisture that is unavailable to grasses and cacti. Vegetation is typically dominated by *Prosopis glandulosa* or *Prosopis velutina* and succulents. Other desert scrub that may codominate or dominate includes *Acacia neovernicosa, Acacia constricta, Juniperus monosperma,* or *Juniperus coahuilensis*. Grass cover is typically low. During the last century, the area occupied by this system has increased through conversion of desert grasslands as a result of drought, overgrazing by livestock, and/or decreases in fire frequency. It is similar to Chihuahuan Mixed Desert and Thorn Scrub, but is generally found at higher elevations where *Larrea tridentata* and other desert scrub are not codominant.

D.1.6 Gypsophilous scrub (also known as Chihuahuan Mixed Salt Desert Scrub)

This system includes extensive open-canopied shrublands of typically saline basins in the Chihuahuan Desert. Stands often occur on alluvial flats and around playas. This habitat type occurs on White Sands NM, and Guadalupe Mountains NP. Substrates are generally fine-textured, saline soils. Vegetation is typically composed of one or more *Atriplex* species such as *Atriplex canescens, Atriplex obovata*, or *Atriplex polycarpa* along with species of *Allenrolfea, Flourensia, Salicornia, Suaeda*, or other halophytic plants. Graminoid species may include *Sporobolus airoides, Pleuraphis mutica*, or *Distichlis spicata* at varying densities.

D.1.7 Lowland riparian woodland

This habitat is described for arroyos and for areas adjacent to perennial streams throughout the Chihuahuan Desert.

Desert Wash/Riparian Woodland and Shrubland -

This ecological system occurs in intermittent washes or arroyos that dissect bajadas, mesas, and plains of the Chihuahuan Desert. This habitat type occurs as linear or braided strips within desert vegetation matrix in all of the parks in CHDN. This is not common in Amistad NRA. The vegetation can be quite variable ranging from sparse to moderately dense often on the banks, but can occur within the steam channel. Species that are dominant in this system include catclaw acacia (*Acacia greggii*), cut-leaf brickellia (*Brickellia laciniata*), desert broom (*Baccharis sarothroides*), desert willow (*Chilopsis linearis)*, Apache plume, burro brush (*Hymenoclea monogyra* and *H. salsola*), mesquite, littleleaf sumac (*Rhus microphylla*), and greasewood (NatureServe 2006).

Desert Riparian Woodland and Shrubland –

This ecological system consists of low elevation (<1200 m) riparian corridors along medium to large perennial streams throughout canyons and the desert valleys of the southwestern United States and adjacent Mexico. The vegetation is a mix of riparian woodlands and shrublands. Dominant trees include *Acer negundo, Fraxinus velutina, Populus fremontii, Salix gooddingii, Salix lasiolepis, Celtis laevigata var. reticulata*, and *Juglans major*. Shrub dominants include *Salix geyeriana, Shepherdia argentea*, and *Salix exigua*. Vegetation is dependent upon annual or periodic flooding and associated sediment scour and/or annual rise in the water table for growth and reproduction. This feature is restricted to the few perennial water ways in the CHDN parks (e.g., Rio Grande through Big Bend NP, Rio Grande WSR, portions of Amistad NRA, Choza Springs in Guadalupe Mountains NP).

Desert Riparian Mesquite Bosque –

This ecological system consists of low-elevation (<1100 m) riparian corridors along intermittent streams in valleys of southern Arizona and New Mexico, and adjacent Mexico. Dominant trees include *Prosopis glandulosa* and *Prosopis velutina*. Shrub dominants include *Baccharis salicifolia, Pluchea sericea*, and *Salix exigua*. Vegetation, especially the mesquites, tap groundwater below the streambed when surface flows stop. Vegetation is dependent upon annual rise in the water table for growth and reproduction. True Mesquite Bosque in not common in CHDN parks.

D.1.8 Playa

This ecological system is comprised of barren to sparsely vegetated playas (generally <10% plant cover) found throughout the intermountain west and into northern portions of the Trans-Pecos region. Playas form with intermittent flooding, followed by evaporation, leaving behind a saline residue. Salt crusts are common throughout, with small saltgrass beds in depressions and sparse shrubs around the margins. The water is prevented from percolating through the soil by an impermeable layer of clay or caliche and is left to evaporate. Soil salinity varies greatly with soil moisture and greatly affects species composition. Large desert playas tend to be defined by vegetation rings formed in response to salinity. Given their common location in wind-swept desert basins, dune fields often form downwind of large playas. The largest continuous playa in the CHDN is Lake Lucero, origin of the famed gypsum dunefields at White Sands NM. In turn, playas associated with dunes often have a deeper water supply. Species may include iodinebush (*Allenrolfea occidentalis*), lemmon's alkali grass (*Puccinellia lemmonii*), *Suaeda* spp., inland saltgrass (*Distichlis spicata, D. stricts*), *Eleocharis palustris, Oryzopsis spp., Sporobolus spp., Tiquilia* spp., or saltbush (*Atriplex* spp.). Ephemeral herbaceous species may have high cover periodically.

Adjacent vegetation is typically Chihuahuan Mixed Salt Desert Scrub or Chihuahuan Creosotebush Basin Desert Scrub. Playas can also be found in the western portion of Guadalupe Mountains NP.

D.2 Grasslands

D.2.1 Grama Grassland

Chihuahuan Piedmont Semi-Desert Grassland –

This ecological system is a broadly defined desert grassland, mixed shrub-succulent or xeromorphic tree savanna that is typical of the Borderlands of Arizona, New Mexico and northern Mexico [Apacherian region], but extends west to the Sonoran Desert, north into the Mogollon Rim and throughout much of the Chihuahuan Desert. It is found on gently sloping bajadas that supported frequent fire throughout the Sky Islands and on mesas and steeper piedmont and foothill slopes in the Chihuahuan Desert. It is characterized by typically diverse perennial grasses. Common grass species include *Bouteloua eriopoda, Bouteloua hirsuta, Bouteloua rothrockii, Bouteloua curtipendula, Bouteloua gracilis, Eragrostis intermedia, Muhlenbergia porteri, Muhlenbergia setifolia, Pleuraphis jamesii, Pleuraphis mutica, and Sporobolus airoides*, succulent species of *Agave, Dasylirion*, and *Yucca*, and tall-shrub/shorttree species of *Prosopis* and various oaks (e.g., *Quercus grisea, Quercus emoryi, Quercus arizonica*). Many of the historical desert grassland and savanna areas have been converted, some to Chihuahuan Mesquite Upland Scrub (*Prosopis* spp.-dominated), through intensive grazing and other land uses.

D.2.2 Sacaton grassland

Chihuahuan Sandy Plains Semi-Desert Grassland –

This ecological system occurs across the Chihuahuan Desert and extends into the southern Great Plains where soils have a high sand content. These dry grasslands or steppe are found on sandy plains and sandstone mesas. The graminoid layer is dominated or codominated by *Achnatherum hymenoides, Bouteloua eriopoda, Bouteloua hirsuta, Hesperostipa neomexicana, Pleuraphis jamesii, Sporobolus cryptandrus, Sporobolus airoides*, or *Sporobolus flexuosus*. Typically, there are found scattered desert shrubs and stem succulents such as *Ephedra torreyana, E. trifurca, Fallugia paradoxa, Prosopis glandulosa, Yucca elata*, and *Y. torreyi* that are characteristic of the Chihuahuan Desert.

D.2.3 Tobosa grassland

There are two common associations described within the Tobosa grassland alliance.

Chihuahuan-Sonoran Desert Bottomland and Swale Grassland –

This ecological system occurs throughout the northern Chihuahuan Desert (e.g., White Sands Missile Range, and Otero Mesa in the Tularosa Basin of south-central New Mexico, Sky Islands of southeastern Arizona and Sonoran Desert), as well as limited areas of the southern Great Plains and Edwards Plateau in relatively small depressions on broad mesas, plains and valley bottoms that receive runoff from adjacent areas. Water generally infiltrates relatively quickly. These depressions have deep, fine-textured soils that are neutral to slightly saline/alkaline. Vegetation is typically dominated by *Pleuraphis mutica* (tobosa swales) or other mesic graminoids such as *Pascopyrum smithii, Panicum obtusum, Sporobolus airoides,* or *Sporobolus wrightii*. With tobosa swales, sand-adapted species such as *Yucca elata* may grow at the swale's edge in the deep sandy alluvium that is deposited there from upland slopes. *Sporobolus airoides* and *Sporobolus wrightii* are more common in alkaline soils typically found around White Sands NM.

Tobosa-black grama association -

This grass system is found principally in low elevation plains of Jeff Davis, Presidio, Brewster, Culberson and Hudspeth counties (McMahan et al. 1984) where Big Bend NP is located. It typically occurs in heavy igneous soils and also on flat limestone areas that sometimes receive excessive runoff from the surrounding areas. This explains why these grasslands are represented within small, internally drained basin bottoms (Diamond 1993). Commonly associated plants found in this subclass consist of blue grama, sideoats grama, chino grama, hairy grama, burrograss, bush muhly, Arizona cottontop, javelina bush, creosote, butterfly bush, palmella, whitethorn acacia, cholla cactus, broom snakeweed and rough menodora (McMahan et al. 1984). The *Tobosa-black grama* community has been invaded by desert shrubs and are now compacted because of over-grazing.

D.2.4 Gypsum grassland

Chihuahuan Gypsophilous Grassland and Steppe –

This ecological system is restricted to gypsum outcrops or sandy gypsiferous and/or often alkaline soils that occur in basins and slopes in the Chihuahuan Desert. Elevation range is from 1100-2000 m. These typically sparse grasslands, steppes or dwarf-shrublands are dominated by a variety of gypsophilous plants, many of which are endemic to these habitats (Dick-Peddie 1993). Characteristic species include *Tiquilia hispidissima, Atriplex canescens, Calylophus hartwegii, Ephedra torreyana, Frankenia jamesii, Bouteloua breviseta, Mentzelia perennis, Nama carnosum, Calylophus hartwegii (=Oenothera hartwegii), Selinocarpus lanceolatus, Sporobolus nealleyi, Sporobolus iroides*, and *Sartwellia flaveriae*. This habitat is common on White Sands NM and is found in a small component at Guadalupe Mountains National Park.

D.2.5 Lowland riparian marshland

This ecological system occurs throughout the arid and semi-arid regions of New Mexico, and is a rare association among the parks in the CHDN, but is found around Rattlesnake Springs in Carlsbad Caverns NP. Soils have anaerobic characteristics and plants that occur are adapted to saturated soil conditions. Common plants to these small wetlands include such species as spikerush (*Eleocharis palustris*), rush (*Juncus* spp.), pondweed (*Potamogeton* spp.), bulrush or sedges(*Scirpus* spp.), broadleaf cattail (*Typha latifolia*), inland saltgrass (*Distichlis spicata*) and reed (*Phalaris* spp.) (NatureServe 2006). Saltcedar (*Tamarisk* spp.) is a common invader.

D.3 Montane Chaparral and Montane Woodlands

D.3.1 Montane chaparral

Coahuilan Chaparral - This ecological system occurs in mountains across southeastern New Mexico (Guadalupe Mountains) and Trans-Pecos Texas (Chisos Mountains in Big Bend NP). It often dominants along the mid-elevation transition from the Chihuahuan Desert into mountains (1700-2500 m). It occurs on foothills, mountain slopes and canyons in drier habitats below the encinal and pine woodlands and is often associated with more xeric and coarse-textured substrates such as limestone, basalt or alluvium, especially in transition areas with more mesic woodlands. The moderate to dense shrub canopy includes many shrub oak species such as *Quercus intricata, Quercus pringlei, Quercus invaginata, Quercus laceyi, Quercus grisea, Quercus emoryi, Quercus toumeyi*, several widespread chaparral species such as *Arctostaphylos pungens, Ceanothus greggii, Fallugia paradoxa*, and *Garrya wrightii*, and species characteristic of this system such as *Arbutus arizonica, Arbutus xalapensis, Fraxinus greggii, Fendlera rigida, Garrya ovata, Purshia mexicana, Rhus virens var. choriophylla*, and endemics *Salvia lycioides, Salvia roemeriana*, and *Salvia regla*. Most chaparral species are fire-adapted, resprouting vigorously after

burning or producing fire-resistant seeds. Stands occurring within montane woodlands are seral and a result of recent fires. This habitat is also common in Carlsbad Caverns NP.

D.3.2 Juniper-pinyon woodland

Southern Rocky Mountain Juniper Woodland and Savanna –

This ecological system occupies the lower and warmest elevations, growing from 1370 to 1830 m in a semi-arid climate, primarily along the east and south slopes of the southern Rockies and Arizona-New Mexico mountains. It is best represented just below the lower elevational range of ponderosa pine and often intermingles with grasslands and shrublands (Dick-Peddie 1993). This system is best described as a savanna that has widely spaced, mature (>150 years old) juniper trees and occasionally *Pinus edulis. Juniperus monosperma* and *Juniperus scopulorum* (at higher elevations) are the dominant tall shrubs or short trees. These savannas may have inclusions of denser juniper woodlands and have expanded into adjacent grasslands during the last century. Graminoid species are similar to those found in Western Great Plains Shortgrass Prairie, with *Bouteloua gracilis* and *Pleuraphis jamesii* being most common. In addition, succulents such as species of *Yucca* and *Opuntia* are typically present. This habitat is more common in Carlsbad Caverns NP and Guadalupe Mountains NP.

Madrean Pinyon-Juniper Woodland –

This system occurs on foothills, mountains and plateaus in the Sierra Madre Occidentale and Sierra Madre Orientale in Mexico, Trans-Pecos Texas, southern New Mexico and Arizona, generally south of the Mogollon Rim. Substrates are variable, but soils are generally dry and rocky. The presence of *Pinus cembroides, Pinus discolor*, or other Madrean trees and shrubs is diagnostic of this woodland system. *Juniperus coahuilensis, Juniperus deppeana, Juniperus pinchotii, Juniperus monosperma*, and/or *Pinus edulis* may be present to dominant. Madrean oaks such as *Quercus arizonica, Quercus emoryi, Quercus grisea,* or *Quercus mohriana* may be codominant. *Pinus ponderosa* is absent or sparse. If present, understory layers are variable and may be dominated by shrubs or graminoids. This habitat occurs on Fort Davis NHS and in Big Bend NP.

D.3.3 Pine-oak woodland

This association of gray oak-pinyon pine-alligator juniper is typically found in sheltered canyons, at cliff bases and north-facing slopes occurring in mid-elevations from 1500-2300 m (4,500 to 7,500 ft.). Typically this community is found in the major mountain ranges such as the Davis (near Fort Davis NHS), Guadalupe (Guadalupe Mountains NP) and Chisos Mountain (Big Bend NP) ranges (McMahan et al. 1984, Diamond 1993, Bezanson 2000). Fires are frequent with perhaps more crown fires than ponderosa pine woodlands, which tend to have more frequent ground fires on gentle slopes. This association is mostly evergreen and typically found in alluvial soils in mountain valleys. Deciduous gray oak-oak series also occur in these areas but are restricted to the bottomlands of mesic mountain canyons. Many of the associated plants are very distinctive and restricted to this plant association alone (Diamond 1993). These plants include Emory oak, silverleaf oak, Gambel's oak, mountain mahogany, evergreen sumac, mountain snowberry, Texas madrone, southwestern chokecherry, bullgrass, Pringle needlegrass, finestem needlegrass, pine dropseed, sideoats grama, blue grama, pine muhly, pinyon ricegrass, largeleaf oxalis, heartleaf groundcherry and Torrey antherium (McMahan et al. 1984). The *gray oak-pinyon pine-alligator juniper* is fairly common throughout the southwestern United States. However, within the CHDN, this community only occurs in a few isolated mountain ranges within the Trans-Pecos making it fairly rare, and therefore, existing habitats should probably be monitored.

D.3.4 Mixed-conifer forest

The following two forests types, primarily occur in Guadalupe NP.

Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest and Woodland –

This is a highly variable ecological system of the montane zone of the Rocky Mountains. It occurs throughout the southern Rockies, north and west into Utah, Nevada, western Wyoming and Idaho. These are mixed-conifer forests occurring on all aspects at elevations ranging from 1200 to 3300 m. Rainfall averages less than 75 cm per year with summer "monsoons" during the growing season contributing substantial moisture. The composition and structure of overstory is dependent upon the temperature and moisture relationships of the site, and the successional status of the occurrence. *Pseudotsuga menziesii* and *Abies concolor* are most frequent, but *Pinus ponderosa* may be present to codominant. *Pseudotsuga menziesii* forests occupy drier sites, and *Pinus ponderosa* is a common codominant. *Abies concolor*-dominated forests occupy cooler sites, such as upper slopes at higher elevations, canyon sideslopes, ridgetops, and north- and east-facing slopes which burn somewhat infrequently. *Picea pungens* is most often found in cool, moist locations, often occurring as smaller patches within a matrix of other associations. As many as seven conifers can be found growing in the same occurrence, and there are a number of cold-deciduous shrub and graminoid species common, including *Arctostaphylos uva-ursi, Mahonia repens, Paxistima myrsinites, Symphoricarpos oreophilus, Jamesia americana, Quercus gambelii*, and *Festuca arizonica*. This system was undoubtedly characterized by a mixed severity fire regime in its "natural condition," characterized by a high degree of variability in lethality and return interval. Naturally occurring fires are characterized by a high degree of variable return intervals and lethality due to the range of moisture found in this habitat.

Rocky Mountain Montane Mesic Mixed Conifer Forest and Woodland –

These are mixed-conifer forests of the Rocky Mountains west into the ranges of the Great Basin, occurring predominantly in cool ravines and on north-facing slopes. Elevations range from 1200 to 3300 m. Examples of this type are found on cooler and more mesic sites than Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest and Woodland . Such sites include lower and middle slopes of ravines, along stream terraces, moist, concave topographic positions and north- and east-facing slopes which burn somewhat infrequently. *Pseudotsuga menziesii* and *Abies concolor* are most common canopy dominants, but *Picea engelmannii, Picea pungens*, or *Pinus ponderosa* may be present. This system includes mixed conifer/*Populus tremuloides* stands. A number of cold-deciduous shrub species can occur, including *Acer glabrum, Acer grandidentatum, Alnus incana, Betula occidentalis, Cornus sericea, Jamesia americana, Physocarpus malvaceus, Robinia neomexicana, Vaccinium membranaceum*, and *Vaccinium myrtillus*. Herbaceous species include *Bromus ciliatus*, *Carex geyeri, Carex rossii, Carex siccata, Muhlenbergia virescens, Pseudoroegneria spicata, Erigeron eximius, Fragaria virginiana, Luzula parviflora, Osmorhiza berteroi, Packera cardamine, Thalictrum occidentale*, and *Thalictrum fendleri*. Naturally occurring fires are of variable return intervals, and mostly light, erratic, and infrequent due to the cool, moist conditions. Naturally occurring fires are characterized by a high degree of variable return intervals and lethality due to the range of moisture found in this habitat.

D.3.5 Montane deciduous woodland

This ecological system occurs in cool ravines, on toe-slopes and slump benches associated with riparian areas in New Mexico and the Trans-Pecos of Texas. These canyons and montane riparian woodlands are found in mesic canyons and valleys sheltered from the heat and wind of the desert (Bezanson 2000). Typically these areas act as isolated microhabitats for many species especially during the summer months (Bezanson and Wolfe 2001). In areas where water flows occasionally, such as at the base of an intermittent waterfall, standing pools of water are typically found creating miniature oases with lush vegetation and great amounts of wildlife activity. Associated species include bigtooth maple, chinkapin oak, western hophornbeam, netleaf hackberry, velvet ash, little walnut, Mexican buckeye, acacia species, Emory oak, alligator juniper, evergreen sumac, Texas madrone, beargrass, Arizona grape, different grasses, sedges and forbs (Bezanson 2000). These habitats are isolated, very small and uncommon. There

are scattered, tiny patches in the Chisos Mountains within Big Bend National Park as well as about 300 ac. in McKittrick Canyon (Guadalupe Mountains NP). It is suggested that these habitats are of high priority for protection due to the relative rareness and high importance of these habitats for desert wildlife species (Bezanson 2000).

D.4 Literature Cited

Barbour, M. G., and W. D. Billings, eds. 2000. North American terrestrial vegetation, 2nd edition. Cambridge, U.K.: Cambridge University Press.

Bezanson, D. 2000. Natural vegetation types of Texas and their representation in conservation areas. University of Texas at Austin.

Bezanson, D., and D.Wolfe 2001. Conservation priorities for Texas: a guide to ten threatened natural areas in the Lone Star State. Unpublished report. Natural Area Preservation Association and Environmental Defense (http://www.edf.org/documents/1947_conserv4.pdf). Last accessed February 18, 2010.

Brown, D. E., ed. 1994. The biotic communities of the American Southwest - United States and Mexico. Salt Lake City: University of Utah Press.

Brown, D. E., F. Reichenbacher, and S.E. Franson. 1998. A classification of North American biotic communities. Salt Lake City: University of Utah Press.

Buffington, L. C., and C. H. Herbel. 1965. Vegetation changes on a semidesert grassland range from 1858 to 1963. Ecological Monographs 35:139–164.

Diamond, D. D. 1993. Plant communities of Texas (series level). Texas Natural Heritage Program.

Dick-Peddie, W. A. 1993. New Mexico vegetation: Past, present, and future. Albuquerque: University of New Mexico Press.

Dinerstein E., D. Olson, J. Atchley, C. Loucks, S. Contreras-Balderas, R. Abell, E. Indigo, E. Enkerlin, C. E. William, and G. Castelleja. 2000. Ecoregion-based conservation in the Chihuahuan Desert: A biological assessment. World Wildlife Fund, Washington, D.C. http://www.worldwildlife.org/what/wherewework/chihuahuandesert/WWFBinaryitem2757.pdf. Last accessed February 16, 2010.

Marshall, B. E., and R. M. Callaway. 1991. Root communication among desert shrubs. Ecology 88:874–876.

McMahan, C. A., R. G. Frye and K. L. Brown. 1984. The vegetation types of Texas including cropland. Texas Parks and Wildlife, Wildlife Division, Austin, Texas.

Montana, C., B. Cavagnaro, and O. Briones. 1995. Soil and water used by co-existing shrubs and grasslands in the Southwest Chihuahuan Desert, Mexico. Journal of Arid Environments 31:1–13.

Muldavin, E., P. Durkin, M. Stuever and P. Mehlhop. 2000. Handbook of western vegetation communities of New Mexico. Volume I: Classification and community descriptions. Final report submitted to the New Mexico Environmental Department, Surface Water Quality Bureau, Santa Fe, New Mexico.

Wood, S., G. Harper, E. Muldavin, and P. Neville. 1999. Vegetation map of the Sierra del Carmen, U.S.A. and Mexico. Unpublished technical report. New Mexico Natural Heritage Program, University of New Mexico, Albuquerque.

Natural Resources Conservation Service (NRCS). 1997. National range and pasture handbook. USDA, NRCS, Grazing Lands Technology Institute, Forth Worth, Texas.

NatureServe. 2006. NatureServe Explorer: An online encyclopedia of life [web application]. Version 4.7. NatureServe, Arlington, Virginia. http://www.natureserve.org/explorer.

New Mexico Department of Game and Fish (NMDGF). 2005. Comprehensive wildlife conservation strategy for New Mexico. New Mexico Department of Game and Fish, Santa Fe, New Mexico.

Pronatura Noreste, The Nature Conservancy, and World Wildlife Fund. 2004. Ecological conservation assessment of the Chihuahuan Desert. Second edition. World Wildlife Fund, Washington, D.C. http://www.parksinperil.org/files/chihuahuan_desert_report_cover_and_toc.pdf. Last accessed February 18, 2010.

Schlesinger, W. H., J. F. Reynolds, G. L. Cunningham, L. F. Huenneke, W. M. Jarrell, R. A. Virginia, and W. G. Whitford. 1990. Biological feedbacks in global desertification. Science 247:1043–1048.

Stein, R. A., and J. A. Ludwig. 1979. Vegetation and soil patterns in the Chihuahuan desert bajada. American Midlands Naturalist 101:28–37.

Stubbendieck, J., S. L. Hatch, and C. H. Butterfield. 1992. North American range plants. Fourth edition. Lincoln: University of Nebraska Press.

Appendix E. Climate Summary for Chihuahuan Desert Network Parks and Additional Areas Within the Region

E.1 Background

Weather and climate are key drivers in ecosystem structure and function. Global- and regional scale climate variations will have a tremendous impact on natural systems (Chapin et al. 1996; Schlesinger 1997; Jacobson et al. 2000; Bonan 2002). Proper understanding of ecosystem dynamics requires an understanding of the roles of climate variability, hydrologic interactions with soils, and adaptive strategies of biota to capitalize on spatially and temporally variable moisture dynamics (Noy-Meir 1973; Bailey 1995; Rodriguez-Iturbe 2000; Reynolds et al. 2004).

Long-term patterns in temperature and precipitation provide first-order constraints on potential ecosystem structure and function. Secondary constraints are realized from the intensity and duration of individual weather events and, additionally, from seasonality and inter-annual climate variability. These constraints influence the fundamental properties of ecologic systems, such as soil–water relationships, plant–soil processes, and nutrient cycling, as well as disturbance rates and intensity. These properties, in turn, influence the life-history strategies supported by a climatic regime (Neilson 1987; Reiser et al. 2006).

Given the importance of climate, it is one of 12 basic inventories to be completed by the National Park Service (NPS) Inventory and Monitoring Program (I&M) network (NPS 2006). As primary environmental drivers for the other vital signs, weather and climate patterns present various practical and management consequences and implications for the NPS (Oakley et al. 2003). Most park units observe weather and climate elements as part of their overall mission. The lands under NPS stewardship provide many excellent locations for monitoring climatic conditions.

It is essential that park units within the Chihuahuan Desert Inventory and Monitoring Network (CHDN) have an effective climate-monitoring system in place to track climate changes and to aid in management decisions relating to these changes. The purpose of this report is to determine the current status of weather and climate monitoring within the CHDN. In this report, we provide the following informational elements:

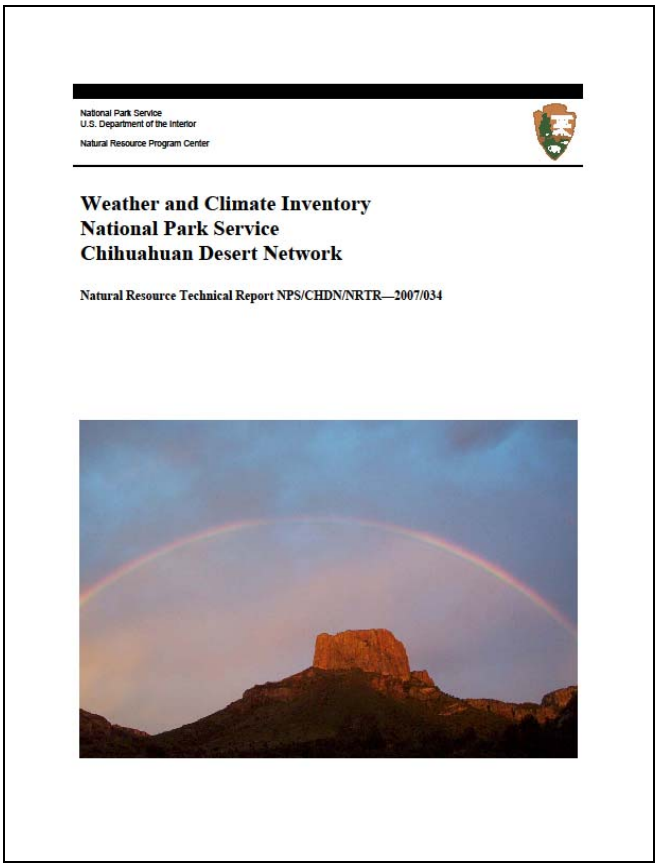
- Overview of broad-scale climatic factors and zones important to CHDN park units.
- Inventory of locations for all weather stations in and near CHDN park units that are relevant to the NPS I&M networks.
- Results of metadata inventory for each station, including weather-monitoring network affiliations, types of recorded measurements, and information about actual measurements (length of record, etc.).
- Initial evaluation of the adequacy of coverage for existing weather stations and recommendations for improvements in monitoring weather and climate.

A primary question to be addressed by climate- and weather-monitoring activities in CHDN is (Reiser et al. 2006): Are temperature and precipitation regimes changing over time (including timing, intensity, duration, and geographic distribution)?

E.2 Climate and the CHDN Environment

Most CHDN parks lie between 900 and 1500 m (about 3,000 to 5,000 ft), although foothill areas and some isolated mountain ranges in the Guadalupe and Chisos Mountains may rise to more than 2300 m (about 7,000 ft). Schmidt (1979) notes the relative uniformity of climate within the Chihuahuan Desert Ecoregion; hot summers and cool to cold, dry winters. This uniformity is due to the more-or-less equal distance of most areas of the desert from moisture sources (Gulf of Mexico and the Sea of Cortez), the uniformity of elevation of surrounding mountain masses, and the position of the desert on the continent which results in little frontal precipitation. As a result the Chihuahuan Desert has a high percentage of its precipitation falling in the form of monsoonal rains during the summer months. This desert has more rainfall than other warm desert ecoregions, with precipitation typically ranging from 150 to 500 mm (6 to 20 in) annually, and the average for this being about 235 mm (10 in) (Schmidt 1979).

For more details on weather and climate for CHDN parks, please read the final report on the weather and climate inventory for the CHDN parks that was published in 2007. This report is packaged with the pdf of this document and can be accessed at the CHDN Intranet site , http://www1.nrintra.nps.gov/im/units/chdn/.


National Park Service
U.S. Department of the Interior
Natural Resource Program Center

Weather and Climate Inventory
National Park Service
Chihuahuan Desert Network

Natural Resource Technical Report NPS/CHDN/NRTR—2007/034

E.3 Literature Cited

Bailey, R. G. 1995. Description of the ecoregions of the United States. Second edition. USDA Forest Service, Washington, D.C. Miscellaneous Publication 1391.

Bonan, G. B. 2002. Ecological climatology: Concepts and applications. Cambridge, U.K.: Cambridge University Press.

Chapin, F. S., III, M. S. Torn, and M. Tateno. 1996. Principles of ecosystem sustainability. American Naturalist 148:1016–1037.

Jacobson, M. C., R. J. Charlson, H. Rodhe, and G. H. Orians. 2000. Earth System Science: From Biogeochemical Cycles to Global Change. Academic Press, San Diego.

National Park Service (NPS). 2006. Natural resource inventories in national parks. http://science.nature.nps.gov/im/inventory/index.cfm. Last accessed February 18, 2010.

Neilson, R. P. 1987. Biotic regionalization and climatic controls in western North America. Plant Ecology 70:135–147.

Noy-Meir, I. 1973. Desert ecosystems: Environment and producers. Annual Review of Ecology and Systematics 4:25–51.

Oakley, K. L., L. P. Thomas, and S. G. Fancy. 2003. Guidelines for long-term monitoring protocols. Wildlife Society Bulletin 31:1000–1003.

Rodriguez-Iturbe, I. 2000. Ecohydrology: A hydrologic perspective of climate-soil-vegetation dynamics. Water Resources Research 36:3–9.

Reiser, M. H., J. P. Ward, Jr., J. T. Richie, and M. A. Powell. 2006. Chihuahuan Desert Network vital signs monitoring plan: Phase II. National Park Service, Chihuahuan Desert Network, Las Cruces, New Mexico.

Reynolds, J. F., P. R. Kemp, K. Ogle, and R. J. Fernandez. 2004. Modifying the 'pulse-reserve' paradigm for deserts of North America: Precipitation pulses, soil water, and plant responses. Oecologia 141:194–210.

Schlesinger, W. H. 1997. Biogeochemistry: An analysis of global change. Second edition. San Diego, Ca.: Academic Press.

Schmidt, R. H., Jr. 1979. A climatic delineation of the "real" Chihuahuan Desert. Journal of Arid Environments 2:243–250.

Appendix F. Chihuahuan Desert Water Resources and Water Quality Standards: An Overview

F.1 National Park Service Mandates for Water Quality

National Park Service (NPS) enabling legislation, the 1916 Organic Act (NPS 1916), directed the NPS to work "within the established water regulatory system while preserving the scenery, natural and historic objects and wildlife, and provides for the enjoyment of same in ways that leave them unimpaired for future generations."

The National Parks Omnibus Management Act (NPS 1998) provides a research mandate for the National Parks "…to assure that management …is enhanced by the availability and utilization of a broad program of the highest quality science and information." It also mandates "a program of inventory and monitoring of the National Park System resources to establish baseline information and provide information on the long-term trends in (resource) condition…"

In 1999, the NPS approved the Natural Resource Challenge (NPS 1999), which states, "The protection of National Park waters, watersheds, and aquatic life is fundamental to maintaining the integrity of natural resources and the quality of the visitor experience in the parks. A consistent approach to identifying and measuring progress toward meeting water quality standards is essential. Protective standards, scientific monitoring, and a program to ensure the protection of water quality, natural flows, and the health of aquatic systems are required to measure and protect this critical environmental component."

The NPS Strategic Plan 2005 to 2008 (NPS 2005a) sets the following goal for the NPS system to meet by September 2008:

- 90% of lake, reservoir, estuarine and marine areas managed by the National Park Service will meet State and Federal water quality standards as defined by the Clean Water Act.

Previous Government Performance and Results Act (GPRA) water quality goals targeted "swimmable beaches." The strategic plan extended that goal to one of preventing the deterioration of the highest-quality waters and improving the quality of the most-degraded NPS waters. Historically, availability of water quality data for the parks has been inconsistent due to the variety of agency and state efforts and protocols. The NPS goal is to rely on its own uniform monitoring data and use it to protect this vital resource.

F.2 General Description of Groundwater and Surface Water Resources in Chihuahuan Desert Network Parks

The status and trends (where applicable) of water resources for each network park were described in a recent report by Porter et al. (2009), a summary of which is presented in the following sections. The purpose of the report, part of a cooperative agreement between CHDN and the Edwards Aquifer Research

and Data Center (Texas State University, San Marcos), was to improve understanding of surface and ground-water hydrology, water quality conditions and trends, and the condition of macroinvertebrate communities in major water resources of the CHDN parks. Data from governmental data bases and published literature were retrieved, compiled into relational data bases and analyzed relative to the condition of the water resource and potential changes in water quality or quantity over time. Sufficient data were available to address surface-water quantity, quality, and macroinvertebrate communities in certain aquatic systems, whereas analyses of groundwater resources were limited mostly to well inventory and water quantity (groundwater level) issues. Previous water-quality reports on the CHDN parks were published by NPS (1995a; 1995b; 1997a; 1997b; and 1999).

F.2.1 Amistad National Recreational Area

F.2.1.1. Groundwater

Bedrock geology of the region is composed of Cretaceous limestone and dolostone, and the predominant groundwater source is the Edwards aquifer of Early Cretaceous age. The Edwards aquifer is comprised of the Devils River and Salmon Peak Formations on the north and south, respectively. The Devils River and Salmon Peak strata are permeable where fractured. The prevailing hydraulic gradient in the region slopes from the Edwards Plateau toward the topographically lower Rio Grande drainage and the more deeply entrenched tributaries such as the Pecos and Devils Rivers. Water levels in most Edwards aquifer wells in hydraulic communication with Amistad Reservoir underwent rises coincident with the late-1960s filling of the reservoir.

Because the duration of water-level records in NPS-owned wells was not sufficient to show long-term trends, groundwater records from other, privately owned, wells in the area were used to assess groundwater dynamics. The dominant pattern of water-level change is associated with the post-impoundment rise of Amistad International Reservoir. Whereas to the north, on the Edwards Plateau, water levels in the aquifer varied between 50 – 75 feet during the 1970s to 1990s, water levels in most wells within five miles of the reservoir varied less than 50 feet during the same time period. The lowest groundwater elevations since the reservoir's filling correspond to the reservoir's lowest stages during the 10-yr (1993 – 2002) drought in the area. Groundwater levels in wells near the reservoir are influenced by the large body of surface water contained behind Amistad dam.

F.2.1.2. Surface water

Amistad International Reservoir, an impoundment of the Rio Grande near Del Rio, Texas, occupies 57,300 acres of United States—Mexico borderland and receives drainage from over 123,000 square miles in the Rio Grande, Rio Conchos, Pecos, and Devils River basins. Reservoir stages range from a conservation pool of 1,117 feet above mean seal level (amsl) to a maximum flood-control stage of 1,144 ft amsl, corresponding to storage capacities of 3,500,000 acre-feet and more than 5,600,000 acre-feet, respectively. Reservoir stage rises and falls in accordance with the net effect of upstream inflows, evapotranspiration losses, and releases required by downstream water users. The reservoir's large surface area makes it vulnerable to high rates of evaporation, whereas the reservoir's vast, low-lying shoreline has become a habitat for invasive plants with high rates of transpiration such as *Tamarix* (salt cedar). Periodic releases of water from the reservoir also are required to satisfy downstream water rights. Drought is a normal component of the arid and semiarid landscape that comprises most of the drainage basin. Inflows to the reservoir appear to be decreasing over time. The diminishing Rio Grande discharge is of increasing concern to agricultural and urban areas downstream from the Amistad dam.

Although the present water-quality condition of Amistad Reservoir appears to be oligotrophic to mesotrophic (relatively low nutrient concentration and nuisance algal growth), the TCEQ has recently (2008) classified the reservoir as being of Special Concern because of increasing concentrations of nutrients (notably nitrate) that present the potential for eutrophication. The quality of Rio Grande inflow

waters (TCEQ Segment 2306) also was listed of Special Concern because of increasing phytoplankton (algae) levels and increases in total phosphorus concentrations. Amistad Reservoir presently supports a highly-productive largemouth bass population and the area is known for its numerous fishing tournaments. Although small to moderate amounts of nutrients can stimulate reservoir food webs that support productive fisheries, the water-quality management challenge will be to reduce nutrient loading to the reservoir and manage reservoir releases to avoid adverse effects of eutrophication (nuisance algal blooms and organic enrichment, leading to low dissolved-oxygen concentrations), particularly during periods of drought.

F.2.2 Big Bend National Park/Rio Grande Wild & Scenic River

F.2.2.1. Groundwater

Geologic formations in Big Bend National Park exhibit the diverse effects of variable depositional patterns and extreme tectonic events during all three eras of geologic time. After being inundated by ancient seas for more than a billion years, the region was subjected to tectonic uplift and crustal buckling that folded, faulted and fractured the older marine strata. Following sporadic volcanic episodes that spewed lava and ash over thousands of square miles, a system of bolsons developed. Material eroded from the adjacent mountains was redistributed as basin-fill deposition within the bolsons. The net effects of these processes and subsequent geologic activity characterize the hydrogeologic framework of aquifers in the region.

Principal aquifers in Big Bend National Park include the Tertiary Volcanics (Igneous) aquifer, characterized by fractures, crevices, and vesicular zones within lava flows, and the Cretaceous Limestone (Santa Elena) aquifer, a southern extension of the Edwards-Trinity aquifer that underlies much of the Big Bend area. Although groundwater yields from the Tertiary Volcanics aquifer generally are low, the quality of groundwater typically is good, in part because of relatively rapid transmission of water between rainfall on to the land surface and the aquifer. By contrast, groundwater yields from the Cretaceous Limestone aquifers generally are good, providing most of the park's well water supply; however, the quality of water (as indicated by total dissolved-solids concentrations) can be poor. The stratigraphic equivalents of the Cretaceous strata that comprise the Edwards-Trinity aquifer system north of the Rio Grande also are major contributors of groundwater inflow to the river and adjacent springs, including those that support the endangered *Gambusia* fish populations near Rio Grande Village.

The permanency of groundwater discharge from springs and seeps along the Rio Grande and within the park is dependent on the long-term stability of aquifers that are hydraulically connected to surface water in the region. The continuation of groundwater discharges to springs and other surface-water bodies depends on the maintenance of groundwater gradients toward the areas of spring and streambed discharge. If aquifer water levels are lowered as a result of drought or excessive well pumpage, these gradients will decrease and reductions in springflow and streamflow can be expected to occur.

Although short-term (4-yr) water-level records from wells located in the Tertiary Volcanics and Upper Cretaceous aquifers in Big Bend National Park show relatively little trends, similar wells completed in the Tertiary Volcanics aquifer near Alpine, Texas have experienced declines in water levels since the date of well construction. Water-level data from several long-term observation wells in the Alpine area indicate declines of several tens to hundreds of feet over the past 50 years. Apart from pumping stresses, water-level dynamics in most wells appear to follow increases and decreases of precipitation in the area. Similar associations among precipitation, pumpage, and groundwater levels, as well as discharges from springs, are likely to occur within relatively large areas of the Park that are underlain by the Tertiary Volcanics aquifers. Spring complexes along the Rio Grande, particularly within the Wild & Scenic River segment, may be threatened by increased, unregulated pumping of the Edwards-Trinity aquifer. Without additional protection from the impacts of future groundwater development in the region, the long-term

response of these pumping activities could lead to the depletion of groundwater discharge to area springs and streams.

F.2.2.2. Surface water

Major surface-water resources in the Big Bend area include the Rio Grande, several intermittent tributaries such as Terlingua, Tornillo, and Alamito Creeks, and numerous springs distributed along the Rio Grande corridor and within Big Bend National Park, including a downstream Wild & Scenic River segment Streamflow in the Rio Grande is controlled by several major impoundments: Elephant Butte Reservoir in central New Mexico, La Boquilla Reservoir (and several other smaller impoundments in the Rio Conchos basin) in the Mexican State of Chihuahua, and Amistad International Reservoir (discussed previously). About 80 percent of Rio Grande flow through Big Bend National Park and the Wild & Scenic River segment originates in the Rio Conchos basin. During low-flow conditions, the Rio Conchos provides nearly all the flow in the Rio Grande downstream from its confluence, and the "forgotten reach" of the Rio Grande between El Paso and Presidio, Texas transports very little water. Large gains of discharge in the Rio Grande were found along the lower segments of the Wild & Scenic River that are presumed to have originated from spring discharges from the Edwards-Trinity aquifer and equivalent aquifers in Mexico.

The flow in the Rio Grande has declined over the past 90 years in association with impoundment controls on the Rio Grande and Rio Conchos, a pattern of declining precipitation, and increases in diversions and withdrawals for agricultural and urban water uses. A prime factor in the reduction of Rio Grande flow during the past 25 years is a similar decline in annual precipitation during the period. Peak flows also have been attenuated, primarily by the impoundments. Reductions in peak flows can result in narrowing of the river channel, changes in channel width-to-depth ratios, and decreases in sediment transport. These factors are associated with changes in the composition and abundance of floodplain vegetation, for example, increases in the abundance of invasive plants such as salt cedar (*Tamarix* sp.)

Long-term water quality data are available for nine locations in the Rio Grande study area, from Presidio, Texas (above the Rio Conchos confluence) downstream to near Del Rio, Texas at a location immediately below Amistad Dam. Relatively little change was observed for water temperature, dissolved oxygen concentrations, and pH values in the Rio Grande during the past 30-35 years; however, specific conductance values (as well as concentrations of major ions such as chloride, sulfate, and total-dissolved solids) have increased since the early 1970s. These increases are likely associated with comparable increases in irrigated agricultural activities in the Rio Grande and Rio Conchos basins during the period. Specific conductance and chloride values decrease in a downstream direction throughout the Rio Grande Wild & Scenic River segment. Those decreases appear to be related to increases in the flow of Rio Grande resulting, in part, from discharges from numerous springs draining the Edwards-Trinity aquifer. Decreases in major-ion concentrations most likely are a result of dilution with higher-quality aquifer waters.

Median values for fecal-indicator bacteria (fecal coliform and *Escherichia coli*) were similar among Rio Grande sites, correlated positively with streamflow, and significantly higher during the summer recreational season. Over 40 percent of samples collected from the Rio Grande below Rio Conchos exceeded USEPA criteria, and this segment of the Rio Grande (from Presidio, Texas to the Alamitos Creek confluence) currently (2008) is on the TCEQ 303(d) list for repeated violations of fecal-indicator bacteria criteria. Sources of bacterial contamination include poorly-treated wastewater from small towns upstream from Big Bend National Park and contamination from livestock (and possibly human sources) along the river corridor. Fecal-coliform values have been increasing at Rio Grande sites in Big Bend National Park since the early 1990s, consistent with trends at upstream sites near Presidio. No trends for fecal-coliform values were detected at Rio Grande sites downstream from the Park boundaries, however, *E. coli* values appear to be increasing in the Wild & Scenic River segment since the early 2000s.

Nutrient and biological (phytoplankton chlorophyll a) indicators of eutrophication generally were highest at the Rio Grande sites near Presidio, decreasing with distance downstream. Median nitrate concentrations increased significantly in the Rio Grande downstream from the Rio Conchos confluence, and median concentrations remained similar throughout the Wild & Scenic River segment. Orthophosphate concentrations in the Rio Grande have been increasing since the mid 1980s. Median chlorophyll *a* values were representative of mesotrophic conditions at most sites. About 17 percent of chlorophyll samples from the Rio Grande within Big Bend National Park (near Santa Elena Canyon) exceeded 30 μg/L, a common criterion for eutrophic conditions. Dense growths of benthic, filamentous algae were noted during a field visit in April 2008. The TCEQ has classified this segment of the river (including the Wild & Scenic River segment) as being of Special Concern because of elevated values for chlorophyll *a* and total phosphorus). As mentioned previously, increases in eutrophication indicators in this segment of the Rio Grande may portend adverse effects in Amistad International Reservoir.

Despite historic mining activities in the Big Bend region, notably mercury mining in the Terlingua mining district, concentrations of metals in water and sediment samples generally were low at all sites, consistent with natural background levels. Metals appear to be accumulating in the bottom sediments of Amistad International Reservoir. Concentrations of arsenic, chromium, and nickel in upper layers of sediment cores (more recent years of deposition) exceeded biological-threshold effect levels.

Macroinvertebrate data have been collected at various Rio Grande sites since the late 1970s; however, differences in study design and location, antecedent hydrologic conditions, sample-collection methods, and, particularly, levels of taxonomic resolution confound analyses of stream condition and trends. Results from a study conducted during the late 1990s indicated that the percentage of sensitive organisms (mayflies and caddisflies) decreased downstream through the Wild & Scenic River segment; however, comparison with results from the late 1970s suggested that biological integrity had not changed appreciably during that 20-year period. Recent (2000s) TCEQ Benthic Macroinvertebrate Rapid Bioassessment Index of Biotic Integrity (BRBIBI) scores were in the "intermediate" aquatic-life use category. The TCEQ designated aquatic-life use for Rio Grande segments 2306 and 2307 is "high;" therefore, macroinvertebrate IBI scores are indicating that the designated use is not being met.

F.2.3 Carlsbad Caverns National Park

F.2.3.1. Groundwater

Rattlesnake Springs has provided water for the Park and private owners of nearby lands for more than 50 years. Water at this site is piped from a water-supply well to park headquarters near the main cavern through a pipeline that was completed in 1935. A 1955 report from the New Mexico State Engineers Office stated that Rattlesnake Springs represented the discharge from an aquifer in the alluvium whose source was considered to be southwest of the springs. As the discharge from Rattlesnake Springs appeared to recede during the 1950s drought, the NPS became concerned about the diminished flow during the summer months when the public use of water at Carlsbad Caverns is greatest. Results of a USGS study conducted during the early 1960s concluded that the rate of discharge from Rattlesnake Springs was adversely affected by upgradient well withdrawals and that there was a common source of water (from the southwest) that was either pumped from the aquifer or allowed to discharge naturally from the springs. Subsequent studies suggested that water discharging from Rattlesnake Spring was a mixture of water from several sources, as indicated by differences in specific conductance measurements at various locations in the pool area.

A relatively recent (1998) hydrologic study of Rattlesnake Springs indicated that observed variations in discharge from the springs were controlled mostly by fluctuations in annual precipitation. The study also concluded that increased rates of well withdrawals could have a significant effect on Rattlesnake Springs,

either by intercepting flow toward the springs or by decreasing flow to the Black River and altering the base level of the system.

Groundwater levels in the Rattlesnake Springs area generally are highest over the winter season (October through March) and lowest during the summer months when local irrigation demands are greatest. Overall downward trends in springflow and groundwater levels have been apparent since at least January 2001. Groundwater hydrographs indicate that recharge to the area's flow regime was probably decreasing since about 1990. Annual precipitation totals for the area reflect a similar pattern of a significant precipitation deficit in the area beginning about 1989 through at least 2004.

F.2.3.2. Surface water

Although the NPS has monitored the quality of treated drinking water for some time, no water-quality or biological data exist for Rattlesnake Springs. Field observations during April 2008 indicated considerable macrophyte and benthic-algal growths in the spring. The status and trends in plant growths in the spring should be considered for future vital-signs monitoring along with periodic sampling for core parameters and nutrient concentrations. Discharge from the spring into an un-named tributary of the Black River should be considered for monitoring macroinvertebrate-community status and trends. The tributary appears to be a high-quality resource.

F.2.4 Fort Davis National Historic Site

F.2.4.1. Groundwater

The hydrogeology of the Fort Davis National Historic Site is dominated by volcanic rocks of Tertiary age that crop out over most of Jeff Davis County and form the surrounding Davis Mountains. Much of Fort Davis area is composed of volcanic flows that overlie thick sequences of buried carbonate rocks of Cretaceous age. As volcanic activity waned during late Tertiary time, tensional forces within the earth's crust produced a series of basins, into which blocks of igneous strata dropped downward relative to adjacent blocks that remained elevated. Streams draining the structurally higher areas subsequently filled, or partly filled, these down-dropped basins (or bolsons) with thick sequences of sedimentary and volcanic detritus eroded from the elevated terrain. Where these alluvial basins are saturated with groundwater, they can provide local sources of potable groundwater that may or may not be connected hydraulically to adjacent igneous-rock aquifers. The resulting hydrogeologic framework is complex.

The dominant (Tertiary Volcanics) aquifer comprises discontinuous permeable zones within a three-dimensional complex of inter-layered volcanic vents and flows and interbedded sedimentary units. Although the region's history of faulting and structural fracturing tends to increase the potential for hydraulic connection among the deeper and shallowest zones, most of the groundwater appears to occur within fractures and rubble zones associated with the tops and bottoms of the lava flows. Despite a complex pattern of groundwater circulation, the principle directions of flow typically radiate away from mountainous areas toward the lower-lying valleys or sunken bolsons.

Most recharge occurs as precipitation infiltrates rocky watersheds on the flanks of surrounding mountains and percolates deeper through vertical joints and fault-related fractures. Recharge also occurs as rainfall infiltrates coarse-grained alluvial fans that skirt the mountainsides. Most discharge results from well withdrawals and springflow. The structurally altered terrain can cause groundwater levels to vary by several hundreds of feet between closely spaced wells.

Although the Tertiary Volcanics aquifer is the sole source of water for most Fort Davis residents, some wells pump from alluvial-filled bolsons or erosional channels that breach individual lava flows. Assuming long-term average rainfall, sufficient groundwater appears to exist to satisfy the projected needs for most the county. Assuming pumpage for municipal, domestic, and agricultural purposes is not increased

significantly above historical rates of withdrawal, groundwater levels near FODA will likely remain closely linked to the area's spatial and temporal distributions of precipitation. However, unpublished reports, letters, and notes regarding well installations at FODA indicate a history of concern regarding the dependability of potable water sources within the park. A key concern for park management issue is the need to avoid excessive pumpage for prolonged periods from existing wells.

Hydrographs of water levels in observation wells near FODA appear to track similar patterns of water-level responses to aquifer conditions, most notably those affected by recharge through precipitation and pumping from nearby water-supply wells. Although no recent hydrograph data for the area indicate water-level variations that exceed plus or minus five feet, the available hydrographs appear to track a slightly downward trend since the beginning of their periods of record (1967 and 2001). One of sharpest groundwater-level drops, occurring during 1991-2003, appears to reflect the effects of a coincidental decrease in precipitation.

F.2.4.2. Surface water

The only surface water resource associated with the Historic Site is Limpia Creek, located on the northern boundary of the Site. According to historical accounts, the quantity and quality of Limpia Creek has been quite variable. Conversations with local residents indicate that there has been relatively less flow in the creek since the early 1960s due to unknown causes. Observations of Limpia Creek during early April 2008 revealed an essentially intermittent stream with several pools separated by considerable distances of dry stream bed. Limited water-quality data were found in the TCEQ data base for 1972-86. Although several exceedances of water-quality criteria were noted for core parameters and concentrations of lead, water-quality conditions generally were good, whereas indicator values for macroinvertebrate communities were somewhat lower than expected for small streams in this part of Texas. Water quality and ecological conditions since 1986 are unknown.

F.2.5 Guadalupe Mountains National Park

F.2.5.1. Groundwater

Groundwater conditions in the Guadalupe Mountains National Park (GUMO) are affected primarily by three aquifers in addition to locally permeable zones within an alluvial fan complex that skirts the eastern front of the Guadalupe Mountains. In order of accessibility and decreasing relevance to the current sources of water at GUMO these aquifers are (1) the Capitan Reef Complex aquifer, (2) Bone Spring-Victorio Peak aquifer, and (3) Salt Bolson and Delaware Mountain Group aquifer. Recharge to these aquifers is minimal due to their depths below land surface and the region's limited rainfall.

The Capitan (Reef Complex) aquifer comprises the saturated remains of a vast Permian reef within which nearly 2,500 feet of dolomite and limestone rocks accumulated more than 225 million years ago. The aquifer provides most of GUMO's water supply and an abundance of freshwater to the city of Carlsbad, New Mexico. Typically, however, the water quality is too poor for municipal or irrigation use, with average TDS values exceeding 3,000 mg/L. Water of the freshest quality occurs nearest the areas of recharge, in the higher elevations of southeastern New Mexico. Most of groundwater pumped from the Capitan aquifer in Texas is used for oil reservoir water-flooding operations in Ward and Winkler counties. A small amount is used for irrigation of salt-tolerant crops in Pecos and Culberson counties. The regional patterns of groundwater flow have evolved over geologic time as the drainage and geomorphologic patterns of the Pecos River changed. Today, the prevailing pattern of regional flow is toward the east, away from GUMO.

The Bone Spring-Victorio Peak aquifer is tapped almost exclusively for irrigation purposes where it occupies the eastern edge of the Diablo Plateau west of the Guadalupe Mountains in northeast Hudspeth County, Texas. The Bone Spring and Victorio Peak Formations that comprise this aquifer include 2,000

feet of Early Permian limestone strata that locally contain groundwater in joints, fractures, and solution cavities. The occurrence and availability of groundwater is highly variable, resulting in well yields that range from about 150 to more than 2,000 gallons per minute. The aquifer extends northward into the Crow Flats area of New Mexico and eastward beneath the Capitan Reef aquifer that directly underlies and provides GUMO with most of its potable water. Although locally acceptable for agricultural purposes, groundwater from the Bone Spring-Victorio Peak aquifer commonly contains between 2,000 mg/L and 6,000 mg/L dissolved solids. To satisfy drinking-water standards, the community of Dell City must de-mineralize the water before distributing it to domestic customers.

The West Texas Bolsons aquifer system of far-west Texas comprises several alluvial aquifers situated within deep basins filled with Quaternary-age sediments of igneous and sedimentary origins. This sequence of loosely connected basins contains significant quantities of groundwater—not only in the bolson deposits, but potentially in the underlying, fractured volcanic rocks. The deposits in each basin differ greatly, ranging from coarse-grained volcanic and limestone remnants to fine-grained lacustrine deposits. Although some well yields reportedly exceed 3,000 gpm, most wells produce less than 1,000 gpm. Water quality, which generally ranges from fresh to slightly saline, differs from basin to basin. The Salt Bolson and Delaware Mountain Group underlies the northernmost (or Salt Flat) segment of the West Texas Bolson system. Considered a potential water supply for GUMO, the Salt Bolson and Delaware Mountain Group aquifer is susceptible to future water-level declines due to the area's increasing demand for irrigation and potable drinking water.

No GUMO well affords enough water-level data to support construction of a water-level hydrograph. However, based on the records of the nearest wells with sufficient water-level data, most of the region's aquifers appear to reflect the effects of recharge from precipitation, or lack thereof. The highest water levels since the early 1970s occurred during the mid-1990s. This most-recent period of relatively high groundwater levels corresponds to three consecutive years of sharply increasing precipitation during 1994-96. The groundwater levels of all aquifers in the GUMO region appear particularly vulnerable to the effects of drought—especially considering the necessity for increased withdrawals of irrigation water to support the region's farming economy.

F.2.5.2. Surface water

Principal surface-water resources in Guadalupe Mountains National Park include McKittrick Creek, Choza Spring, Manzanita Spring, Frijole Spring, Guadalupe Spring and several other springs within the Park boundary. The water quality of McKittrick appears to be excellent and macroinvertebrate communities consist of diverse populations of sensitive taxa. Although not formally designated as such, McKittrick Creek would be a good candidate for classification as an Outstanding National Resource Water. Other water bodies within the Park also appear to be of high quality.

F.2.6 White Sands National Monument

F.2.6.1. Groundwater

Two groundwater bodies underlie the White Sands National Monument. The deepest, most widespread unit comprises the "basin-fill" aquifer, a collection of alluvial deposits that partially fill the Tularosa Basin of south-central New Mexico. Much of the alluvial fill originated as material eroded from the adjacent mountain ranges after the basin was down-faulted and formed the ancestral Rio Grande Valley. The eroded detritus was transported downslope and re-deposited along the flanks of the basin to form broad alluvial fans that, in lower elevations, coalesce with fluvial sediments along the ancient Rio Grande watercourse. The alluvial-fan deposits grade basinward into progressively finer-grained fluvial and lacustrine deposits; from less than 100 feet thick along the mountain flanks, the thickness of the basin-fill aquifer increases basinward to as much as 4,000 feet.

The basin-fill aquifer is overlain locally by a shallower aquifer of relatively fine-grained lacustrine and fluvial material. This shallow aquifer is perched atop an intervening layer of ancient lakebed deposition that appears to underlie the main dune field at depths of roughly 25 ft below land surface. The perched and basin-fill aquifers apparently are isolated hydraulically by the intervening remnant of organic clay associated with ancient Lake Otero, which retreated during the Pleistocene to lower elevations which now form Lake Lucero.

In contrast to the perched aquifer sustained by relatively fresh water of meteoric origin, the deeper basin-fill aquifer is dominated by much older brackish-to-briny water that increases in dissolved solids toward central parts of the basin. This briny water migrates from both sides of the closed Tularosa Basin toward Lake Lucero, where it collects at land surface into a natural evaporating pan—from which selenite (a variety of gypsum) and other evaporite minerals precipitate. The selenite crystals subsequently break into sand-size grains that are picked up and redistributed throughout the White Sands dune field by prevailing southwest winds.

Water-level differences of about 80 feet appear to exist between the perched and deeper zones at WHSA, where the shallowest levels are monitored through eight observation wells near the picnic loop and park headquarters. The disparity in hydraulic head appears to decrease—if not disappear altogether—away from the dune field, toward the lowest-lying part of the basin occupied by Lake Lucero.

In addition to the general, east-to-west decrease in the depth to groundwater below land surface, water-level trends in the perched aquifer appear for the most part to reflect the effects of recharge from local precipitation. With minor exception, the observation wells at WHSA appear to reflect the net effect of evapotranspiration and precipitation that infiltrates the soils on the valley floor or the gypsum sand that forms the dunes at White Sands.

F.2.6.2. Surface water

Surface-water resources within the boundary of White Sands National Monument include Lucero, Garton, Foster, and other lakes or ponds, Lost River and other intermittent stream channels, Holloman Lake, and other smaller reservoirs and ponds, plus several springs. Limited water-quality data are available for Lake Lucero, Lake Stinky, Garton Lake and a number of unidentified sites. The quality of surface waters could be characterized as hypersaline and of poor quality for freshwater aquatic life. Concentrations of chloride and sulfate exceed USEPA drinking water and acute freshwater life criteria. Elevated concentrations of metals have been reported from water and sediment samples. Macroinvertebrate and diatom samples were dominated by relatively few taxa that are tolerant to high concentrations of dissolved salts.

A number of surface-water bodies in the Tularosa Valley without prior beneficial uses were recently added to the New Mexico Environment Department's 303(d) list of impaired water bodies based on a presumed use of "marginal warm water aquatic life" (MWWAL). These water bodies include Lake Holloman, Lake Lucero (North), Lake Lucero (South), Lake Stinky, Malpais Springs, and Mound Springs, some of which are located within the boundary of White Sands National Monument (or Holloman Air Force Base).

F.3 Baseline Water Quality Data Inventory and Analysis Reports

A cooperative endeavor was initiated in 1993 by the NPS Water Resources Division (WRD) and the Inventory and Monitoring Program to characterize baseline surface water quality at all units of the National Park System containing significant natural resources. The goal of this effort was to provide descriptive surface water quality information to every national park unit in a format usable for park planning and management. Surface water quality and related data was retrieved from the Environmental

Protection Agency's (EPA) STORET and other database systems and used to develop a complete inventory of available data. Descriptive statistics including box and whiskers and time series plots of these data were developed to characterize annual, seasonal, and period of record central tendencies and trends. Park surface water quality data were then compared with relevant EPA national water quality criteria to identify potential water quality issues. These reports are available at: http://www1.nature.nps.gov/water/horizon.htm.

With the exception of BIBE/RIGR and AMIS, the number of water quality analyses reported in the network is limited. The amount of data available for each park varied from 44 to 56 years of historical data, except CAVE which had no available data from the park. "Baseline" data in water chemistry usually refers to data gathered over several years of sampling to portray natural temporal and seasonal variations. The data available in these reports may not constitute "baseline" data for each park. Most water quality studies have also been limited in geographical scope and duration. The majority of monitoring efforts have been either one-time or intensive single-year sampling efforts. Three network parks had longer term monitoring stations: AMIS, BIBE/RIBR and GUMO. Basic information regarding data contained within these reports is provided in Tables F.3-1 and Table F.3-2 (Huff et al. 2006, NPS 1995a, NPS 1995b, NPS 1997a, NPS 1997b, NPS 1999, Reid and Reiser 2005).

Table F.3-1. Information contained within the EPA STORET database and Baseline Water Quality Data Inventory and Analysis Reports for CHDN parks.

Parameter	AMIS	BIBE	FODA	GUMO	WHSA
Date of STORET retrieval	8/6/1995	1/3/1995	4/21/1999	7/7/1997	8/25/1997
Period of record	01/11/67–07/08/93	12/02/53–08/20/92	No data in park	05/15/59–03/31/97	12/17/65–04/06/93
# agencies collecting data	3	3	0	2	2
# STORET stations in park	36	14	0	30	10
# longer term stations in park	9	4	0	14	0
# parameters measured	313	212	0	46	116
# water quality observations	12,912	4,727	0	7,479	465
# water gages	7	4	0	1	0

Table F.2. Specific park resources and resource threats provided in Phase II Water Resources report (Huff et al. 2006) and from park-vital signs scoping meetings.

Park name	Water resources and threats
Amistad National Recreation Area	Receives surface flows from all surrounding lands and three significant rivers (Devils, Pecos and Rio Grande). Threats: Surface-water contamination by sediments, bacteria, and anthropogenic organic compounds transported through surface-water discharge and storm-water runoff; deposition from atmospheric pollution
Big Bend National Park and Rio Grande Wild & Scenic River	Receives flow from the Rio Grande and Rio Conchos and from Mexican lands along the rivers; numerous springs, intermittent and perennial streams. Threats: Surface-water contamination by sediments, bacteria, and anthropogenic organic compounds transported by surface-water discharge and storm water runoff, and groundwater contamination by infiltration of anthropogenic organic compounds.
Carlsbad Caverns National Park	Receives no significant surface flows from surrounding lands; Rattlesnake Springs most important spring; other seeps and springs. Threats: Infiltration of anthropogenic organic compounds, introduced at land surface, into caves (van der Heijde et al. 1997), potential contamination of groundwater and surface water by oil and gas activity (Richard 1988a, 1988b, 1989a, 1989b)
Fort Davis National Historic Site	Receives surface flows from adjacent Davis Mountains State Park and development lands of adjacent Ft. Davis Tx. Threats: Surface-water and groundwater contamination from surrounding urban sources.
Guadalupe Mountains National Park	Receives no significant surface flows from surrounding lands; several perennial streams and springs. Threats: Surface-water contamination by bacteria and anthropogenic organic compounds transported through surface-water runoff from camping areas, McKittrick Creek and parking lots, potential changes in quantity and quality of groundwater resources associated with groundwater development and waste disposal in the Salt Basin.
White Sands National Monument	Receives surface and groundwater flows from surrounding military and BLM lands; very shallow groundwater table, playas and Lake Lucero. Threats: Surface-water and groundwater contamination associated with runoff from, and infiltration through, surrounding military lands; and lowering of groundwater levels associated with regional groundwater development.

The baseline surface water quality reports identified potential water quality problems in each park by comparing water-quality observations to published EPA water-quality screening criteria. It was noted that the criteria may have been exceeded due to any number of factors including errors in the field, laboratory or recording procedures. It should be noted that the data include results from areas outside of park boundaries including three miles upstream and one mile downstream. The reader is encouraged to examine the original reports to make proper interpretations regarding water quality in the parks.

F.4 Water Quality Standards for States in the Chihuahuan Desert Network

Under the Water Quality Act of 1965, each state is required to develop water quality standards to achieve water quality goals for interstate waters. The Federal Water Pollution Control Act Amendments of 1972

(the Clean Water Act) established the National Pollutant Discharge Elimination System (NPDES), which requires each point source discharger to waters of the United States to obtain a discharge permit. These amendments also extended the water quality standards program to intrastate waters, required the establishment of technology-based effluent limitations for NPDES permits, and required permits to be consistent with applicable state water quality standards. The original intent of this legislation was to protect water quality and improve polluted Unites States waters to at least "fishable and swimmable" quality.

Water quality standards are the basis for a water quality-based approach to pollution control and are a fundamental part of watershed management. The basic components of water quality standards are the designated uses defining the goals for a water body, numeric criteria adopted or established to protect the uses, an anti-degradation policy to protect existing uses and high quality waters, and implementation policy. States must consider public drinking supply, fish and aquatic life, agriculture, industrial and navigation uses, and other needs when designation water body uses. The federal guidelines provide policy and implementation guidance to protect uses that states must meet. Section 303(c) of the Clean Water Act established the basis for the current water quality standards program, including oversight of state standards by the Environmental Protection Agency (EPA).

F.4.1 Impaired water bodies—303(d) list

Under Section 305(b) of the Clean Water Act, each state is required to conduct water quality surveys to determine the overall health of the waters of the state, including whether designated uses are being met. States report to the EPA every two years. When impaired water bodies are identified through 305(b) assessments, they are included on 303(d) lists for ranking of priority sites and Total Maximum Daily Load (TMDL) development in order to limit discharges of specific contaminants to that water body.

The Water Quality Act of 1987 required states to identify waters that do not meet water quality standards, adopt numeric criteria for pollutants in such waters, and establish effluent limitations of individual discharges to such water bodies. These amendments to the Clean Water Act also explicitly recognized the EPA's anti-degradation policy to protect the level of water quality necessary to sustain existing uses and provide a means for assessing the need for developments that may lower water quality in high quality waters.

F.4.2 State of Texas water quality standards—Texas Commission on Environmental Quality (TCEQ)

A complete listing of water quality criteria for Texas is available through the Texas Commission on Environmental Quality (TCEQ) at: http://www.tceq.state.tx.us/nav/eq/eq_swqs.html. Water quality criteria can consist of narrative standards and/or numerical values. Reflecting general provisions of the Clean Water Act, the following narrative standards and numeric criteria are contained in the Texas Water Quality Standards:

F.4.2.1. Aesthetic parameters

(1) Concentrations of taste and odor producing substances shall not interfere with the production of potable water by reasonable water treatment methods, impart unpalatable flavor to food fish including shellfish, result in offensive odors arising from the waters, or otherwise interfere with the reasonable use of the water in the state.

(2) Surface water shall be essentially free of floating debris and suspended solids that are conducive to producing adverse responses in aquatic organisms or putrescible sludge deposits or sediment layers that adversely affect benthic biota or any lawful uses.

(3) Surface waters shall be essentially free of settleable solids conducive to changes in flow characteristics of stream channels or the untimely filling of surface water in the state. This provision does not prohibit dredge and fill activities which are permitted in accordance with the Federal Clean Water Act.

(4) Surface waters shall be maintained in an aesthetically attractive condition.

(5) Waste discharges shall not cause substantial and persistent changes from ambient conditions of turbidity or color.

(6) There shall be no foaming or frothing of a persistent nature.

(7) Surface waters shall be maintained so that oil, grease, or related residue will not produce a visible film of oil or globules of grease on the surface or coat the banks or bottoms of the watercourse; or cause toxicity to man, aquatic life, or terrestrial life.

F.4.2.2. Radiological substances

Radioactive materials shall not be discharged in excess of the amount regulated by Chapter 336 of this title (relating to Radioactive Substance Rules).

F.4.2.3. Toxic substances

Surface waters will not be toxic to man from ingestion of water, consumption of aquatic organisms, or contact with the skin, or to terrestrial or aquatic life. Additional requirements and criteria for toxic substances are specified in §307.6 of this title (relating to Toxic Materials). Criteria to protect aquatic life from acute toxicity apply to all surface waters in the state except as specified in §307.8(a)(2) of this title. Criteria to protect aquatic life from chronic toxicity apply to surface waters with a significant aquatic life use of limited, intermediate, high, or exceptional as designated in §307.10 of this title (relating to Appendices A - E) or as determined on a case-by-case basis in accordance with subsection (l) of this section. Toxic criteria to protect human health for consumption of fish apply to waters with a sustainable or incidental fishery, as described in §307.6(d) of this title. Additional criteria apply to water in the state with a public drinking water supply use, as described in §307.6(d) of this title. The general provisions of this subsection do not change specific provisions in §307.8 of this title for applying toxic criteria.

F.4.2.4. Nutrients

Nutrients from permitted discharges or other controllable sources shall not cause excessive growth of aquatic vegetation which impairs an existing, attainable, or designated use. Site specific nutrient criteria, nutrient permit limitations, and/or separate rules to control nutrients in individual watersheds will be established where appropriate after notice and opportunity for public participation and proper hearing.

F.4.2.5. Temperature

Temperature in industrial cooling lake impoundments and all other surface water in the state shall be maintained so as to not interfere with the reasonable use of such waters. Numerical temperature criteria have not been specifically established for industrial cooling lake impoundments, which in most areas of the state contribute to water conservation and water quality objectives. With the exception of industrial cooling impoundments, temperature elevations due to discharges of treated domestic (sanitary) effluent, and within designated mixing zones, the following temperature criteria, expressed as a maximum temperature differential (rise over ambient) are established: freshwater streams - 5 degrees Fahrenheit; freshwater lakes and impoundments - 3 degrees Fahrenheit; tidal river reaches, bay and gulf waters - 4 degrees Fahrenheit in fall, winter, and spring, and 1.5 degrees Fahrenheit in summer (June, July, and

August). Additional temperature criteria (expressed as maximum temperatures) for classified segments are specified in Appendix A of §307.10 of this title.

F.4.2.6. Salinity

Concentrations and the relative ratios of dissolved minerals such as chlorides, sulfates, and total dissolved solids will be maintained such that existing, designated, and attainable uses will not be impaired. Criteria for chlorides, sulfates, and total dissolved solids for classified freshwater segments are specified in Appendix A of §307.10 of this title.

F.4.2.7. Aquatic life uses and dissolved oxygen

(1) Dissolved oxygen concentrations shall be sufficient to support existing, designated, and attainable aquatic life uses. Aquatic-life use categories and corresponding dissolved oxygen criteria are described in §307.7(b)(3) of this title (relating to Site-specific Uses and Criteria).

(2) Aquatic life use categories and dissolved oxygen criteria for classified segments are specified in Appendix A of §307.10 of this title. Aquatic life use categories and dissolved oxygen criteria for other specific water bodies are specified in Appendix D of §307.10 of this title. Where justified by sufficient site-specific information, dissolved oxygen criteria which differ from §307.7(b)(3) of this title may be adopted for a particular water body in §307.10 of this title.

(3) Perennial streams, rivers, lakes, bays, estuaries, and other appropriate perennial waters which are not specifically listed in Appendix A or D of §307.10 of this title are presumed to have a high aquatic life use and corresponding dissolved oxygen criteria. In accordance with results from statewide ecoregion studies, unclassified perennial streams in southeast and northeast Texas are assigned dissolved oxygen criteria as indicated in §307.7(b)(3)(A)(ii) of this title. Higher uses will be protected where they are attainable.

(4) When water is present in the streambed of intermittent streams, a 24-hour dissolved oxygen mean of at least 2.0 mg/L and an absolute minimum dissolved oxygen concentration of 1.5 mg/L will be maintained. Intermittent streams which are not specifically listed in Appendix A or D of §307.10 of this title are considered to not have a significant aquatic life use except as indicated below in this subsection. For intermittent streams with seasonal aquatic life uses, dissolved oxygen concentrations commensurate with the aquatic life uses will be maintained during the seasons in which the aquatic life uses occur. Unclassified intermittent streams with significant aquatic life uses created by perennial pools are presumed to have a limited aquatic life use and corresponding dissolved oxygen criteria. Higher uses will be protected where they are attainable.

(5) Aquatic life uses and habitat. Vegetative and physical components of the aquatic environment will be maintained or mitigated to protect aquatic life uses. Procedures to protect habitat in permits for dredge and fill activities are specified in Federal Clean Water Act, §404 and in Chapter 279 of this title (relating to Water Quality Certification).

(6) Aquatic recreation. Existing, designated, and attainable uses of aquatic recreation will be maintained, as determined by criteria that indicate the potential presence of pathogens. Categories of recreation and applicable criteria are established in §307.7(b)(1) of this title. Contact recreation is presumed as a use for all water bodies except where listed otherwise for specific water bodies in Appendix A of §307.10 of this title.

(7) Assessment of unclassified waters. Waters which are not specifically listed in Appendices A or D of §307.10 of this title are designated for the specific uses that are attainable or characteristic of those waters. Upon administrative or regulatory action by the executive director or commission

which affects a particular unclassified water body, the characteristics of the affected water body will be reviewed by the agency to determine which aquatic life uses are appropriate. Additional uses so determined shall be indicated in public notices for discharge applications. Uses which are not applicable throughout the year in a particular unclassified water body will be assigned and protected for the seasons in which such uses are attainable. Initial determinations of use shall be considered preliminary, and in no way preclude redeterminations of use in public hearings conducted under the provisions of the Texas Water Code. For unclassified waters where the presumed minimum uses or criteria specified in this section are inappropriate, site-specific standards may be developed in accordance with §307.2(d) of this title (relating to Modification of Standards). Uses and criteria will be assigned in accordance with this section and with §307.7(b)(3) of this title. Procedures for assigning uses and criteria are described in the standards implementation procedures.

F.4.2.8. Numerical criteria for freshwater aquatic life

Numerical criteria in the Texas Water Quality Standards are presented in Table F.4.2.8. Numerical criteria are based on ambient water quality criteria documents published by EPA. EPA guidance criteria have been appropriately recalculated to eliminate the effects of toxicity data for aquatic organisms which are not native to Texas, in accordance with procedures in the EPA guidance document entitled *Guidelines for Deriving Numerical Site-specific Water Quality Criteria* (EPA 600/3-84-099). Specific numerical acute aquatic life criteria are applied as 24-hour averages, and specific numerical chronic aquatic life criteria are applied as seven-day averages. Specific numerical aquatic life criteria for metals and metalloids in Table 3 apply to dissolved concentrations where noted (d). Dissolved concentrations can be estimated by filtration of samples prior to analysis, or by converting from total recoverable measurements in accordance with procedures approved by the commission in the latest revision of the standards implementation procedures. Specific numerical aquatic life criteria for non-metallic substances in Table 3 apply to total recoverable concentrations unless otherwise noted.

For toxic materials for which specific numerical criteria are not listed in Table 3, the appropriate criteria for aquatic life protection may be derived in accordance with current EPA guidelines for deriving site-specific water quality criteria. When insufficient data are available to use EPA guidelines, the following provisions shall be applied in accordance with this section and §307.8 of this title:

(A) acute criteria will be calculated as 0.3 of the LC_{50} of the most sensitive aquatic species; LC_{50} x (0.3)= acute criteria;

(B) concentrations of non-persistent toxic materials shall not exceed concentrations which are chronically toxic (as determined from appropriate chronic toxicity data or calculated as 0.1 of acute LC_{50} values) to the most sensitive aquatic species; LC_{50} x (0.1) = chronic criteria;

(C) concentrations of persistent toxic materials that do not bioaccumulate shall not exceed concentrations which are chronically toxic (as determined from appropriate chronic toxicity data or calculated as 0.05 of LC_{50} values) to the most sensitive aquatic species; and

(D) concentrations of toxic materials that bioaccumulate shall not exceed concentrations that are chronically toxic (as determined from appropriate chronic toxicity data or calculated as 0.01 of LC_{50} values) to the most sensitive aquatic species.

For toxic substances where the relationship of toxicity is defined as a function of pH or hardness, numerical criteria are presented as an equation based on this relationship. Site-specific values for pH and hardness are used where available. When pH and hardness values are not known for a specific site in the Rio Grande basin, a pH of 7.7 and hardness of 250 mg/L are used to estimate toxicity criteria.

Table F.4.2.8. Numerical water quality criteria (micrograms per liter) for freshwater aquatic life.

Parameter	Freshwater acute criteria	Freshwater chronic criteria
Aldrin	3.0	---
Aluminum (d)	991w	---
Arsenic (d)	360w	190w
Cadmium (d)	$0.973w^{(1.128(\ln(hardness))-1.6774)}$	$0.909\ w^{(0.7852(\ln(hardness))-3.490)}$
Carbaryl	2.0	---
Chlordane	2.4	0.004
Chlorpyrifos	0.083	0.041
Chromium (Trivalent) (d)	$0.316w^{(0.8190(\ln(hardness))+3.688)}$	$0.860w^{(0.8190(\ln(hardness))+1.561)}$
Chromium (Hexavalent) (d)	15.7w	10.6w
Copper (d)	$0.960e^{(0.9422(\ln(hardness))-1.3844)}$	$0.960e^{(0.8545(\ln(hardness))-1.386)}$
Cyanide (free)	45.8	10.7
4,4'- DDT	1.1	0.001
Demeton	---	0.1
Dicofol	59.3	19.8
Dieldrin	2.5	0.002
Diuron	210	70
Endosulfan I (alpha)	0.22	0.056
Endosulfan II (beta)	0.22	0.056
Endosulfan sulfate	0.22	0.056
Endrin	0.18	0.002
Guthion	---	0.01
Heptachlor	0.52	0.004
Hexachlorocyclohexane (Lindane)	2.0	0.08
Lead (d)	$0.889e^{(1.273(\ln(hardness))-1.460)}$	$0.792e^{(1.273(\ln(hardness))-4.705)}$
Malathion	---	0.01
Mercury	2.4	1.3
Methoxychlor	---	0.03
Mirex	---	0.001
Nickel (d)	$0.998e^{(0.8460(\ln(hardness))+3.3612)}$	$0.997e^{(0.8460(\ln(hardness))+1.1645)}$
Parathion (ethyl)	0.065	0.013
Pentachlorophenol	$e^{(1.005(pH)-4.830)}$	$e^{(1.005(pH)-5.290)}$
Phenanthrene	30	30
Polychlorinated Biphenyls	2.0	0.014

Parameter	Freshwater acute criteria	Freshwater chronic criteria
(PCBs)		
Selenium	20	5
Silver, as free ion	0.8w	---
Toxaphene	0.78	0.0002
Tributlytin (TBT)	0.13	0.024
2,4,5 Trichlorophenol	136	64
Zinc (d)	$0.978e^{(0.8473(\ln(hardness))+0.8604)}$	$0.986e^{(0.8473(\ln(hardness))+0.7614)}$

(w) Indicates that a criterion is multiplied by a water-effects ratio in order to incorporate the effects of local water chemistry on toxicity. The water-effects ratio is equal to 1 except where sufficient data is available to establish a site-specific, water-effects ratio. Water-effects ratios for individual water bodies are listed in Appendix E when standards are revised. The number preceding the w in the freshwater criterion equation is an EPA conversion factor.

(d) Indicates dissolved concentrations are specified for that parameter.

F.4.2.9. Numerical criteria for human health protection

Categories of human health criteria include concentration criteria to prevent contamination of drinking water, fish and other aquatic life to ensure that they are safe for human consumption. These criteria apply to freshwaters which are designated or used for public drinking water supplies. (Column A in Table F.4.2.9), and concentration criteria to prevent contamination of fish and other aquatic life to ensure that they are safe for human consumption. These criteria apply to freshwaters which have sustainable fisheries, and are not used for public water supply (Column B in Table F.4.2.9).

Table F.4.2.9. Texas numerical water quality criteria (micrograms per liter) for human health.

Parameter	(A) Water	(B) Freshwater Fish
Acrylonitrile	1.28	10.9
Aldrin	0.00408	0.00426
Arsenic (d)	10	---
Barium (d)	2000	---
Benzene	5	106
Benzidine	0.00106	0.00347
Benzo(a)anthracene	0.099	0.81
Benzo(a)pyrene	0.099	0.81
Bis(chloromethyl)ether	0.00462	0.0193
Cadmium (d)	5	---
Carbon Tetrachloride	3.76	8.4
Chlordane	0.021	0.0213
Chlorobenzene	776	1,380
Chloroform	100	1,292
Chromium (d)	100	3,320
Chrysene	0.417	8.1

Appendix F. Chihuahuan Desert Water Resources and Water Quality Standards: An Overview, cont.

Parameter	(A) Water	(B) Freshwater Fish
Cresols	3,313	13,116
Cyanide (free)	200	---
4,4' - DDD	0.0103	0.010
4,4' - DDE	0.0073	0.007
4,4' - DDT	0.0073	0.007
2,4 - D	70	---
Danitol	0.709	0.721
Dibromochloromethane	9.2	71.6
1,2 - Dibromoethane	0.014	0.335
1,3 - Dichloropropene	22.8	161
Dieldrin	0.00171	0.002
p-Dichlorobenzene	75	---
1,2 - Dichloroethane	5	73.9
1,1 - Dichloroethylene	1.63	5.84
Dicofol	0.215	0.217
Dioxins/Furans (TCDD Equivalents)	1.34E-07	1.40E-07
Endrin	1.27	1.34
Fluoride	4	---
Heptachlor	0.00260	0.00265
Heptachlor Epoxide	0.159	1.1
Hexachlorobenzene	0.0194	0.0198
Hexachlorobutadiene	2.99	3.6
Hexachlorocyclohexane (alpha)	0.163	0.413
Hexachlorocyclohexane (beta)	0.570	1.45
Hexachlorocyclohexane (gamma)(Lindane)	0.2	2.00
Hexachloroethane	84.2	278
Hexachlorophene	0.0531	0.053
Lead (d)	4.98	25.3
Mercury	0.0122	0.0122
Methoxychlor	2.21	2.22
Methyl Ethyl Ketone	52,917	9.94E+06
Nitrate-Nitrogen as total Nitrogen	10,000	---
Nitrobenzene	37.3	233
N-Nitrosodiethylamine	0.0382	7.68
N-Nitroso-di-n-Butylamine	1.84	13.5
PCBs (Polychlorinated Biphenyls)	0.0013	0.0013

Parameter	(A) Water	(B) Freshwater Fish
Pentachlorobenzene	6.10	668
Pentachlorophenol	1.0	135
Pyridine	88.1	13,333
Selenium	50	---
1,2,4,5 -Tetrachlorobenzene	0.241	0.243
Tetrachloroethylene	5	323
Toxaphene	0.005	0.014
2,4,5 - TP (Silvex)	47.0	50.3
2,4,5 - Trichlorophenol	953	1,069
Trichloroethylene	5	612
1,1,1 - Trichloroethane	200	12,586
TTHM (Sum of total trihalomethanes)	100	---
Vinyl Chloride	2	415

F.4.3 Site-specific uses and associated criteria

(1) Recreation. Recreational use consists of two categories - contact recreation waters and noncontact recreation waters. Classified segments are designated for contact recreation unless elevated concentrations of indicator bacteria frequently occur due to sources of pollution which cannot be reasonably controlled by existing regulations or contact recreation is considered unsafe for other reasons such as ship or barge traffic. In a classified segment where contact recreation is considered unsafe for reasons unrelated to water quality, a designated use of noncontact recreation may be assigned criteria normally associated with contact recreation. A designation of contact recreation is not a guarantee that the water so designated is completely free of disease-causing organisms. Indicator bacteria, although not generally pathogenic, are indicative of potential contamination by feces of warm blooded animals. The criteria for contact recreation are based on these indicator bacteria, rather than direct measurements of pathogens. Criteria are expressed as the number of "colony forming units" of bacteria per 100 milliliters (ml) of water. Even where the concentration of indicator bacteria is less than the criteria for contact recreation, there is still some risk of contracting waterborne diseases.

Contact recreation. The geometric mean of *E. coli* should not exceed 126 per 100 mL. In addition, single samples of *E. coli* should not exceed 394 per 100 mL. The geometric mean of fecal coliform should not exceed 200 per 100 mL. In addition, single samples of fecal coliform should not exceed 400 per 100 mL.

Noncontact recreation. The geometric mean of *E. coli* should not exceed 605 per 100 mL. Fecal coliform shall not exceed 2,000 per 100 mL as a geometric mean. In addition, single samples of fecal coliform should not exceed 4,000 per 100 mL.

(2) Aquatic life. The establishment of numerical criteria for aquatic life is highly dependent on desired use, sensitivities of usual aquatic communities, and local physical and chemical characteristics. Five subcategories of aquatic life use are established. They include limited, intermediate, high, and exceptional aquatic life and oyster waters. Aquatic life use subcategories designated for segments listed in Appendix A of §307.10 of this title recognize the natural variability of aquatic community requirements and local environmental conditions.

Dissolved oxygen: The characteristics and associated dissolved oxygen criteria for limited, intermediate, high, and exceptional aquatic life use subcategories are indicated in Table F.4.3.

Table F.4.3. Dissolved oxygen criteria for aquatic life uses.

Aquatic life use category	Dissolved oxygen criteria, mg/L	
	Freshwater mean/minimum	Freshwater in Spring mean/minimum
Exceptional	6.0 / 4.0	6.0 / 5.0
High	5.0 / 3.0	5.5 / 4.5
Intermediate	4.0 / 3.0	5.0 / 4.0
Limited	3.0 / 2.0	4.0 / 3.0

Dissolved oxygen means are applied as a minimum average over a 24-hour period. Daily minima are not to extend beyond 8 hours per 24-hour day. Lower dissolved oxygen minima may apply on a site-specific basis, when natural daily fluctuations below the mean are greater than the difference between the mean and minima of the appropriate criteria. Spring criteria to protect fish spawning periods are applied during that portion of the first half of the year when water temperatures are 63.0^{o} F to 73.0^{o} F.

Segment-specific criteria for chloride, sulfate, and total dissolved-solids (TDS) concentrations are given for three Rio Grande segments within the area of Big Bend National Park, the Rio Grande Wild & Scenic River section, and Amistad International Reservoir. All three segments are classified for contact recreation, high aquatic life uses, and domestic water supply. The dissolved oxygen criterion is 5.0 mg/L, the acceptable pH range is 6.5 - 9.0 standard units, and the indicator bacteria (*E. coli*) criterion is 126 colonies per 100 mL. For Amistad International Reservoir (Segment 2305) the chloride, sulfate, and TDS criteria are 150 mg/L, 270 mg/L, and 800 mg/L, respectively. For the Rio Grande upstream from Amistad Reservoir (Segment 2306), the criteria are 300 mg/L, 570 mg/L, and 1,550 mg/L, respectively. For the Rio Grande below Riverside Diversion Dam (Segment 2307), the criteria are 300 mg/L, 550 mg/L, and 1,500 mg/L, respectively.

F.4.3.1. Nutrient criteria

Although the EPA has encouraged states to develop nutrient criteria for streams and rivers for nearly 10 years (EPA 2000), TCEQ has yet to develop such criteria for Texas surface water bodies. Nutrients are forms of nitrogen and phosphorus that can stimulate undesirable growths of algae and other aquatic plants in surface waters, a common manifestation of eutrophication processes. The only form of nutrients that is currently regulated by TCEQ is ammonia nitrogen (NH_4^+ or NH_3); potential toxic effects on aquatic organisms is evaluated on a case-by-case basis and no numerical criteria currently (2009) exist. Numerical criteria for nutrient concentrations most likely will be promulgated by TCEQ in the coming years, thus, NPS personnel should be encouraged to consult with TCEQ from time to time to determine when Texas nutrient criteria will be available for comparison with monitoring data collected from rivers and streams. Common nutrient constituents include ammonia nitrogen, nitrate nitrogen (NO_3), total nitrogen (often as Total Kjeldahl Nitrogen, TKN), dissolved orthophosphate (PO_4), and total phosphorus (TP).

F.5 State of New Mexico Water Quality Standards—New Mexico Environment Department (NMED)

A complete listing of water quality criteria for New Mexico is available through the New Mexico Environment Department (NMED) at http://www.nmenv.state.nm.us/swqb/standards/index.html.

Similar to Texas, the New Mexico water quality criteria are based on general provisions of the EPA Clean Water Act. Copies of 305(b) and 303(d) reports can be retrieved at: http://www.nmenv.state.nm.us/swqb/303d-305b/2008-2010/. A number of surface-water bodies in the Tularosa Valley without prior beneficial uses were recently added to the 303(d) list of impaired water bodies based on a presumed use of "marginal warmwater aquatic life" (MWWAL). These water bodies include Lake Holloman, Lake Lucero (North), Lake Lucero (South), Lake Stinky, Malpais Springs, and Mound Springs, some of which are located within the boundary of White Sands National Monument (or Holloman Air Force Base). CHDN should monitor NMED activities relative to these and other potential additions to the 303(d) list in the Tularosa Valley.

Narrative water quality criteria for New Mexico are similar to those mentioned previously for Texas. In addition, New Mexico classifies streams by the following categories and promulgates numerical criteria for certain constituents:

EPHEMERAL WATERS - All ephemeral surface waters of the state that are not included in a classified water of the state in 20.6.4.101 through 20.6.4.899 NMAC.

A. Designated Uses: livestock watering, wildlife habitat, limited aquatic life and secondary contact.

B. Criteria:

(1) The use-specific criteria in 20.6.4.900 NMAC, with the exception of the chronic criteria for aquatic life, are applicable for the designated uses listed in Subsection A of this section.

(2) The monthly geometric mean of *E. coli* bacteria shall not exceed 548 cfu (colony forming units)/100 mL, no single sample shall exceed 2507 cfu/100 mL (see Subsection B of 20.6.4.14 NMAC).

INTERMITTENT WATERS - All intermittent surface waters of the state that are not included in a classified water of the state in 20.6.4.101 through 20.6.4.899 NMAC.

A. Designated Uses: livestock watering, wildlife habitat, aquatic life and secondary contact.

B. Criteria:

(1) The use-specific criteria in 20.6.4.900 NMAC.

(2) The monthly geometric mean of *E. coli* bacteria shall not exceed 548 cfu/100 mL, no single sample shall exceed 2507 cfu/100 mL (see Subsection B of 20.6.4.14 NMAC).

PERENNIAL WATERS - All perennial surface waters of the state that are not included in a classified water of the state in 20.6.4.101 through 20.6.4.899 NMAC.

A. Designated Uses: aquatic life, livestock watering, wildlife habitat and secondary contact.

B. Criteria:

(1) Temperature shall not exceed 34°C (93.2°F). The use-specific criteria in 20.6.4.900 NMAC are applicable to the designated uses listed in Subsection A of this section.

(2) The monthly geometric mean of *E. coli* bacteria shall not exceed 548 cfu/100 mL, no single sample shall exceed 2507 cfu/100 mL (see Subsection B of 20.6.4.14 NMAC).

PECOS RIVER BASIN - The main stem of the Pecos river from the New Mexico-Texas line upstream to the mouth of the Black river (near Loving). This basin would include discharges from Rattlesnake Spring to an un-named tributary to the Black River.

A. Designated Uses: irrigation, livestock watering, wildlife habitat, secondary contact and warmwater aquatic life.

B. Criteria:

(l) In any single sample: pH within the range of 6.6 to 9.0 and temperature 32.2°C (90°F) or less. The use-specific numeric criteria set forth in 20.6.4.900 NMAC are applicable to the designated uses listed above in Subsection A of this section.

(2) The monthly geometric mean of *E. coli* bacteria 126 cfu/100 mL or less; single sample 410 cfu/100 mL or less (see Subsection B of 20.6.4.14 NMAC).

(3) At all flows above 50 cfs: TDS 20,000 mg/L or less, sulfate 3,000 mg/L or less and chloride 10,000 mg/L or less.

CRITERIA APPLICABLE TO ATTAINABLE OR DESIGNATED USES

A. Fish Culture, Water Supply and Storage: Fish culture and municipal and industrial water supply and storage are designated uses in particular classified waters of the state where these uses are actually being realized. However, no numeric criteria apply uniquely to these uses. Water quality adequate for these uses is ensured by the general criteria and numeric criteria for bacterial quality, pH and temperature that are established for all classified waters of the state listed in 20.6.4.97 through 20.6.4.899 NMAC.

B. Domestic Water Supply: Surface waters of the state designated for use as domestic water supplies shall not contain substances in concentrations that create a lifetime cancer risk of more than one cancer per100,000 exposed persons. Those criteria listed under domestic water supply in Subsection J of this section apply to this use.

C. Irrigation and Irrigation Storage: The following numeric criteria and those criteria listed under irrigation in Subsection J of this section apply to this use:

(1) dissolved selenium 0.13 mg/L

(2) dissolved selenium in presence of >500 mg/L SO4 0.25 mg/L

D. Primary Contact: The monthly geometric mean of *E. coli* bacteria of 126 cfu/100 mL and single sample of 410 cfu/100 mL, apply to this use and pH shall be within the range of 6.6 to 9.0.

E. Secondary Contact: The monthly geometric mean of *E. coli* bacteria of 548 cfu/100 mL and single sample of 2507 cfu/100 mL apply to this use.

F. Livestock Watering: The criteria listed in Subsection J for livestock watering apply to this use.

G. Wildlife Habitat: Wildlife habitat shall be free from any substances at concentrations that are toxic to or will adversely affect plants and animals that use these environments for feeding, drinking, habitat or propagation; can bioaccumulate; or might impair the community of animals in a watershed or the ecological integrity of surface waters of the state. The discharge of substances that bioaccumulate, in excess of levels listed in Subsection J for wildlife habitat is allowed if, and only to the extent that, the substances are present in the intake waters that are diverted and utilized prior to discharge, and then only if the discharger utilizes best available treatment technology to reduce the amount of bioaccumulating substances that are discharged. The numeric criteria listed in Subsection J for wildlife habitat apply to this use except when a site-specific or segment-specific criterion has been adopted under 20.6.4.101 through 20.6.4.899 NMAC.

H. Aquatic Life: Surface waters of the state with a designated, existing or attainable use of aquatic life shall be free from any substances at concentrations that can impair the community of plants and animals in or the ecological integrity of surface waters of the state. Except as provided in paragraph 6 below, the acute and chronic aquatic life criteria set out in subsections I and J of this section are applicable to this use. In addition, the specific criteria for aquatic life subcategories in the following paragraphs shall apply to waters classified under the respective designations.

(1) High Quality Coldwater: Dissolved oxygen 6.0 mg/L or more, temperature 20°C (68°F) or less, pH within the range of 6.6 to 8.8 and specific conductance a limit varying between 300 µmhos/cm and 1,500 µmhos/cm depending on the natural background in particular surface waters of the state (the intent of this criterion is to prevent excessive increases in dissolved solids which would result in changes in community structure). The total ammonia criteria set out in Subsections K, L and M of this section and the human health criteria for pollutants listed in Subsection J of this section are applicable to this use.

(2) Coldwater: Dissolved oxygen 6.0 mg/L or more, temperature 20°C (68°F) or less and pH within the range of 6.6 to 8.8. The total ammonia criteria set out in Subsections K, L and M of this section and the human health criteria listed in Subsection J of this section are applicable to this use.

(3) Marginal Coldwater: Dissolved oxygen than 6 mg/L or more, on a case by case basis maximum temperatures may exceed 25°C (77°F) and the pH may range from 6.6 to 9.0. The total ammonia criteria set out in Subsections K, L and M of this section and the human health criteria listed in Subsection J of this section are applicable to this use.

(4) Warmwater: Dissolved oxygen 5 mg/L or more, temperature 32.2°C (90°F) or less, and pH within the range of 6.6 to 9.0. The total ammonia criteria set out in Subsections K, L and M of this section and the human health criteria listed in Subsection J of this section are applicable to this use.

(5) Marginal Warmwater: Dissolved oxygen 5 mg/L or more, pH within the range of 6.6 to 9.0 and on a case by case basis maximum temperatures may exceed 32.2°C (90°F). The total ammonia criteria set out in Subsections K, L and M of this section and the human health criteria listed in Subsection J of this section are applicable to this use.

(6) Limited Aquatic Life: Criteria shall be developed on a segment-specific basis. The acute aquatic life criteria of Subsections I and J of this section shall apply. Chronic aquatic life criteria do not apply unless adopted on a segment specific basis.

The following schedule of equations for the determination of numeric criteria for the substances listed and those criteria listed in Subsection J for aquatic life shall apply to the subcategories of aquatic life identified in this section.

(1) Acute criteria:

(a) dissolved silver 0.85 e(1.72(ln(hardness))-6.59) µg/L

(b) dissolved cadmium (e(1.0166(ln(hardness))-3.924))cf µg/L, the hardness-dependent formulae for cadmium must be multiplied by a conversion factor (cf) to be expressed as dissolved values; the acute factor for cadmium is cf = 1.136672 - ((ln hardness)(0.041838))

(c) dissolved chromium 0.316 e(0.819(ln(hardness))+3.7256) µg/L

(d) dissolved copper 0.960 e(0.9422(ln(hardness))-1.700) µg/L

(e) dissolved lead (e(1.273(ln(hardness))-1.46))cf µg/L, the hardness-dependent formulae for lead must be multiplied by a conversion factor (cf) to be expressed as dissolved values; the acute and chronic factor for lead is cf = 1.46203 - ((ln hardness)(0.145712))

(f) dissolved nickel 0.998 e(0.8460(ln(hardness))+2.255) µg/L

(g) dissolved zinc 0.978 e(0.8473(ln(hardness))+0.884) µg/L

(2) Chronic criteria:

(a) dissolved cadmium (e(0.7409(ln(hardness))-4.719))cf µg/L, the hardness-dependent formulae for cadmium must be multiplied by a conversion factor (cf) to be expressed as dissolved values; the chronic factor for cadmium is cf = 1.101672 - ((ln hardness)(0.041838))

(b) dissolved chromium 0.860 e(0.819(ln(hardness))+0.6848) µg/L

(c) dissolved copper 0.960 e(0.8545(ln(hardness))-1.702) µg/L

(d) dissolved lead (e(1.273(ln(hardness))-4.705))cf µg/L, the hardness-dependent formulae for lead must be multiplied by a conversion factor (cf) to be expressed as dissolved values; the acute and chronic factor for lead is cf = 1.46203 - ((ln hardness)(0.145712))

(e) dissolved nickel 0.997 e(0.846(ln(hardness))+0.0584) µg/L

(f) dissolved zinc 0.986 e(0.8473(ln(hardness))+0.884) µg/L

Table F.5 presents chronic total ammonia criteria as a function of pH and water temperature.

Table F.5. Chronic Criteria, Total Ammonia (mg/L), Fish Early Life Stages Present

	Temperature (^oC)										
pH	**0**	**14**	**15**	**16**	**18**	**24**	**20**	**24**	**26**	**28**	**30**
6.5	6.67	6.67	6.46	6.06	5.33	4.68	4.12	3.62	3.18	2.8	2.46
6.6	6.57	6.57	6.36	5.97	5.25	4.61	4.05	3.56	3.13	2.75	2.42
6.7	6.44	6.44	6.25	5.86	5.15	4.52	3.98	3.50	3.07	2.70	2.37
6.8	6.29	6.29	6.10	5.72	5.03	4.42	3.89	3.42	3.00	2.64	2.32
6.9	6.12	6.12	5.93	5.56	4.89	4.30	3.78	3.32	2.92	2.57	2.25
7.0	5.91	5.91	5.73	5.37	4.72	4.15	3.65	3.21	2.82	2.48	2.18
7.1	5.67	5.67	5.49	5.15	4.53	3.98	3.5	3.08	2.7	2.38	2.09
7.2	5.39	5.39	5.22	4.90	4.31	3.78	3.33	2.92	2.57	2.26	1.99
7.3	5.08	5.08	4.92	4.61	4.06	3.57	3.13	2.76	2.42	2.13	1.87
7.4	4.73	4.73	4.59	4.30	3.78	3.32	2.92	2.57	2.26	1.98	1.74
7.5	4.36	4.36	4.23	3.97	3.49	3.06	2.69	2.37	2.08	1.83	1.61
7.6	3.98	3.98	3.85	3.61	3.18	2.79	2.45	2.16	1.9	1.67	1.47
7.7	3.58	3.58	3.47	3.25	2.86	2.51	2.21	1.94	1.71	1.50	1.32
7.8	3.18	3.18	3.09	2.89	2.54	2.23	1.96	1.73	1.52	1.33	1.17
7.9	2.80	2.80	2.71	2.54	2.24	1.96	1.73	1.52	1.33	1.17	1.03
8.0	2.43	2.43	2.36	2.21	1.94	1.71	1.50	1.32	1.16	1.02	0.897
8.1	2.10	2.10	2.03	1.91	1.68	1.47	1.29	1.14	1.00	0.879	0.773
8.2	1.79	1.79	1.74	1.63	1.43	1.26	1.11	0.973	0.855	0.752	0.661
8.3	1.52	1.52	1.48	1.39	1.22	1.07	0.941	0.827	0.727	0.639	0.562
8.4	1.29	1.29	1.25	1.17	1.03	0.906	0.796	0.700	0.615	0.541	0.475
8.5	1.09	1.09	1.06	0.990	0.87	0.765	0.672	0.591	0.520	0.457	0.401
8.6	0.920	0.920	0.892	0.836	0.735	0.646	0.568	0.499	0.439	0.386	0.339
8.7	0.770	0.770	0.754	0.707	0.622	0.547	0.480	0.422	0.371	0.326	0.287
8.8	0.660	0.660	0.641	0.601	0.528	0.464	0.408	0.359	0.315	0.277	0.244
8.9	0.560	0.560	0.548	0.513	0.451	0.397	0.349	0.306	0.269	0.237	0.208
9.0	0.480	0.480	0.471	0.442	0.389	0.342	0.300	0.264	0.232	0.204	0.179

Currently, the State of New Mexico has narrative criteria to determine nutrient impairment, which states: "Plant nutrients from other than natural causes shall not be present in concentrations which will produce undesirable aquatic life or result in a dominance of nuisance species in surface waters of the state" (NMAC 2005).

This narrative criterion can be challenging to assess because the relationships between nutrient levels and impairment of designated uses are not defined, and distinguishing nutrients from "other than natural causes" is difficult. Therefore, the Surface Water Quality Bureau's Monitoring and Assessment Section

(SWQB/MAS) (with the assistance from the U.S. Environmental Protection Agency [EPA] and the U.S. Geological Survey [USGS]), developed a Nutrient Assessment Protocol to assist in meeting these challenges. The protocol was developed for wadeable streams because they represent the majority of assessed surface waters in the state. It addresses both cause (total nitrogen and total phosphorus) and response variables (DO, pH, periphyton chlorophyll a, and benthic macroinvertebrate metrics) and uses a weight-of-evidence approach. Analysis of existing data and literature reviews were utilized to develop impairment threshold values for each of the cause and response variables to translate the narrative nutrient criterion into quantifiable endpoints.

F.6 Water Resource Monitoring in the Chihuahuan Desert Network

A survey of water monitoring projects was conducted for the parks in the CHDN. Long-term monitoring of surface-water and groundwater resources in and near CHDN parks has been undertaken by individual park units within the CHDN, International Boundary and Water Commission (IBWC), New Mexico Office of the State Engineer (NMOSE), TCEQ, Texas Water Development Board (TWDB), and the USGS. Within the Texas part of the CHDN, long- term water-quality monitoring is largely restricted to the Rio Grande and its tributaries. Sites of long-term and current surface -water and Chihuahuan Desert Network Water Resource Information and Assessment Report groundwater-resources monitoring within and near CHDN parks are shown in Tables F.6-1 and F.6-2.

Table F.6-1. Location of, and information on, selected surface-water monitoring sites within and near Chihuahuan Desert Network park units.

Park unit	Station number	Station operator	Latitude	Longitude	Station description	Years of continuous gage operation	First and last years of water-quality record	Water-quality data collected
AMIS	13835	TCEQ	29° 27' 30"	101° 03' 26"	AMISTAD RESERVOIR AT BOUY NUMBER 1	—	1999-2005 (TCEQ)	selected basic water-quality parameters 2, nutrients, inorganics, bacteria, metals
AMIS	15340	TCEQ	29° 25' 27"	101° 02' 28"	RIO GRANDE BELOW AMISTAD RESERVOIR	—	1997-current (TCEQ)	selected basic water-quality parameters 2, nutrients, inorganics, bacteria, metals
AMIS	15892	TCEQ	29° 37' 31"	101° 15' 04"	AMISTAD RESERVOIR, RIO GRANDE ARM	—	1997-2005 (TCEQ)	selected basic water-quality parameters 2, nutrients, inorganics, bacteria, metals
AMIS	15893	TCEQ	29° 36' 05"	100° 58' 34"	AMISTAD RESERVOIR, DEVILS RIVER ARM	—	1997-2005 (TCEQ)	selected basic water-quality parameters 2, nutrients, inorganics, bacteria, metals
AMIS	8377200	IBWC	29° 46' 50 "	101° 45' 20 "	RIO GRANDE AT FOSTER RANCH NEAR LANGTRY, TEXAS	1961–current	1973-current (USGS)	NASQAN parameters 1
AMIS	8447410	IBWC	29° 48' 10 "	101° 26' 45 "	PECOS RIVER NEAR LANGTRY, TEXAS	1967–current	1971-current (USGS)	NASQAN parameters 1
AMIS	8449000	USGS	29° 57' 48"	101° 08' 42"	DEVILS RIVER NEAR JUNO, TEXAS	1925–1973	1964-1970 (USGS)	selected basic water-quality parameters 2, nutrients, inorganics
AMIS	8449400	IBWC	29° 40' 35 "	101° 00' 00 "	DEVILS RIVER AT PAFFORD CROSSING NEAR COMSTOCK, TEXAS	1900–1914; 1960–current	1973-2006 (TCEQ)	selected basic water-quality parameters 2, nutrients, inorganics, bacteria, metals
AMIS	8450800	IBWC	--	--	INTERNATIONAL AMISTAD RESERVOIR STORAGE	1968–current	--	--
AMIS	8450900	IBWC	29° 25' 30 "	101° 02' 27 "	RIO GRANDE BELOW AMISTAD DAM NEAR CD. ACUNA	1954–current	1971-2005 (USGS)	NASQAN parameters 1

Appendix F. Chihuahuan Desert Water Resources and Water Quality Standards: An Overview, cont.

Park unit	Station number	Station operator	Latitude	Longitude	Station description	Years of continuous gage operation	First and last years of water-quality record	Water-quality data collected
AMIS	8451300	IBWC	29° 23' 15 "	100° 56' 00 "	CANTU SPRING NEAR DEL RIO, TEXAS	1961–current	--	--
AMIS	8451500	IBWC	29° 21' 10 "	100° 56' 35 "	CIENEGAS CREEK NEAR DEL RIO, TEXAS	1965–current	--	--
AMIS	8451800	IBWC	29° 20' 07"	100° 55' 41"	RIO GRANDE AT DEL RIO, TEXAS	1923–1941; 1968–current	--	--
BIBE/ RIGR	08371200	IBWC	30° 10' 30"	104° 41' 10"	RIO GRANDE NEAR CANDELARIA, TEXAS	1975–present	--	--
BIBE/ RIGR	8371500	IBWC	29° 36' 15"	104° 27' 05"	RIO GRANDE ABOVE RIO CONCHOS NEAR PRESIDIO, TEXAS	1889–current	--	--
BIBE/ RIGR	08373000	IBWC	29° 34' 57"	104° 25' 52"	RIO CONCHOS NEAR OJINAGA, CHIHUAHUA	1896–1913; 1924–current	--	--
BIBE/ RIGR	08374000	IBWC	29° 31' 25"	104° 17' 15"	ALAMITO CREEK NEAR PRESIDIO, TEXAS	1932–current	--	--
BIBE/ RIGR	08374200	IBWC	29° 31' 10"	104° 17' 10"	RIO GRANDE BELOW RIO CONCHOS NEAR PRESIDIO, TEXAS	1955–current	1999-current (USGS)	NASQAN parameters 1
BIBE/ RIGR	08374500	IBWC	29° 12' 10"	103° 37' 10"	TERLINGUA CREEK NEAR TERLINGUA, TEXAS	1932–current	--	--
BIBE/ RIGR	08374550	TCEQ	29° 08' 14"	103° 31' 28"	RIO GRANDE NEAR CASTOLON, TEXAS	2005–current	2005-current (TCEQ)	selected basic water-quality parameters 2, nutrients, inorganics
BIBE/ RIGR	08375000	IBWC	29° 02' 05"	103° 23' 25"	RIO GRANDE AT JOHNSON RANCH NEAR CASTOLON, TEXAS	1936–current	--	--

Appendix F. Chihuahuan Desert Water Resources and Water Quality Standards: An Overview, cont.

Park unit	Station number	Station operator	Latitude	Longitude	Station description	Years of continuous gage operation	First and last years of water-quality record	Water-quality data collected
BIBE/ RIGR	08375300	TCEQ	29° 11' 08"	102° 58' 23"	RIO GRANDE AT BIG BEND NATIONAL PARK, TEXAS	2005–current	2005-current (TCEQ)	selected basic water-quality parameters 2
BIBE/ RIGR	08376300	USGS	30° 07' 42"	102° 23' 04"	SANDERSON CREEK AT SANDERSON, TEXAS	2003–current	--	--
BIBE/ RIGR	08450805	IBWC	29° 26' 37"	101° 03' 27"	CARMINA SPRINGS NEAR CD. ACUNA, COAHUILA	1969–current	--	--
BIBE/ RIGR	08450904	IBWC	29° 25' 20"	101° 02' 40"	SPRING M-15 NEAR CD. ACUNA, COAHUILA	1969–current	--	--
BIBE/ RIGR	08450905	IBWC	29° 24' 25"	101° 02' 20"	ARROYO DE LOS JABONCILLOS NEAR CD. ACUNA, COAHUILA	1969–current	--	--
BIBE/ RIGR	08450906	IBWC	29° 25' 20"	101° 02' 35"	SPRING M-5 NEAR CD. ACUNA, COAHUILA	1969–current	--	--
BIBE/ RIGR	8450910	IBWC	29° 24' 20 "	101° 02' 25 "	ARROYO DEL BUEY NEAR CD. ACUNA, COAHUILA	1961–current	--	--
BIBE/ RIGR	8451120	IBWC	29° 24 '00 "	101° 01' 55 "	MARIS SPRING NEAR CD. ACUNA, COAHUILA	1961–1984; 1985–current	--	--
BIBE/ RIGR	8451130	IBWC	29° 24' 00 "	101° 00' 55 "	EIGHT MILE CREEK NEAR DEL RIO, TEXAS	1961–current	--	--
BIBE/ RIGR	8451140	IBWC	29° 23' 35 "	101° 01' 15 "	MCKEE SPRING NEAR DEL RIO, TEXAS	1961–current	--	--
BIBE/ RIGR	8451150	IBWC	29° 22' 35 "	101° 01' 15 "	ARROYO DE LA TREINTA Y UNA NEAR CD. ACUNA, COAHUILA	1961–current	--	--

Park unit	Station number	Station operator	Latitude	Longitude	Station description	Years of continuous gage operation	First and last years of water-quality record	Water-quality data collected
CAVE	8405300	USGS	32° 06' 36"	104° 28' 17"	RATTLESNAKE SPRING NEAR WHITES CITY, NM	1961–1962	--	--
CAVE	8405301	USGS	32° 06' 32"	104° 28' 17"	RATTLESNAKE SPRING EAST NEAR WHITES CITY, NM	2003–2004	--	--
CAVE	8405303	USGS	32° 06' 38"	104° 28' 16"	RATTLESNAKE SPRING NORTH NEAR WHITES CITY, NM	2003–2004	--	--
FODA	8431700	USGS	30° 36' 48"	104° 00' 04"	LINPIA CREEK ABOVE FORT DAVIS, TEXAS	1965–current	1967-1986 (USGS)	NASQAN parameters

Table F.8. Location of and information on selected groundwater monitoring sites within and near Chihuahuan Desert Network.

Park unit	Well number	Data source	Aquifer	Latitude	Longitude	First and last years of water–level record	First and last years of water–quality record	Water-quality parameters
AMIS	5455904	TWDB	Edwards Limestone	30° 07' 57"	101° 09' 34"	2004–2004	1999–2004	temperature, specific conductance, pH, major inorganics
AMIS	7112503	TWDB	Edwards Limestone	29° 48' 51"	101° 34' 05"	1967–1968	—	--
AMIS	7122403	TWDB	Edwards Limestone	29° 42' 06"	101° 21' 54"	—	1994–1994	temperature, specific conductance, pH, major inorganics
AMIS	7122501	TWDB	Edwards Limestone	29° 42' 16"	101° 19' 27"	1977–2003	1977–2003	temperature, specific conductance, pH, major inorganics
AMIS	7123506	TWDB	Edwards Limestone	29° 41' 51"	101° 11' 10"	1990–1990	1997–1997	temperature, specific conductance, pH, major inorganics
AMIS	7140302	TWDB	Edwards Limestone	29° 27' 59"	101° 01' 21"	1962–1964	1967–1967	temperature, specific conductance, pH, major inorganics
AMIS	7140303	TWDB	Edwards Limestone	29° 28' 10"	101° 01' 03"	1964–1969	1964–1969	temperature, specific conductance, pH, major inorganics
AMIS	7140501	TWDB	Edwards Limestone	29° 27' 03"	101° 03' 12"	1964–1964	1964–1964	temperature, specific conductance, pH, major inorganics
AMIS	7140602	TWDB	Edwards Limestone	29° 27' 29"	101° 01' 46"	1966–1993	1993–1993	temperature, specific conductance, pH, major inorganics
BIBE	7249401	TWDB	Santa Elena Limestone	29° 10' 52"	102° 59' 32"	—	1994–1998	temperature, specific conductance, pH, major inorganics
BIBE	7249501	TWDB	Edwards-Trinity	29° 10' 56"	102° 57' 09"	—	1987–2003	temperature, specific conductance, pH, major inorganics
BIBE	7249503	TWDB	Upper Cretaceous	29° 10' 55"	102° 57' 12"	—	1977–1994	temperature, specific conductance, pH, major inorganics

Appendix F. Chihuahuan Desert Water Resources and Water Quality Standards: An Overview, cont.

Park unit	Well number	Data source	Aquifer	Latitude	Longitude	First and last years of water–level record	First and last years of water–quality record	Water-quality parameters
BIBE	7346701	TWDB	Tertiary Volcanics	29° 16' 56"	103° 20' 12"	—	1954–1994	temperature, specific conductance, pH, major inorganics
BIBE	7346702	TWDB	Tertiary Volcanics	29° 17' 28"	103° 20' 12"	1989–1989	—	--
BIBE	7346703	TWDB	Tertiary Volcanics	29° 17' 27"	103° 20' 03"	1989–1989	—	--
BIBE	7346704	TWDB	Upper Cretaceous	29° 16' 25"	103° 20' 07"	—	1954–1989	temperature, specific conductance, pH, major inorganics
BIBE	7346803	TWDB	Alluvium	29° 16' 44"	103° 18' 08"	—	1961–1987	temperature, specific conductance, pH, major inorganics
BIBE	7346804	TWDB	Alluvium	29° 16' 48"	103° 19' 46"	—	1972–1987	temperature, specific conductance, pH, major inorganics
BIBE	7347401	TWDB	Alluvium and Cretaceous	29° 19' 12"	103° 12' 44"	1979–1985	1973–1994	temperature, specific conductance, pH, major inorganics
BIBE	7347501	TWDB	Upper Cretaceous	29° 19' 43"	103° 11' 57"	—	—	--
BIBE	7347504	TWDB	Upper Cretaceous	29° 18' 26"	103° 10' 57"	1979–1984	1977–1994	temperature, specific conductance, pH, major inorganics
BIBE	7347505	TWDB	Upper Cretaceous	29° 18' 09"	103° 10' 41"	1979–1979	1977–1987	temperature, specific conductance, pH, major inorganics
BIBE	7352901	TWDB	Rio Grande Alluvium	29° 08' 01"	103° 30' 56"	—	1980–1982	temperature, specific conductance, pH, major inorganics
BIBE	7352902	TWDB	Rio Grande Alluvium	29° 08' 19"	103° 31' 26"	—	1987–1994	temperature, specific conductance, pH, major inorganics
BIBE	7352903	TWDB	Alluvium and Cretaceous	29° 08' 24"	103° 31' 25"	—	1977–1977	major inorganics
BIBE	7352904	TWDB	Alluvium and Cretaceous	29° 08' 52"	103° 30' 32"	1979–1979	1979–1979	temperature, specific conductance, pH, major inorganics
BIBE	7352905	TWDB	Rio Grande Alluvium	29° 08' 20"	103° 31' 30"	1985–1985	1987–1994	temperature, specific conductance, pH, major inorganics

Appendix F. Chihuahuan Desert Water Resources and Water Quality Standards: An Overview, cont.

Park unit	Well number	Data source	Aquifer	Latitude	Longitude	First and last years of water–level record	First and last years of water–quality record	Water-quality parameters
BIBE	7352906	TWDB	Rio Grande Alluvium	29° 08' 23"	103° 31' 23"	—	1987–1994	temperature, specific conductance, pH, major inorganics
CAVE	3.2E+14	USGS	Capitan Reef	32° 17' 41"	104° 20' 49"	1963–1999	—	--
CAVE	3.2E+14	USGS	Capitan Reef	32° 22' 35"	104° 19' 10"	1947–1998	—	--
CAVE	3.2E+14	USGS	Capitan Reef	32° 23' 29"	104° 16' 18"	1955–1998	—	--
CAVE	3.2E+14	USGS	Capitan Reef	32° 23' 30"	104° 15' 53"	1947–2003	—	--
CAVE	3.2E+14	USGS	Capitan Reef	32° 24' 11"	104° 14' 54"	1954–2003	—	--
CAVE	3.2E+14	USGS	Capitan Reef	32° 24' 56"	104° 16' 49"	1953–2003	—	--
CAVE	C-00509	NMOSE	--	32° 05' 37"	104° 29' 39"	1954–1954	—	--
CAVE	C-00860	NMOSE	--	32° 11' 17"	104° 21' 27"	1958–1958	—	--
CAVE	C-01367	NMOSE	--	32° 06' 30"	104° 27' 36"	1967–1967	—	--
CAVE	C-01546	NMOSE	--	32° 09' 59"	104° 22' 29"	—	—	--
CAVE	C-02047	NMOSE	--	32° 07' 23"	104° 28' 38"	—	—	--
CAVE	C-02236	NMOSE	--	32° 06' 30"	104° 27' 05"	1992–1992	—	--
CAVE	C-02815	NMOSE	--	32° 07' 09"	104° 30' 57"	—	—	--
GUMO	4701401	TWDB	Quaternary Alluvium	31° 56' 39"	104° 58' 02"	1948–1948	—	--
GUMO	4702501	TWDB	Capitan Reef Complex	31° 55' 08"	104° 48' 25"	—	—	--
GUMO	4702801	TWDB	Capitan Reef Complex	31° 54' 53"	104° 48' 06"	1973–1974	1973–1974	temperature, specific conductance, pH, major inorganics
GUMO	4702802	TWDB	Capitan Reef Complex	31° 54' 26"	104° 48' 03"	—	1995–1999	temperature, specific conductance, pH, major inorganics
GUMO	4709101	TWDB	Quaternary Alluvium	31° 50' 25"	104° 57' 38"	1949–1949	—	--

Appendix F. Chihuahuan Desert Water Resources and Water Quality Standards: An Overview, cont.

Park unit	Well number	Data source	Aquifer	Latitude	Longitude	First and last years of water–level record	First and last years of water–quality record	Water-quality parameters
GUMO	4717217	TWDB	Quaternary Alluvium	31° 43' 54"	104° 57' 20"	1972–1972	—	--
GUMO	4717301	TWDB	Capitan Reef Complex	31° 43' 32"	104° 54' 06"	1960–1993	1960–1963	temperature, specific conductance, pH, major inorganics
GUMO	4717302	TWDB	Capitan Reef Complex	31° 43' 31"	104° 54' 06"	1958–2006	1964–2003	temperature, specific conductance, pH, major inorganics
GUMO	4717303	TWDB	Capitan Reef Complex	31° 43' 30"	104° 54' 06"	1959–1993	1992–1992	temperature, specific conductance, pH, major inorganics
GUMO	4717304	TWDB	Capitan Reef Complex	31° 44' 22"	104° 54' 03"	1965–2003	1965–1965	temperature, specific conductance, pH, major inorganics
GUMO	4717307	TWDB	Capitan Reef Complex	31° 44' 05"	104° 54' 06"	1965–1994	1965–1965	temperature, specific conductance, pH, major inorganics
GUMO	4717312	TWDB	Capitan Reef Complex	31° 44' 37"	104° 53' 05"	1965–1965	1965–1965	temperature, specific conductance, pH, major inorganics
GUMO	4717315	TWDB	Capitan Reef Complex	31° 44' 46"	104° 54' 44"	1965–1965	1965–1965	temperature, specific conductance, pH, major inorganics
GUMO	4717317	TWDB	Capitan Reef Complex	31° 44' 37"	104° 54' 59"	1965–2000	1965–1968	temperature, specific conductance, pH, major inorganics
GUMO	4743601	TWDB	Capitan Reef Complex	31° 17' 35"	104° 38' 38"	1965–1972	1971–1971	temperature, specific conductance, pH, major inorganics
GUMO	4744701	TWDB	Capitan Reef Complex	31° 15' 21"	104° 36' 03"	1970–1972	—	--
GUMO	4807610	TWDB	Quaternary Alluvium	31° 56' 17"	105° 08' 21"	1948–1951	—	--
GUMO	4824201	TWDB	Quaternary Alluvium	31° 44' 14"	105° 02' 42"	1965–1965	1972–1972	temperature, specific conductance, pH, major inorganics
GUMO	4824501	TWDB	Quaternary Alluvium	31° 42' 16"	105° 02' 41"	1972–1972	—	--

Appendix F. Chihuahuan Desert Water Resources and Water Quality Standards: An Overview, cont.

Park unit	Well number	Data source	Aquifer	Latitude	Longitude	First and last years of water–level record	First and last years of water–quality record	Water-quality parameters
GUMO	4824901	TWDB	Quaternary Alluvium	31° 38' 55"	105° 00' 22"	1965–1965	—	--
GUMO	4850309	TWDB	Quaternary Alluvium	31° 14' 31"	105° 47' 23"	—	—	--
GUMO	4850310	TWDB	Quaternary Alluvium	31° 14' 38"	105° 47' 24"	—	—	--
WHSA	3.2E+14	USGS	Tertiary Basin Fill	32° 46' 18"	106° 10' 51"	2000–2000	2000–2000	temperature, specific conductance, pH, major inorganics, organics
WHSA	3.2E+14	USGS	Tertiary Basin Fill	32° 46' 48"	106° 10' 27"	2000–2000	2000–2000	temperature, specific conductance, pH, major inorganics, organics
WHSA	3.2E+14	USGS	Tertiary Basin Fill	32° 47' 12"	106° 10' 59"	2000–2000	2000–2000	temperature, specific conductance, pH, major inorganics, organics
WHSA	3.2E+14	USGS	Tertiary Basin Fill	32° 48' 50"	106° 15' 30"	2000–2000	2000–2000	temperature, specific conductance, pH, major inorganics, organics
WHSA	3.2E+14	USGS	Tertiary Basin Fill	32° 48' 54"	106° 16' 02"	2000–2000	2000–2000	temperature, specific conductance, pH, major inorganics, organics
WHSA	3.2E+14	USGS	Tertiary Basin Fill	32° 49' 24"	106° 16' 02"	2000–2000	2000–2000	temperature, specific conductance, pH, major inorganics, organics
WHSA	T-00227	NMOSE	Tertiary Basin Fill	32° 45' 22"	106° 05' 09"	—	—	--
WHSA	T-00228	NMOSE	Tertiary Basin Fill	32° 46' 02"	106° 05' 06"	1936–1937	—	--
WHSA	T-00613	NMOSE	Tertiary Basin Fill	32° 44' 59"	106° 28' 59"	—	—	--
WHSA	T-02073	NMOSE	Tertiary Basin Fill	32° 51' 50"	106° 30' 17"	1967–1967	—	--
WHSA	T-02758	NMOSE	Tertiary Basin Fill	32° 48' 01"	106° 07' 55"	—	—	--

F.7 Literature Cited

Huff, G. F., M. H. Reiser, and J. T. Richie. 2006. Chihuahuan Desert Network water resource information and assessment report, phase II. National Park Service, Chihuahuan Desert Network, Las Cruces, New Mexico.

National Park Service Organic Act of 1916 (16 USC 1 et seq. [1988], Aug. 25, 1916).

NPS (National Park Service). 1995a. Baseline water quality data inventory and analysis, Big Bend National Park. NPS/NRWRD/NRTR—95/51. National Park Service, Washington, D.C.

——. 1995b. Baseline water quality data inventory and analysis, Amistad National Recreation Area. NPS/NRWRD/NRTR—95/72. National Park Service, Washington, D.C.

——. 1997a. Baseline water quality data inventory and analysis, Guadalupe Mountains National Park. NPS/NRWRD/NRTR—97/133. National Park Service, Washington, D.C.

——. 1997b. Baseline water quality data inventory and analysis, White Sands National Monument. NPS/NRWRD/NRTR—97/139. National Park Service, Washington, D.C.

——. 1999. Baseline water quality data inventory and analysis, Fort Davis National Historic Site. NPS/NRWRD/NRTR-99/237. National Park Service, Washington, D.C.

New Mexico Administrative Code (NMAC). 2005. Water quality: Standards for interstate and intrastate surface waters. Title 20, Chapter 6, Part 4, Section 1.3. http://www.nmcpr.state.nm.us/nmac/. Last accessed February 17, 2010.

Porter, S. D., R. A. Barker, R. M. Slade, Jr., and G. Longley. 2009. Historical perspective of surface water and groundwater resources in the Chihuahuan Desert Network, National Park Service: Edwards Aquifer Research & Data Center Report R1-09, Texas State University, San Marcos, Texas.

Reid, W. H., and M. H. Reiser. 2005. Water resource information and assessment report, Phase I. Chihuahuan Desert Network, Las Cruces, New Mexico.

Richard, M. 1988a. Review of geohydrology in the vicinity of Rattlesnake Spring and the contamination problem. Department of Environmental Health, Colorado State University, Fort Collins, Colorado. NPS contract RFQ 7029-8-0025.

——. 1988b. Report of the first field investigations. Department of Environmental Health, Colorado State University, Fort Collins, Colorado. NPS contract RFQ 7029-8-0025.

——. 1989a. Report of the second field investigation. Department of Environmental Health, Colorado State University, Fort Collins, Colorado. NPS contract RFQ 7029-8-0025.

——. 1989b. Final summary of the investigation. Department of Environmental Health, Colorado State University, Fort Collins, Colorado. NPS contract RFQ 7029-8-0025.

U.S. Environmental Protection Agency (EPA). 2000. Nutrient criteria technical guidance manual: Rivers and streams. U.S. Environmental Protection Agency, Office of Water, EPA-822-B-00-002.

van der Heijde, P. K. M., K. K. Koln, H. Dawson, and M. Brooke. 1997. Determining water infiltration routes from structures located above Carlsbad Cavern, Carlsbad Caverns National Park, Carlsbad, New Mexico. International Ground Water Modeling Center, Colorado School of Mines, Golden, Colorado.

Appendix G. Vital Signs Scoping Workshop Materials and Results

G.1 Questionnaire used in interviews with park staff in preparation for Phase I Vital Signs Scoping Workshops, Fall 2004.

CHIHUAHUAN DESERT NETWORK QUESTIONAIRE

FOR VITAL SIGNS PHASE I SCOPING MEETING #1

Park Unit: **Date:**

Staff Name:

Position: **Yrs. at Park:**

Areas of Expertise:

Other areas of expertise:

1. What are the park's most valuable/important/significant species of concern?
2. What are the park's stated species of concern?
3. What are the park's most important resource management issues?
4. What are the greatest current threats to significant park resources?
5. What are the greatest potential threats to significant park resources?
6. What are the park's most significant resource needs?
7. Are there current research, inventory, or monitoring projects being conducted in the park?
8. Are there any historic research, inventory, or monitoring projects that you think are especially valuable in understanding the park's ecosystems?
9. Are you working with other agencies/land owners on any inventory, monitoring, research, or restoration projects? Please provide & indicate in what capacity.
10. Does climatologic data (historic through present) exist in electronic format for your park?
11. Which ecosystem components are most important to protect? Why?

12. In your opinion, which stressor is the most significant? Why?

13. In your opinion, what are the park's top three monitoring questions?

14. If you could only have one long-term monitoring project in your park, what would it be and why?

15. What 3 GIS themes should have the highest priority for completion?

16. What 3 other data layers should you have in your park's GIS database?

17. We want information produced by the Inventory and Monitoring Program to be widely interpreted. What is the best way to make this information available to interpretive staff and the public?

18. Are there problems perceived by local government officials, other federal or state agencies or military as to management of the park's resources?

19. Are there any real or perceived impacts directly due to visitors, visitor use or visitor activities?

20. Are there any real or perceived impacts due to routine maintenance activities or NPS/park activities?

21. Are there other issues you would like considered? For example, interdisciplinary topics, landscape level changes, or topics about which you think we need more information to help us further identify important monitoring needs?

22. Are there any other comments you would like to make?

G.1.1 Amistad National Recreation Area (21-22 March 2005)

Summary of staff interviews for the Amistad Lake National Recreation Area Vital Signs Phase I scoping meeting.

Questions	AMIS respondents				
	A	B	C	D	E
1. What are the park's most valuable/important/significant species of concern?	interior least tern, peregrine falcon, brown pelican, Devil's River minnow, bald eagle, great blue heron rookery, cacti, tamarisk, bamboo, turkey	Texas Tortoise, Indigo Snake, Western Coral Snake, Trans-Pecos Rat Snake, Texas Horned Lizard, Mexican free-tailed bat, Cave Myotis, Yuma Myotis, Townsend's Big-eared bat, Pallid Bat, Western Mastiff Bat, Western Red Bat, Monarch Butterfly, Proserpine Shiner, Blue Catfish, Interior Least Tern, Snowy Plover, Neo-tropical migrant breeders (e.g., Yellow-billed Cuckoo, Painted Bunting, Yellow-breasted Chat, Bell's Vireo, White-eyed Vireo, Black-chinned Hummingbird), Olive Sparrow, Long-billed Thrasher; beaver; Guayacan/Iron Wood (Guaiacum angustifolium), Plateau Oak (Quercus fusiformis), Texas Pistache (Pistacia texana);Val Verde Agave Borer; echinocereous cactus; agave butterfly; beaver	Seasonal diversity of birds; Interior Least Tern; butterflies (some fairly rare), giant skipper; monarch butterflies; Mountain lion & bobcat, blue sucker & Devil's River minnow, cliff thistle, rydberg skirfpea, white-tailed deer	interior least tern	game fish; endangered fish; gray-banded kingsnake

Appendix G. Vital signs scoping workshop materials and results, cont.

Questions	AMIS respondents				
	A	B	C	D	E
2. What are the park's species of concern?	NR	Devils River minnow; interior least tern; Texas Tortoise	Interior Least Tern, Black-capped Vireo; Texas tortoise; Great-horned lizard; Devil's River minnow; Texas trumpet flower; Wright's trumpet flower	see GMP	not determined
3. What are the park's most important natural resource management issues?	fluctuating lake levels, interior least tern nest sites, trespass grazing, exotic plants	International Management of Fisheries and Water (Quantity and Quality); Grazing; Interior Least Tern nesting areas; Off-road driving; Encroachment from housing developments; riparian habitat below dam; Old barbed-wire fence in hunt areas; Excessive motorized boat use on upper reaches of rivers; hunter/deer take levels in hunt areas; use of hunt area 2 as park gun range and drying location for fish cleaning stations; Maintenance/protection of Huisache (Acacia farnesiana) woodlands; Protection of bat colonies in Train Tunnel on upper reaches of Rio Grande	Exotic animals; Trespass livestock grazing; Exotic plants; Encroachment from private development; Maintaining water quality & water quantity	exotic species; encroachment	border impacts; unrestricted camping; fluctuating lake levels; illegal grazing; encroachment; exotics

Appendix G. Vital signs scoping workshop materials and results, cont.

Questions	AMIS respondents				
	A	B	C	D	E
4. What are the greatest current threats to significant park natural resources?	grazing, exotic plants, lake fluctuation, bamboo, fires	Minimum communication with Mexico and State of Texas counterparts/managers. Current loss of Plateau oak motts/habitat found within the boundary of the park due to over grazing. Loss of monitoring effort on deer herds and vegetation within hunting areas of park. Mouflon sheep in area 5; Expansion of buffelgrass (exotic); Access of motorized boats; exotic wildlife impacts on vegetation and cultural resources (Audad and Mouflon).	Trespass livestock; invasive plants	illegal grazing	as in 3
5. What are the greatest potential threats to significant park resources?	catastrophic flooding, human caused damage (drug smugglers, aliens)	Loss of Opuntia spp., to exotic borer moth; Loss of riparian habitats; Loss of plateau oak habitats; Increased motor boat use; Road mortalities on species of concern; Loss of breeding colonies of Tern species due to visitor use/harassment; Potential air quality impacts; loss of water quantity; Sediment loading in upper reaches of reservoir.	Encroachment; flooding; wave action & shoreline erosion & currents; Exotic animals & spread of invasive plants	exotics; alien/drug traffic	

Appendix G. Vital signs scoping workshop materials and results, cont.

Questions	AMIS respondents				
	A	B	C	D	E
6. What are the park's most significant natural resources needs?	data on nongame fish, spring flow monitoring	Regular/frequent communication with State of Texas and Mexico counterparts; Staffing to continue with resource monitoring projects; close the historic train tunnel; create non-motorized zones; Fence out sheep livestock at oak mott sites; Remove excess hunt area roads.	biologist, hydrologist, Resource Staff or in-house expertise, GIS, data on water quality & aquatic biological assessment & riparian assessment.	staffing	biologist on staff; get natural history collections
7. Are there current research, inventory, or monitoring projects on natural resources being conducted in the park?	monarch butterfly migration monitoring; water quality; mammal, reptile, plant inventories completed	White-tailed Deer Census Program; Interior Least Tern populations; "Range Inventory"; inventory and monitoring of fisheries resources ; MAPS station; Large-mouth Bass mortality; herp surveys; bat inventory and monitoring; Monarch Butterfly monitoring; cave map; Floristic Survey; one water quality sampling station; Creel census; "Water Resources Scoping Report"	annual Interior Least Tern surveys; deer surveys; limited water quality monitoring; air quality monitor; sport fish monitoring; Devil's River & other aquatic resources.	binational fisheries management plan (NPS, Mexico, TPW)	yes

Appendix G. Vital signs scoping workshop materials and results, cont.

Questions	AMIS respondents				
	A	B	C	D	E
8. Are there any historic research, inventory, or monitoring projects that you think are especially valuable in understanding the park's natural systems?	pre dam arch studies with photos; 1970's Sul Ross mammal thesis	Texas Parks and Wildlife fish inventories and monitoring sites; Range Inventory vegetation transects; MAPS station below dam; Least Tern Surveys; Sediment monitoring by IBWC on upper reaches of reservoir.	Water quality resources scoping report; Historic deer population data; Scudday (Sul Ross State Univ) 1970's mammal biogeography on islands; Red-eared slider "replacing" Rio Grande slider study; Trophic modeling in AMIS in the reservoir; Monitoring approaches to biological health of reservoirs vs. spring ecology; Muttiha: published a paper on mixing patterns of hydrologic dynamics; Matt Boehm mammal inventory thesis (Sul Ross)	TECQ may have historic water data	IBWC; Ray Camp limnology project
9. Are you working with other agencies/land owners on any inventory, monitoring, research, or restoration projects? Please provide list & indicate in what capacity.	Arizona group working on human border issues	TPWD and Mexico (SAGARPA) in the management of fisheries resources in the park; TPWD deer surveys & censusing protocols & herp inventories.	Binational Fisheries Cooperative agenda	TECQ, TPWD	Texas State University limnology study
10. Does climatologic data (historic through present) exist in electronic format for your park?	nothing electronic	90+ years of climatologic data from the Del Rio National Weather Station at the airport	IBWC might have original weather data in electronic format. Park gets summary info: precip, tempt, but paper only. Air Force base will also have weather data;	university air quality study, TECQ air quality monitoring	historic NOAA station

Appendix G. Vital signs scoping workshop materials and results, cont.

Questions	AMIS respondents				
	A	B	C	D	E
11. Which ecosystem components are most important to protect? Why?	native plants; Aoudad sheep; mouflon	Oak motts-Most rare neotropical migrants and residents occur in these areas including eastern screech-owl, elf owl, Yellow-billed cuckoo. Hunt areas-Very little trespass grazing, but some at low water.	Upland terrestrial resources, because there is so little of it & the park is surrounded by private lands (agricultural uses primarily); Riparian zones are scarce resources, extreme condition exists for riparian zones in the park, largely untouched & impt to protect.	fisheries	water; air quality
12. In your opinion, which stressor is the most significant? Why?	drought; grazing	Reservoir water level fluctuations (fish populations and spawning potential. Loss of vegetation and riparian habitats once water levels increase)	Anything that grazes or browsing whether trespass or exotic animal; Fluctuating lake level – differential impacts to wildlife pops. & ecological communities.	fluctuating lake levels	Mexico as source of air/water pollution; silt
13. In your opinion, what are the park's top three monitoring questions?	interior least tern; monarch butterflies; fisheries (including commercial fishing impacts)	Water quality; Fish populations; Visitor Use and Park Management Impacts on Resources	upland terrestrial plant communities; Impact to native veg by exotics; riparian areas	water quality; exotics; illegal alien activities	air; water quality; fish community structure
14. If you could only have one long-term monitoring project in your park, what would it be, and why?	interior least tern	visitor use; veg transects; Fish monitoring & water; quality bat	Riparian zone monitoring.	fisheries	water quality and biodiversity (especially draw down zone)
15. What 3 GIS themes should have the highest priority for completion?	caves; backcountry use sites; vegetation; grazing	Vegetation community, including low reservoir hab types; Recent DOQQs; Fenceline survey & condition assessment	historic nesting sites for least terns	boundary map; aerial photography	lake surface

Appendix G. Vital signs scoping workshop materials and results, cont.

Questions	AMIS respondents				
	A	B	C	D	E
16. What 3 other important data layers should you have in your park's GIS database?	ranch property boundaries/fences; livestock (especially in relation to arch sites)	Lake Bathymetry; Boundary cadastral survey near developments; lake Water Quality Data and/or Model	Veg/plant community map; tamarisk & other invasive plants; Aoudad sheep	NR	fire
17. We want information produced by the Inventory and Monitoring Program to be widely interpreted. What is the best way to make this information available to interpretive staff and the public & other park staff?	website; interpretive staff	Newsletter; localized publications for the network on I&M topics; Web site, etc,.	Websites; brochure	website	distribute to resource managers; website; bulletin; newspaper; educators to classrooms
18. Are there problems perceived by local government officials, other federal or state agencies or military as to management of the park's resources?	local fire dept called for fires set by drug smugglers and aliens but park letting them burn	Mexico counterparts have had concerns in the past about fish stocking procedures and species used by TPWD. TPWD has had concerns about commercial fishing program on Mexico side. Bi-national management of fisheries was initiated in 1999/2000 to deal with these perceived conflicts	fish stocking complaints	tie to community economics (keep lake full of fish); Tx controls water	homeland security does what want
19. Are there any real or perceived impacts directly due to visitors, visitor use or visitor activities?	collectors of fossils, cactus, arch remains; backcountry use (waste, veg cutting, fires)	Noise from motorized watercraft; Excessive wave action; Garbage; tires along shoreline; Fishing gear entanglements; Fires and fire rings; Vegetation extraction, cactus removal; Reptile/amphibian removal; excessive hunting pressures; 2-stroke engines and water pollution; Improper fish handling	social roads; backcountry camping	very little (mostly to cultural)	invasive fish; impacts fishing; unregulated camping

Appendix G. Vital signs scoping workshop materials and results, cont.

Questions	AMIS respondents				
	A	B	C	D	E
20. Are there any real or perceived impacts due to routine maintenance activities or other NPS activities?	boat ramp problems	Perceived problem between law enforcement & resources; Law enforcement gun range in hunt area 2; Excessive roads in hunt areas; Excessive motorized boat tours by NPS staff in upper reaches of park (Pecos, Devil's River).	maintenance in visitor use areas: cutting back/down native vegetation.	clear boat facilities that had been at low levels	road grading (especially to arch sites); ranger activities in caves
21. Are there other issues you would like considered? For example, interdisciplinary topics, landscape-level changes, or topics about which you think we need more information to help us further identify important monitoring needs?	NR	NR	NR	NR	NR
22. Are there any other comments you would like to make?	NR	NR	NR	NR	thanks to I&M for interest in park/monitoring

G.1.2 Big Bend National Park (28 Feb – 2 March 2005)

Summary of staff interviews for the Big Bend National Park and Rio Grande Wild & Scenic River Vital Signs Phase I scoping meeting.

Questions/	BIBE respondents				
	A	B	C	D	E
1. What are the park's most valuable/important/significant species of concern?	NR	aquatic species (especially assoc with Rio Grande, mussels, mollusks, fish, reptile (BIBE slider), amphibians); Endangered species; Large broad ranging animals (black bear, mt. lion, desert big horned sheep); Exotic/invasive plant & animals (feral hog, aoudad Barbary sheep); buffelgrass	NR	Mariposa cactus; Bunched-Cory cactus; Chisos hedge-hog cactus; Guadalupe fescue; buffelgrass, saltcedar, & Lehmans's lovegrass.	Black bear; Mt. lion; mule deer; Peregrine Falcon
2. What are the park's species of concern?	NR	NR	NR	only listed species	Black-capped vireo; Black bear; Mt. lion; Peregrine Falcon
3. What are the park's most important natural resource management issues?	air quality; water quality/quantity; exotics	air quality; loss biological diversity in Rio Grande; soil/grasslands; lack staffing/funding	groundwater/surface water interactions; air quality	Exotic plants; Water quantity & quality; encroachment; Climate change; air quality; Restoration; Veg management in developed areas; prescribed fire management; fire effects and urban interface; Relationships of T&E species/exotics & fire	air quality; water quality & quantity; exotics
4. What are the greatest current threats to significant park natural resources?	air quality; water quality/quantity	river flow changes; exotics; camping impacts/feeding animals; soil	air quality; water development; upland degradation	as in 3	Vandalism of arch sites; Poaching; encroachment; herbicides; high visitation

Appendix G. Vital signs scoping workshop materials and results, cont.

Questions/	BIBE respondents				
	A	B	C	D	E
		erosion/grassland loss			
5. What are the greatest potential threats to significant park resources?	coal-fired plants; exotics	encroachment; air quality	water development	as in 3	encroachment, poaching
7. Are there current research, inventory, or monitoring projects on natural resources being conducted in the park?	NR	water source; air quality; black-capped vireo; peregrine falcon; BB Gambusia; amphibians; wildlife-human conflicts; reptile inventories; Neotropical migrants; exotics; nutria; exotic plants	spring surveys; Rio Grande water quality North Rosillos restoration site; response Rio Grande channel to diminishing flows	annual monitoring of 4 endangered plant species; annual Agave survey tied in with Mex long-nosed bat; Spring surveys; Air & water quality; Weed mapping & monitoring	black bear study; I&M herp inventory
8. Are there any historic research, inventory, or monitoring projects that you think are especially valuable in understanding the park's natural systems?	NR	veg monitoring back to 30's; general biological surveys; fish inventories; 30 years of spring data	spring inventory; grassland restoration project; geology BB	Warnock veg transects remeasured since 1955; Circular plot data from 1955; Dunham veg plots; Fire plots	PEFA research started in 1972; 2 Mt. Lion dissertations on this animal
11. Which ecosystem components are most important to protect? Why?	NR	Rio Grande, Chisos Mtns.; desert oases; desert grasslands/soil; broad-ranging mammals	air, water soil	What meet NPS mission. Landscape integrity; Biodiversity surrogate.	Chisos Mts; Desert grasslands; Rio Grande
12. In your opinion, which stressor is the most significant? Why?	exotics; trespass cattle	exotics; altered Rio Grande flow; grazing; air quality	lower elevations-grazing effects; higher elevations-air quality; Rio Grande-loss flow and regulation; loss groundwater	Long-term climate change; Exotics; Air & water quality	Drought; Lack of water in the river; grazing
13. In your opinion, what are the park's top three monitoring questions?	air quality; water; saltcedar; drug smugglers/illegal alien	exotics; aquatic species; large broad-ranging mammals	impact air quality & climate on soils and water quality; relation river level & invasive species; riffles as food base	Effects exotics; Diversity at different at landscape scales; climate; Water quality & quantity; Loss of spatial diversity	Short and long-term effects of air quality on flora & fauna, and humans; What is happening on the river to the flora & fauna

Appendix G. Vital signs scoping workshop materials and results, cont.

Questions/	BIBE respondents				
	A	B	C	D	E
14. If you could only have one long-term monitoring project in your park, what would it be, and why?	air quality	exotics	surface/spring water	everything	River health & function.
19. Are there any real or perceived impacts directly due to visitors, visitor use or visitor activities?			hand-dug well safety	Trampling, digging up plants, vandalizing, collecting firewood, spreading weeds; Landscape level, poaching may or may not be an issue..	off-road driving; viewshed/backcountry campsites; air pollution is impacting night skies.
20. Are there any real or perceived impacts due to routine maintenance activities or other NPS activities?			Road maintenance; homeland security requires no NEPA; plane low-level flights	ground disturbance, road maintenance, construction; Mowing shoulders – spread of weeds	Other divisions & employees see the science & resource management activities may be impacting the park; Mowing & blading roads;
21. Are there other issues you would like considered? For example, interdisciplinary topics, landscape-level changes, or topics about which you think we need more information to help us further identify important monitoring needs?					monitor landscape level changes; redo Warnock plots

G.1.3 Carlsbad Caverns National Park (23 March 2005)

Summary of staff interviews for the Carlsbad Caverns National Park Vital Signs Phase I scoping meeting.

Question	CAVE respondents						
	A	B	C	D	E	F	G
1. What are the park's most valuable/important/significant species of concern?	NR	Mexican free-tailed bats; rare/T&E cactus, spotted owl, Barbary sheep, lions	Barbary sheep, Lee's pincushion cactus, spotted owl	free-tailed bats, endangered cacti, mt. lions, spotted owl, cave microbe community	Varied Bunting (Passerina versicolor), Bell's Vireo (Vireo bellii) ST *, Gray Vireo (Vireo vicinior) ST, Yellow-billed Cuckoo, Montezuma Quail, Black-throated Sparrow, Cave Swallow, MSOW, Vermillion flycatcher, Painted bunting, Western River Cooter (Pseudemys gorzugi) ST, Gray Banded Kingsnake (Lampropeltis alterna) SE, Plain Bellied Watersnake, Red-eared Slider, Yellow Mud turtle, Rio Grande Leopard Frog, Extirpated cricket frog (still at Blue Spring, 10mi NE on pvt land), Mottled rock rattlesnake, In general almost all of the snakes, Bats as a group, esp cave myotis, fringed myotis & Mex freetail, Nelson's pocket mouse, Puma, Mule deer, Bobcat, western spotted skunk (carnivores in general), Lee's pincushion cactus, relic species of Texas madrone, chinquapin oak, range limit on soapberry, edge for ponderosa pine, Veg community: curly-leaf muhly grass (unique type associated with 1-	Texas Madrone (Arbutus xalapensis); Chinkapin Oak (Quercus muehlenbergii); Netleaf Hackberry (Celtis laevigata var. reticulata); Gooding's Willow; Green Sotol (Dasylirion leiophyllum); Pincho Juniper (Juniperus pinchotii); Lee's pincushion cactus (Coryphantha sp.); Greenthroat Darter (Etheostoma lepidium) ST *; Roundnose Minnow (Micropterus salmoides) *; Baird's Sparrow (Ammodramus bairdii) ST; Varied Bunting (Passerina versicolor) ST; Peregrine Falcon (Falco peregrinus anatum) ST; Common Ground Dove (Columbina passerina pallesens) SE; Bell's Vireo (Vireo bellii) ST *; Gray Vireo (Vireo vicinior) ST; Bald Eagle (Haliaeetus leucocephalus) ST; Common Blackhawk (Buteogallus	invertebrates

Appendix G. Vital signs scoping workshop materials and results, cont.

Question	CAVE respondents						
	A	B	C	D	E	F	G
					seed juniper), Gooding willow & netleaf hackberry &cottonwood at RSS	anthracinus) ST; Cowbird (Molothrus ater) NP *; Cave Swallow (Hirundo fulva); Mexican Free-tailed Bat (Tadarida brasiliensis mexicana); Fringed Myotis (Myotis thysanoides); Cave Myotis (Myotis velifer); Ringtail (Bassariscus astutus); Pocket Gopher (Pappogeomys castanops); Banner Tail Kangaroo Rat (Dipodomys spectabilis); Spotted Skunk (Spilogale putorius); Mule Deer (Odocoileus hemionus); Mountain lion (Felis concolor); Western River Cooter (Pseudemys gorzugi) ST; Gray Banded Kingsnake (Lampropeltis alterna) SE; Plain-Bellied Watersnake (Nerodia erythrogaster) SE; Mottled Rock Rattlesnake (Crotalus lepidus lepidus) ST	
2. What are the park's species of concern?	bats	free-tailed bats, mountain lion, Barbary sheep	Lee's pincushion cactus, Mexican free-tailed bat	all bats, highlight free-tailed		Bell's Vireo (Vireo bellii); Mexican Free-tailed Bat (Tadarida brasiliensis mexicana); Mule Deer (Odocoileus hemionus); Mountain Lion (Felis concolor);	see fire plan

Appendix G. Vital signs scoping workshop materials and results, cont.

Question	CAVE respondents						
	A	B	C	D	E	F	G
						Lee‘s pincushion cactus (Coryphantha sp.)	
3. What are the park’s most important natural resource management issues?	ground-level infrastructure causing cave contamination	cave preservation, maintain wilderness while provide public access, oil/gas development	oil/gas development, lack baseline data	visitor impacts	Role of prescribed fire ; Water allocation at RSS and irrigation management.	Wildland fire management; Invasive species; Subterranean resource management, enabling legislation, little biological inventory; needs systematic inventories; Wilderness management; T&E species; visitation, primarily for cave resources	lack of info on sensitive communities, visitor impacts, noise/light impacts on bats, spotted owl, endangered cacti, rattlesnake spring management plan, trespass grazing
4. What are the greatest current threats to significant park natural resources?	ground-level infrastructure causing cave contamination	oil/gas development, visitor impacts in caves	oil/gas development impacts on cave and water	human visitors, park infrastructure, oil/gas development, light pollution	Oil & gas develop; air & water quality; Configuration of the park (long & narrow); Nonnative/invasive plants; Barbary sheep, bullfrog, eastern foxtail squirrel; cowbird parasitism	Oil & gas development; Lack of landscape-base fire management approach; Felis concolor control on non NPS lands; Visitation activities in caves	visitor impacts to bats, park infrastructure, drought, oil/gas, herbicides, BLM grassland burning, cowbirds, lack park constituency
5. What are the greatest potential threats to significant park resources?	ground-level infrastructure causing cave contamination	oil/gas development, visitor impacts in caves	oil/gas development; decrease air quality	oil/gas development, especially to Rattlesnakes	House sparrow; Wildlife disease; Current administration; Climate change; Water	Oil & gas development; Lack of Resource Management Plan; Current DOI	as above

Appendix G. Vital signs scoping workshop materials and results, cont.

Question	CAVE respondents						
	A	B	C	D	E	F	G
				Springs	development at RSS; Pesticide from ag feedlots around RSS, increase cowbird	Administration, undermining the stewardship mission; Visitation	
6. What are the park's most significant natural resources needs?	research	bat migration data, water resources, cave microbial communities	understand role of fire, baseline data on cave invertebrates, bat migration patterns, soil inventory, relation between vegetation and stressors	Rattlesnakes Springs underground watershed	Fire ecology; invertebrates; ecological modeling (including need for state & transition models; Understanding desired future conditions (DFC); Lack of knowledge or planning to handle issues outside of our expertise	T&E species ID and mapping; Exotic species eradication, control & monitoring; RMP; Cave macro-invertebrate inventory; Reintroduction of extirpated species (Bighorn Sheep, Montezuma's quail), listed in the GMP; green-throated darter	research/monitoring, data gaps
7. Are there current research, inventory, or monitoring projects on natural resources being conducted in the park?	cave surveys of physical features; cave microbial communities; human impacts; photo monitoring of Lechuguilla Cave; monitor cave floor; vertebrate cave use; photo monitoring backcountry	Barbary sheep, bat population, cave mapping	cave microbes, cave invertebrates	photo monitoring in cave, cave microbes	Cougar sign, DNA, and scent stations; live mammal trapping; winter bat work in NM, variation in Mex freetail echolocations; bat outflights by sex	Thermal imaging Tadarida population; (Barbary Sheep; Vireo bellii nest mapping and reproductive success; Fish found in RSS are native to region, but were never native or historical known from RSS. Fish species eradication at Rattlesnake Spring.	
8. Are there any historic research, inventory, or monitoring projects that you think are especially valuable in understanding the park's natural systems?	NR	NR	little knowledge about past activities	some spring flow and water chemistry	1980's cougar radiotelemetry; 70's fire study; 50's bats in Left Hand Tunnel; Myotis research; diet of freetails; rare plant surveys; Herp inventory; 1997 survey of	Cave invertebrate study; Tadarida research; Vegetation map; Odocoileus hemionus population dynamics	Rattlesnake springs mollusks, DDT spraying, cave swallow

Appendix G. Vital signs scoping workshop materials and results, cont.

Question	CAVE respondents						
	A	B	C	D	E	F	G
					herps at RSS; Habitat model for Lee's pincushion cactus		
11. Which ecosystem components are most important to protect? Why?	caves; above cave surface	cave and karst system	geological resources	park surface, backcountry caves, geomicrobial	riparian areas; Mex free-tailed bats; Migratory birds; big predators	Ecosystem integrity of cave resources; Plant community diversity; Rattlesnake Springs resource base; T&E species; Air quality; wilderness character:	all
12. In your opinion, which stressor is the most significant? Why?	human use; carbon	NR	oil/gas development	human impacts in caves, infrastructure over caves	Level & timing of precipitation	climate, fire, visitation	role of fire
13. In your opinion, what are the park's top three monitoring questions?	Cave floor processes; social trails in caves; cave visitors	NR	spotted owls, Lee's pincushion cactus, vandalism	air quality, water quality	Mex free-tailed bats; Invasive plants; Predator pop	Effects of fire on ecosystem structure and function; Impacts of Felis concolor predation on ungulate populations; What is the diversity of macro invertebrate populations in Carlsbad Cavern; Impacts of non-native animals on vegetation communities	
14. If you could only have one long-term monitoring project in your park, what would it be, and why?	not known	NR	pincushion cactus, free-tailed bats	air or water quality	Mex free-tailed bat; Riparian/water resources;	Air quality; Cave macro-invertebrates	
19. Are there any real or perceived impacts directly due to visitors, visitor use or visitor activities?	vandalism	visitor impacts	vandalism in caves, visitor impacts on bats	vandalism, lint, lunchroom odor/visual impact	Automobiles & pollution; fires started by visitors; indirect with the infrastructure; water & sewage use.	Impacts to biological & geological cave resources from visitor activity.	noise at bat flight

Appendix G. Vital signs scoping workshop materials and results, cont.

Question	CAVE respondents						
	A	B	C	D	E	F	G
20. Are there any real or perceived impacts due to routine maintenance activities or other NPS activities?	lighting, cave exploration	lighting	maintenance does not know where T&E species are located	salt on trails, irrigation at rattlesnake springs	Irrigation ditch clean-up; a lot of seasonal activities scheduled to avoid at RSS or in the caves at the wrong time of year; Flood irrigation at RSS; mowing at RSS	Cave maintenance, lighting system, cleaning trails, etc.; Road maintenance, shoulder maint & loop road; Trail maintenance, terrestrial: little done on backcountry trails, time frames are so far apart, they are "starting" over; issues with T&E plants; doing clearances & compliance before action	no maintenance standards, trail maintenance

G.1.4 Fort Davis National Historic Site (30-31 March 2005)

Summary of staff interviews for the Fort Davis National Historic Site Vital Signs Phase I scoping meeting.

Questions	FODA respondents			
	A	B	C	D
1. What are the park's most valuable/important/significant species of concern?	unknown	historic cottonwood grove	no comment	Foothill grasslands community are conservation concern ; Other species low ranked: scented croton (limited distribution in Tx), found base of mountains in the rocks; dense corycactus (Escobaria dasycantha); Cassin's sparrow; Chihuahuan desert subspecies of meadowlark; Kit fox; Davis Mt. cottontail, landscape perspective-black bear & pronghorn; guild of grassland birds. Springs, streams & riparian corridors; cottonwoods; neotropical guild; bats; Texas false saltgrass; Warnock's coralroot (may be in Hospital Canyon), G2 ranked plants: Murray's plum; trans-pecos butterfly weed, Davis Mts. horse nettle; Tx. Horned lizard; Lichen flora
2. What are the park's species of concern?	none noted	list in study plan	no comment	see question #1
3. What are the park's most important natural resource management issues?	resource stewardship plan (fire, historic scene, tree); flood mitigation	maintain cultural landscape; trail maintenance; prescribed fire; mechanical thinning	no comment	Maintaining or improving grasslands; reducing shrub encroachment; maintaining shrub comm., groundwater quantity; cottonwood genetics & maintaining grove with as genetically similar a species to the natives as possible (need to be maintaining age structure & recruitment with plantings every 20 yrs or so.)
4. What are the greatest current threats to significant park natural resources?	lack knowledge	human use; exotics; dogs; irrigation; view shed	no comment	Groundwater in relation to cottonwoods; town of Ft. Davis water corporation groundwater pumping; development pressures have already occurred (built up to the boundary already); park may be important linkage to Davis Mt. State Park
5. What are the greatest potential threats to significant park resources?	encroachment; groundwater depletion; drought; altered fire regime; air quality	development affecting water table	no comment	Push by some town folks to expand housing & tourist attractions, which means more water consumption (most likely from groundwater) & septic tank issues; what happens if population goes from 1000 people to 5000. General concern in the area is the future of ranchlands, biggest threat

Appendix G. Vital signs scoping workshop materials and results, cont.

Questions	FODA respondents			
	A	B	C	D
				intergenerational transfer of lands – subdivides, & inheritance taxes
7. Are there current research, inventory, or monitoring projects on natural resources being conducted in the park?	herp study, riparian bird study, fern study	ferns, herps, riparian birds	no comment	Sul Ross State – vascular plant survey completed, (check with Jim Zech (432-837-8114) & Martin Terry (botanists at Sul Ross State); Mammals of Davis Mts (Texas Tech) Ferns – Yarborough Birds – Meyers; fire science project with TNC, long-term fire history & climate change in the Chisos, Davis & Maderas del Carmen; Analysis not completed; Penn State professor (former advisor to Mills), doing similar study in the Guadalupe Mts.
8. Are there any historic research, inventory, or monitoring projects that you think are especially valuable in understanding the park's natural systems?	TNC conservation assessment for Davis Mountains	1997-98 veg study with comparison to historical conditions	no comment	
11. Which ecosystem components are most important to protect? Why?	native species; drought impacts; wildlife; land use patterns	discuss with outside participants at scoping meeting	Grasslands, one of the most threatened ecosystem because of human pop growth. Grasslands are in a "tension" situation because of climatological issue. Any water associated situation, riparian & spring systems.	Water resources (spring reduction in high country); very large Rio Grande Basin study just started. Researchers at Sul Ross & Texas State University (San Marcos). The study focused on hydrology & ecosystem function of the Trans-Pecos portion of the basin (Pecos & Rio Grande mainstem & main tributaries; Limpia Creek is a trib. To Pecos River. Kevin Urbanczyk (head of geology dept.) kevenu@sulross.edu (432-837-8259). Started in the last year.

Appendix G. Vital signs scoping workshop materials and results, cont.

Questions	FODA respondents			
	A	B	C	D
12. In your opinion, which stressor is the most significant? Why?	drought; routine mowing	drought; ground water depletion (green houses)	Population growth in terms of human occupation; unsustainable water use. Doesn't think fire played a key role in maintaining mid-elevation grasslands (4,000'- 6,000'); historic records evidence from fire in high plains or PIPO communities; altered disturbance regime but to what degree; climate much more important.	Climate change & aridification in the Davis Mts.; possibly altered fire regimes.
13. In your opinion, what are the park's top three monitoring questions?	groundwater; exotics; vegetation	don't know	Monitoring of the hydrologic functions – spring flow, critical to what is happening in the area; better climate monitoring, poor weather station coverage (evapo-transpiration, precip, temp, etc.); Monitoring of certain indicator species; insect & bat population; pollinators, amphibians, certain veg communities or plants; understand these groups; why are these populations changing (ranges of bat species moving west)	* need assessment of the cottonwood – possible indicator of ecosystem health; * lichen flora & stresses on those systems, * Develop intact grasslands away from developed sites, will likely need to sustain with fire. Larger scale on TNC lands impt issue: Restoring forest health (via prescribed fire); reduce fuel load, restore ecosystem health by reducing competition, brush & woodland abatement on the savanna grasslands.

Appendix G. Vital signs scoping workshop materials and results, cont.

Questions	FODA respondents			
	A	B	C	D
14. If you could only have one long-term monitoring project in your park, what would it be, and why?	vegetation (historic scene)	don't know		
19. Are there any real or perceived impacts directly due to visitors, visitor use or visitor activities?	none noted	off-trail hiking		
20. Are there any real or perceived impacts due to routine maintenance activities or other NPS activities?	maintaining cultural landscape alters floodplain; artificial watering	mowing		

G.1.5 Guadalupe Mountains National Park (16-17 March 2005)

Summary of staff interviews for the Guadalupe Mountains National Park Vital Signs Phase I scoping meeting.

Question	GUMO respondents		
	A	B	C
1. What are the park's most valuable/important/significant species of concern?	NR	Guadalupe violet; Barbary sheep; Elk;	Guadalupe violet, McKittrick pennyroyal, Frijole chinquapin oak, Mex Spotted Owl
2. What are the park's species of concern?	NR	Mexican spotted owl; (also mt short horned lizard, tx horned lizard, black bear, mt. lion, montz quail, merriam's turkey, burrow owl, gypsum scale-broom, Guadalupe rabbitbrush, chaplain's columbine, yellow-billed cuckoo, gray-banded kingsnake; javelina	No additional species to add.
3. What are the park's most important natural resource management issues?	lack resource data management personnel; balance visitor use with protection; geology collecting	Lack of basic inventories; current veg map; exotics; Restoration of extirpated species (desert big horn sheep, black-tailed prairie dog, American pronghorn); Highway corridor & wildlife mortality	Water-all facets (quality, quantity, etc.); Protection of scenic vistas; & Fire management
4. What are the greatest current threats to significant park natural resources?	as in #3; ground water	Slow implementation of fire management; exotics	Water: water mining in West Tx, esp in Dell Valley. Development includes desalination plant, groundwater mining, saline byproduct dumping & any associated contaminants. Scenic vistas: encroachment, human occupation, wind farms & associated impacts to desert big horn, migrating raptors & bats, etc. Fire management: role in maintaining a balance in ecological processes.
5. What are the greatest potential threats to significant park resources?	air quality; brine disposal; encroachment	Slow implementation of fire management; exotics; encroachment; light pollution	No other, except potential from oil & gas exploration.

Appendix G. Vital signs scoping workshop materials and results, cont.

Question	GUMO respondents		
	A	B	C
7. Are there current research, inventory, or monitoring projects on natural resources being conducted in the park?	water quality; air quality	riparian bird survey (I&M); paleontology inventory; water chemistry selected locations; airshed; Fire history	Tree ring studies by Penn State Univer, MSOW inventories, propagation of Guadalupe violet, I&M funded inventories
8. Are there any historic research, inventory, or monitoring projects that you think are especially valuable in understanding the park's natural systems?	water quality; spring discharge	15 yrs mtn. lion monitoring; deer pellet transects1974 browse survey map; McKit pennyroyal surveys	stream flow/discharge
11. Which ecosystem components are most important to protect? Why?	surface water/springs; soil	riparian deciduous woodlands; Rocky Mt mixed-conifer zone; migration corridors for terrestrial organisms	all components are impt because of interrelations. All pieces necessary for functioning system.
12. In your opinion, which stressor is the most significant? Why?	drought; acid rain; visitors	Drought; Increased vehicle traffic	Drought
13. In your opinion, what are the park's top three monitoring questions?	groundwater quality/quantity; air quality	air quality effects; water quantity-groundwater/surface water	1) How will introduction of millions of gallons of brine into the salt basin affect species, dune formation & microclimate? 2) Can the park sustain on a long-term basis a population of desert big horn sheep? 3) Is the "bowl" susceptible to a catastrophic wildlife?
14. If you could only have one long-term monitoring project in your park, what would it be, and why?	groundwater quality/quantity	see #13	Water quality, quantity, flow rates, etc.
19. Are there any real or perceived impacts directly due to visitors, visitor use or visitor activities?	vandalism/theft to paleo resources; backcountry sanitation	Visitors are impacting park's resources; McKit Canyon corridor sensitive	introduction of exotics, impacts due to human waste disposal in backcountry & MKCanyon
20. Are there any real or perceived impacts due to routine maintenance activities or other NPS activities?	trail maint. Impacts to paleo resource	Need to systematically replace trails with a system that is more inert like textured concrete; trail maint can be a threat to paleontological specimens; Clean equipment to help reduce spread of exotic plants	mostly negligible, occasional trail & road maintenance & repair & effects on paleontological features

Appendix G. Vital signs scoping workshop materials and results, cont.

Question	GUMO respondents		
	A	B	C
21. Are there other issues you would like considered? For example, interdisciplinary topics, landscape-level changes, or topics about which you think we need more information to help us further identify important monitoring needs?	NR	One of the elements to help us ID future monit needs, better effort of staff knowle & presence of park staff in the field, & getting those observation back to the program managers.	need a holistic perspective on how to deal with encroachment, preservation of wilderness values, importance of wildlife corridors form one sky island complex to another

G.1.6 White Sands National Monument (20 December 2004 & 12 April 2005)

Summary of staff interviews for the White Sands National Monument Vital Signs Phase I scoping meeting.

Question	New Items	WHSA respondent				
		A	B	C	D	E
1. What are the park's most valuable/important/significant species of concern?		L: large animals movements restricted by fence	unknown (possibly food plants-U, insect pollinators-U, cryptobiotic species-M or H)	saltcedar-H; white species-scientific interest; not necessarily keystone species or T&E; desert grasslands-declining resources-M; cottonwoods-potential indicator species of ground water-M to H; Lake Lucero inverts/bacteria-U; cryptograms-M to H; gypsophilic plants-L to M	cryptograms; water-dependent species-L; gypsophiles; pedestal -forming plants-L; saltcedar (related to enhancing wildlife habitat); porcupine-U	all species; bats-L for park
2. What are the park's species of concern?		NR	pupfish-L; white species' those on official list	there is no formal SOC list; white species	Gambel's quail; scaled quail; cotton rats; hanta virus; cottonwood; pupfish; neotropical migrants; pronghorn	NA
3. What are the park's most important natural resource management issues?	High importance: hydrological function/groundwater; saltcedar; Oryx (high maintenance issue)	need increased staff; air quality declining-; make visitors aware of diversity	saltcedar invasion-H; erosion	groundwater depth -H; saltcedar; potential hydrazine contamination (especially of Lake Lucero) from missile crash; air quality (impact cryptograms?)	groundwater hydrology and relation to plant communities	impact roads and accessibility into dunes; Oryx
4. What are the greatest current threats to significant park natural resources?	High import: saltcedar, declining water tables/ground water	lack grasslands; invasives; exotics	loss groundwater	saltcedar (playas at risk; relation between climate, groundwater, saltcedar); Lost River loss; soil erosion	exotic plants; water table	NA

Appendix G. Vital signs scoping workshop materials and results, cont.

Question	New Items	WHSA respondent				
		A	B	C	D	E
5. What are the greatest potential threats to significant park resources?	see above, climate change-M	loss groundwater	loss groundwater; climate change; air quality	groundwater loss; brine discharge; climate change; hydrozine contamination; air quality; light pollution	groundwater loss & quality	NA
6. What are the park's most significant natural resources needs?	High importance: high resolution saltcedar map; understand groundwater-dune formation interactions	better understanding ecosystem function; should fire be introduced?	increased research	increased staffing; high resolution saltcedar map; geologic research (dune movement, groundwater/sand interaction)	NA	NA
7. Are there current research, inventory, or monitoring projects on natural resources being conducted in the park?		no	herp inventory; dune movement (UTEP); soil survey (NRCS); pollen/C14 on 10 pedestal hearth sites	7 active permits (2 geological, 5 biological); Rosenblum's project; Meyer riparian bird survey	NA	NA
8. Are there any historic research, inventory, or monitoring projects that you think are especially valuable in understanding the park's natural systems?		unknown	old herbarium; insect collection	Reid's grad student (UTEP) project from 70's & 80's; Fryburger's geology report; historic inventories back to 30's; past aerial photos	grazing & relation to vegetation; pre-European landscape	NA
9. Are you working with other agencies/land owners on any inventory, monitoring, research, or restoration projects? Please provide list & indicate in what capacity.		NA	soil survey?	HAFB, WSMR (saltcedar control); WS pupfish conservation team; NMDGF Oryx removal; NRCS/DOD/NPS soil survey	NA	NA

Appendix G. Vital signs scoping workshop materials and results, cont.

Question	New Items	WHSA respondent				
		A	B	C	D	E
10. Does climatological data (historic through present) exist in electronic format for your park?		yes	staff will make decision on who takes this over	Alamogordo airport (since 1916); WSMR & HAFB (since 1940's); park data at Santa Teresa NOAA office	as hard copy; records from 1990; NOAA weather station	hard copy (daily high and low temp, monthly & ytd precip); key punch data sent to Santa Teresa; designated national weather observer (e.g., storms, tornados, etc.)
11. What 3 GIS themes should have the highest priority for completion?	H importance: generate accurate saltcedar distribution map; soil condition layer (level of erosion); shrub vs. grassland cover (better veg map); military roads (could be impt for wilderness assessment)	exotics (including shrubs); archaeological sites; military roads	saltcedar; better soil; finer grained vegetation; plant/animal location; biotic soil; cottonwood monitoring	saltcedar map; disturbance (including military roads)	NA	NA
12. What 3 other important data layers should you have in your park's GIS database?	H import.: dune movement which is related to dune formation & hydrology/groundwater	effects main road on dune dynamics	dune movement	park has good coverages; digital veg map	NA	NA

Appendix G. Vital signs scoping workshop materials and results, cont.

Question	New Items	WHSA respondent				
		A	B	C	D	E
13. Which ecosystem components are most important to protect? Why?	H impt: groundwater; soil formation/processes/ prevent further degradation to a less diverse state	water; air quality	possibly groundwater	Lake Lucero invertebrates; grassland ecosystem & shrub conversion (historic grazing); erosion	sand production at Lake Lucero (dune formation not continuous dependent on hydrology)	control non-natives
14. In your opinion, which stressor is the most significant? Why?	H: groundwater loss; saltcedar invasion	nothing imminent; exotic plants most visible	climate; groundwater loss	saltcedar; exotics; Oryx exclusion; loss wetlands; groundwater loss; military contaminants; noise; Past stressors: grazing, loss Lost River	groundwater (greatest impact on geologic & biologic processes)	NA
15. In your opinion, what are the park's top three monitoring questions?	H impt: groundwater; dune movement/formation monitored via aerial photos; saltcedar	animal populations (including reptiles)	groundwater; water quality; plant ecology (finer vegetation/habitat map)	saltcedar spread; grassland/shrubland ecotone; soil erosion; dune formation/movement; cottonwoods as indicators moisture [5 years groundwater depth/chemistry exists- no need to continue]	groundwater level; dune formation/movement (existing 1995-2004 dune edge monitoring)	parking accessibility at visitor station
16. If you could only have one long-term monitoring project in your park, what would it be, and why?	groundwater	groundwater	groundwater--relates to dune formation, movement, plant community	saltcedar invasion	groundwater (Fryberger for recommendations)	NA

Appendix G. Vital signs scoping workshop materials and results, cont.

Question	New Items	WHSA respondent				
		A	B	C	D	E
17. We want information produced by the Inventory and Monitoring Program to be widely interpreted. What is the best way to make this information available to interpretive staff and the public & other park staff?		Interpretive staff should interact with research/resource staff and go in field; resource staff should participate in interp	need reports written for layperson	brochure produced through Harper's Ferry; site bulletins; use website	put on web site; brown bag lunch presentations to staff; rewrite reports for use by public; brochures; need real interpretive techniques	use electronic media and web site
18. Are there other issues you would like considered? For example, interdisciplinary topics, landscape-level changes, or topics about which you think we need more information to help us further identify important monitoring needs?		more staff or more research from outside; increase coop with military installations	understand historical ecological conditions and conversion grassland to shrubland; outside research; paleontological evaluation; writeup on human settlement	showcase white species and rapid evolution; Steve Hagarth thesis on behavior; Hagar 1998 dissertation on lesser earless lizard; too little info on grazing impacts; what were pre-Anglo plant communities?	evolutionary processes of white species	monitor other parks to look for issues overlooked
19. Are there problems perceived by the local govt officials/military as to management of the park?	No resource issues; primarily economic					
20. Perceived impacts due to visitors.	Where visitors go, the "sites" are durable; no real issues					

Appendix G. Vital signs scoping workshop materials and results, cont.

Question	New Items	WHSA respondent				
		A	B	C	D	E
21. Perceived impacts due to maintenance?	Road maintenance activities is the prime activity; was analyzed via NEPA, & no significant impacts identified. Kit fox may be habituated to the garbage; no monitoring wells around the evaporation ponds, but the ponds are lined. This is primary sewage-Ford may need to be asked about this.					

G.2. Parks' level of concern for the complete list of resource issues and potential vital signs identified in Phase I Vital Signs Scoping Workshops (2004-2005).

Resources follow the National Ecological Framework, Level I. Results shown are issue rankings (level of concern) from park responses via the CHDN Intranet online application.

Key

- low
- moderate
- high

	Park					
Resource Issue/Potential Vital Sign	**AMIS**	**BIBE**	**CAVE**	**FODA**	**GUMO**	**WHSA**
Air and Climate						
Air chemistry	low	high	moderate		high	moderate
Historic vegetation data					moderate	
Ozone	low	high	low		moderate	moderate
Particulate pollution/Visibility	low	high	moderate		high	low
Pollinator distribution					moderate	
Weather & Climate	low	high	moderate	moderate	moderate	moderate
Tree growth bands					moderate	
Vegetation communities			moderate	moderate		
Wet and dry deposition	low	high			high	moderate
Geology and Soils						
Air pollution affecting soil chemistry		moderate			moderate	
Alluvial deposition					low	
Bat community structure	moderate					
Biological crusts		moderate			moderate	
Cave biota	low				low	
Cave floor chemistry					low	
Cave microclimate			moderate			
Cave/karst processes			moderate			
Caves/karst features			moderate			
Changes in dune stability						low
Erosion	low	moderate			low	

Appendix G. Vital signs scoping workshop materials and results, cont.

	Park					
Resource Issue/Potential Vital Sign	**AMIS**	**BIBE**	**CAVE**	**FODA**	**GUMO**	**WHSA**
Groundwater dynamics						
Infiltration and other soil characteristics						
Microbial functional diversity						
Migration of patch edges						
Physical disturbance of cave floors (natural & from visitors)						
Stream channel characteristics						
Visitor usage						
Water quality & quantity						
Waterflow in dry arroyos						
Water						
Animal utilization						
Aquatic macroinvertebrates						
Contaminant levels in fish						
Endemic spring species						
Exotic plants and animals in springs						
Flood events						
Groundwater chemistry in the unsaturated zone						
Groundwater dynamics						
Lake salinity						
Lake water levels						
Microorganisms						
Native fish communities & other key components						
Nutrient dynamics						
Persistence of the spring (flows) at a location						
Regional groundwater levels						
Relict communities						
River flow and quantity						
Siltation rates						
Spring dependent biota						
Spring flow and characteristics						
Spring-dependent species (i.e. aquatic macroinvertebrates)						
Surface water dynamics (hydroperiods, flow rates)						
Toxics						

Appendix G. Vital signs scoping workshop materials and results, cont.

	Park					
Resource Issue/Potential Vital Sign	**AMIS**	**BIBE**	**CAVE**	**FODA**	**GUMO**	**WHSA**
Visitor use						
Water chemistry						
Biological Integrity						
Algal communities						
Animals associated with special plant communities						
Aquatic communities						
Bats						
Black bear food supply						
Broad-ranging Species (mt. lion, mule deer)						
Burned areas						
Changes in habitat area						
Community structure						
Curly-leaf Muhly associated community						
Demographics of overstory species						
Desert community						
Desert surface crusts						
Development						
Distribution & diversity of bajada communities						
Distribution of exotics across the landscape						
Distribution of stream features/geomorphology						
Diversity of species within native and altered habitats						
Exotic animals & plants						
Fish communities, especially natives						
Flow regimes impacting aquatic organisms						
Fuel loads						
Grassland bird community						
Grassland vegetation						
Groundwater levels effecting species						
Historic cottonwood grove						
Hydrologic function						
Incidence of mutations						
Invertebrate communities						
Landscape-level changes in habitat quality						

Appendix G. Vital signs scoping workshop materials and results, cont.

	Park					
Resource Issue/Potential Vital Sign	**AMIS**	**BIBE**	**CAVE**	**FODA**	**GUMO**	**WHSA**
Loss of critical food sources						
Meta-populations						
Mussels						
Native plant community composition						
Native species' response to exotics						
Neotropical migrants						
Oak mott age structure & other special woodlands						
Poaching of special status species						
Population and distribution of "white-coloration" species						
Population monitoring						
Populations & distribution of special status species						
Reptiles & amphibians						
Riparian communities						
Small to moderate-sized carnivores						
Soil & sediment erosion						
Soil biota						
Soil chemistry						
Special plant communities						
Species composition (floral & faunal - native & exotic)						
Species of concern						
Spread of exotics within the range of special status species						
Stream channel characteristics						
Stream characteristics						
Structure and composition of native vegetation						
UV levels						
Visitor use patterns						
Water chemistry						
Water fluctuation regimes impacts to wildlife						
Wetlands						
Human Use						
Air quality						
Algal blooms						
Backcountry campsite trampling & erosion						

Appendix G. Vital signs scoping workshop materials and results, cont.

	Park					
Resource Issue/Potential Vital Sign	**AMIS**	**BIBE**	**CAVE**	**FODA**	**GUMO**	**WHSA**
Cultural landscape						
Decibel levels & frequency						
Feral cats						
Focal faunal & vegetation communities						
Grassland bird community effected by visitors						
Grassland vegetation effected by visitors						
Healthy ecosystems						
Human-caused fire						
Human-exotic interactions						
Integral vistas						
Invasive/Exotic plants						
Litter & waste density						
LM levels would give an indication of changes in night skies						
Night skies						
Number of human constructed elements						
Quantity of vandalism sites						
River campsite availability						
Social trails						
Soundscape						
Visitor statistics						
Visual resource integrity						
Water quality						
Ecosystem Patterns and Processes						
Elevational migration of plant communities						
Fire events						
Fuel dynamics (distribution & loading)						
Land cover, pattern and land use changes over time						
Night skies						
Soundscape						
Viewsheds						

Appendix H. Existing Monitoring Programs Relevant to the Chihuahuan Desert Network

H.1 Existing Monitoring Programs in Chihuahuan Desert Network Parks

This section was completed based on information provided through park interviews, workshops, and entry of information into the network's Dataset Catalog. Monitoring projects were broadly defined and include, in some cases, available data (e.g. research, baseline) that may contribute to future monitoring (Table H.1).

Table H.1. Existing monitoring programs in CHDN parks, organized by NPS Ecological Framework.

Level 1	Monitoring project	Duration/Status	Park
Air and Climate	Visibility Monitoring, IMPROVE	1988–present	BIBE
	Wet Deposition Monitoring, NADP/NTN	1980–present	BIBE
	Dry Deposition Monitoring, CASTNET	1995–present	BIBE
	Visibility Monitoring, IMPROVE	1988–present	GUMO
	Wet Deposition Monitoring, NADP/NTN	1984–present	GUMO
	Ozone	2005–present	CAVE
	Climatological and weather records[1]	1949–1969	AMIS
	Climatological and weather records[1]	1910–present	BIBE
	Climatological and weather records[1]	1930–present	CAVE
	Cave temperature and humidity	Active	CAVE
	Climatological and weather records[1]	Active	FODA
	Climatological and weather records[1]	1984–present	GUMO
	Climatological and weather records[1]	1939–present	WHSA
Water	Surface water quality - Amistad Reservoir	1971–present	AMIS
	Surface water quality - Rio Grande	1999–present	BIBE/RIGR
	Surface water dynamics - Amistad Reservoir storage	1968–present	AMIS
	Surface water dynamics - Rio Grande	1924–present	BIBE/RIGR
	Surface water dynamics - Rattlesnake Spring	1961–1962	CAVE
	Surface water dynamics - Rattlesnake Spring	2003–present	CAVE
	Various monitoring wells[2]	1962–2004	AMIS
	Various monitoring wells[2]	1979–1985	BIBE
	Various monitoring wells[2]	1947–2003	CAVE
	Various monitoring wells[2]	Active	FODA
	Various monitoring wells[2]	1948–present	GUMO

Appendix H. Existing monitoring programs relevant to the Chihuahuan Desert Network, cont.

Level 1	Monitoring project	Duration/Status	Park
	Various monitoring wells[2]	1936–present	WHSA
	Springs	1975–present	BIBE
Biological Integrity	MAPS Station	2000–2004	AMIS
	Interior Least Tern nesting	Active	AMIS
	Game fish populations[3]	Active	AMIS
	American Peregrine Falcon	1980–present	BIBE
	Black bear & mountain lion	Active	BIBE
	Fish communities[3]	Active	BIBE
	Endangered cactus species	Active	BIBE
	Invasive/Non-native plant species	Active	BIBE
	Vegetation change-ESSB plots[4]	1950's–present	BIBE
	Bell's vireo-nesting		BIBE
	Cave swallows	1985–present	CAVE
	Mexican spotted owl	1990–present	GUMO
	Invasive/Non-native plant species	Active	GUMO
	Invasive/Non-native plant species	Active	WHSA
	White Sands pupfish-when water present	1996–present	WHSA

H.2 Air Quality

H.2.1 National Atmospheric Deposition Program/National Trends Network

Operated by State Agricultural Experiment Station at University of Illinois (with USGS, USDA, others) this program was initiated in 1978. The National Atmospheric Deposition Program/National Trends Network (NADP/NTN) monitors precipitation at a nationwide network of sites. Several groups cooperate to maintain the network, including the State Agricultural Experiment Stations, U.S. Geological Survey, U.S. Department of Agriculture, and numerous other governmental and private entities. Data is collected on the chemistry of precipitation for monitoring of geographical and temporal long-term trends. Weekly precipitation samples are collected and then analyzed for hydrogen (acidity as pH), sulfate, nitrate, ammonium, chloride, and base cations, at the Central Analytical Laboratory.

H.3 Climate

H.3.1 National Oceanic and Atmospheric Administration, U.S. Climate Reference Network

The National Oceanic and Atmospheric Administration (NOAA) is establishing a network of climate stations (Climate Reference Network) with the help of the Western Regional Climate Center, as part of a NOAA initiative. The goal of this project is to monitor long-term precipitation and temperature observations to couple with past observations in order to investigate present and future climate change. If fully implemented, the network will have established about 250 stations nationwide.

H.3.2 U.S. Geological Survey (USGS), Earth Surface Dynamics Program, Southwest Climate Impacts Project

The Southwest Climate Impacts Project investigates how climate and human activities affect geologic processes (weathering, erosion, deposition) that change the landscape. The project involves the use of remotely placed CLIM-MET meteorological stations, which function for long periods of time, usually long enough to support a parent project that monitors surficial processes. This project is part of the USGS Earth Surface Dynamics Program, which is one of several areas of research the USGS leads as part of its participation in the larger U.S. Global Change Research Program.

H.4 Earth Sciences

H.4.1 Interpreting Indicators of Rangeland Health: Land Health Assessments

A collaboration among the U.S. Geological Survey, the USDA Agricultural Research Station, the Bureau of Land Management, and the NRCS, the Interpreting Indicators of Rangeland Health program is designed to provide a quick, qualitative assessment of rangeland health based on the functional status of 17 indicator variables. These indicators reflect three resource attributes of rangelands: soil stability, hydrologic function, and biotic integrity. The program is not a quantitative monitoring technique, but is designed to identify areas of concern, which would then need further quantitative assessment and/or monitoring.

H.5 Water Quality and Water Quantity Monitoring

H.5.1 U.S. Geological Survey – Water Monitoring

The U.S. Geological Survey was created by an act of Congress in 1879 and has become the principal Federal agency providing water information needed to manage the Nation's water resources. In 1889, the U.S. Geological Survey established the first streamflow-gauging station on the Rio Grande River in New Mexico. The U.S. Geological Survey now operates and maintains a network of about 7,000 streamflow-gauging stations nationwide and about 70% of these have real-time capabilities. The U.S. Geological Survey monitors the quantity and quality of water in many rivers, streams, lakes, and reservoirs. The monitoring program is a cooperative effort that is funded jointly by numerous Federal, State, and local agencies. Streamflow data collected as part of the monitoring program are used for hydrologic research, reservoir operations, forecasting floods and droughts, maintaining water quality, and monitoring water-quality conditions and trends (http://water.usgs.gov/).

H.6 Avian

H.6.1 Institute for Bird Populations, Monitoring Avian Productivity and Survivorship Program

The Institute for Bird Populations (IBP) at Point Reyes Station, California, is a non-profit corporation focused on research and monitoring of avian populations at a global scale. In 1989, the Institute initiated the Monitoring Avian Productivity and Survivorship Program (MAPS) in cooperation with USGS, NPS, USFWS, state fish and wildlife agencies, and others to monitor avian productivity and survivorship at constant-effort mist net trapping and banding stations across the United States. Currently, data from over 500 MAPS stations have contributed to productivity indices and improving understanding of population trends, ranges and habitat of various species. MAPS stations can be run by any agency or organization, which follows the standard protocols, used by the IBP, and which contributes their data to the national MAPS database (http://www.birdpop.org/).

H.6.2 National Audubon Society, Christmas Bird Count

The National Audubon Society's Christmas Bird Count (CBC) is an annual 15-mile diameter circle Area Search for birds, conducted on one day in the winter by volunteers. Results from the CBC achieve the primary objective of monitoring the status and distribution of bird populations across the Western Hemisphere. The CBC has been conducted since 1900, and results are available from a national website sponsored by the National Audubon Society and the Cornell Lab of Ornithology (http://www.audubon.org/bird/cbc/index.html).

H.6.3 North American Breeding Bird Survey

Begun in 1966, the North American Breeding Bird Survey (BBS) was first administrated by the U.S. Fish and Wildlife Service, and is currently being administered by the U.S. Geological Survey, Patuxent Wildlife Research Center. The survey is conducted once in June across North America, at over 3500 routes. Routes are 24.5 miles long, with observers stopping every 0.5 miles to record all birds seen and heard during a 3-minute point count. Analysis of the data results in continent-scale abundance maps, and trend information on individual species and groups such as neotropical migrants (http://www.mbr-pwrc.usgs.gov/bbs/bbs.html).

H.6.4 U.S. Geological Survey (USGS), Breeding Biology Research & Monitoring Database

A component of the USGS Global Change Research Program, the Breeding Biology Research and Monitoring Database (BBIRD) is a national program that uses standardized protocols to study bird nest success and nesting habitat requirements. Study sites consist of nest-finding plots, a minimum of 4 ha in size, which are intensively surveyed throughout the breeding season. Study sites often match unaltered with altered plots to examine how land use affects the ability of habitats to support source or sink populations of birds. Participants contribute their data to the national BBIRD database, which can then be used to identify large-scale patterns and trends. BBIRD sites on the Colorado Plateau do not appear to be common (http://www.umt.edu/bbird).

H.6.5 Partners in Flight Program

Partners in Flight (PIF) began in 1989 as a national effort to document and reverse apparent declines in neotropical migratory birds. It is a cooperative effort with federal, state, and local government agencies, philanthropic foundations, professional organizations, conservation groups, industry, the academic community, and private individuals. PIF is now international in scope, with PIF Mexico and PIF Canada (http://www.partnersinflight.org/).

H.7 Fish

H.7.1 Texas Department of Parks and Wildlife (TDPW) Sport and Native Fish Monitoring Programs

The TDPW conducts routine “creel” surveys of Amistad Reservoir for sports fisheries using standard protocols.

H.7.2 New Mexico Department of Game and Fish

In cooperation with Department of Defense, and National Park Service (when applicable) monitor White Sands Pupfish in the Tularosa Basin (where WHSA is located).

H.8 Mammals

H.8.1 U.S. Geological Survey (USGS), Bat Population Status in the United States and Territories

The USGS Bat Population Status project is intended to synthesize bat information from states, conservation organizations, and Interior Department land managers that will then support hypothesis testing, developing monitoring protocols, and a summary of conservation needs. The initial phase of the project involved the creation of a Bat Population Database. This database will then be used for hypothesis testing, statistical analysis, and in the design of potential long-term monitoring programs.

H.9 Reptiles and Amphibians

H.9.1 U.S. Geological Survey (USGS), Amphibian Research and Monitoring Initiative

In response to growing awareness of amphibian declines and malformations, the USGS Amphibian Research and Monitoring Initiative (ARMI) program was initiated by the United States Congress in 2000 to monitor trends in amphibian populations on Department of Interior (DOI) lands, and to research the cause of amphibian declines. While intensive monitoring will be focused on DOI lands, ARMI will also provide a framework for incorporating amphibian monitoring data by other agencies outside of DOI lands. Partnerships with other DOI agencies include a nationwide survey by the Fish and Wildlife Service on 48 National Wildlife Refuges in 31 states for contaminants that may induce malformations in amphibians.

H.9.2 U.S. Geological Survey (USGS) Inventory, Monitoring, and Research Database for Reptiles

The USGS reptile database project originally aimed to collect information about reptile inventory, monitoring, and research projects on U.S. Department of Interior lands. It has expanded its scope to include all federal lands, as well as to include amphibian data. The database is intended to complement database work under the Amphibian Initiative, and will eventually become part of the PARC (Partners in Amphibian and Reptile Conservation) website and the USGS website.

H.10 Plants

H.10.1 New Mexico Rare Plant Technical Council

The New Mexico Rare Plant Technical Council is a volunteer organization that has developed and now maintains an internet database that contains information on biology and conservation status of the nearly 200 plant species found in New Mexico (http://nmrareplants.unm.edu/index.html).

H.10.2 USDA Forest Service, Forest Health Monitoring Program

USDA Forest Service, Forest Health Monitoring (FHM) is a component of the national Forest Inventory and Analysis program. Forest Health Monitoring is designed to determine status, changes, and trends in indicators of forest condition on an annual basis. Its focus is on forest health issues that affect ecosystem sustainability. Intensive data are collected from a subset of plots already established by the FIA program. These data, identified as indicators of forest health, collect information about vegetation diversity, soils, lichens, downed woody debris, and tree crowns. They provide the basis for developing analytical approaches to addressing forest health issues (http://fhm.fs.fed.us/).

H.10.3 USDA Forest Service, Forest Inventory and Analysis Program

The Forest Inventory and Analysis Program (FIA) is a national USDA Forest Service program that provides a census of landscape level information about forestry resources since 1930. The FIA program inventories all forested lands, including federal, private and state lands. Access to the data is available through the National Forest Inventory and Analysis Geospatial Data Service Center, which can be accessed on the internet at: http://www.fs.fed.us/ne/fia/spatial/index_ss.html. FIA data is collected in 3 Phases, the third phase of which comprises the Forest Health Monitoring Program. Phase I data are collected at a coarse scale to make broad land cover classifications. Phase II data are collected at a fine scale on randomly selected plots located at the intersections of a 5000 m x 5000m grid. Phase II data collection requires a large data collection effort in the field. Together, Phase I and Phase III plots measure over 120 variables. Phase III intensive data collection, done on a subset of Phase II plots, is aimed towards indicators of forest health including vegetation, soils, lichens, downed woody debris and tree crowns.

H.11 Regional Research, Monitoring, and Database Programs

H.11.1 Jornada Experimental Range

Originally set aside in 1912, these lands are now operated by the USDA – Agricultural Research Service. Research projects cover a wide-range of topics from nutrient cycling, temporal changes in vegetation, rangeland health, key process and linkages in desert landscapes, and the role and impact of biota in ecosystems. Over 100 permanent quadrats were established in 1915 to monitor vegetation patterns. These were monitored annually until 1947 with a subset annually monitored until 1979. Many of these quadrats were relocated and measured in 1995 and 2001 (http://usda-ars.nmsu.edu/).

H.11.2 Jornada Basin Long-Term Ecological Research Project

The Jornada Basin Long-Term Ecological Research (LTER) site is comprised of the Chihuahuan Desert Rangeland Research Center operated by New Mexico State University and the USDA Jornada Experimental Range (see description in this section). The LTER covers approximately 100,000 ha in the Chihuahuan Desert of southern New Mexico. Research at the LTER focuses on five habitat types: black grama grassland (*Bouteloua eriopoda*), creosote bush scrub (*Larrea tridentata*), mesquite duneland (*Prosopis glandulosa*), tarbush shrublands (*Flourensia cernua*) and playa. Research focuses primarily on factors influencing desertification including animal-induced soil disturbances, primary production, biodiversity and ecosystem function, soil microbial processes, and eolian processes (http://jornada-www.nmsu.edu/).

H.11.3 Natural Heritage New Mexico

The Arizona Natural Heritage Program is one of 86 primary data centers throughout the United States, Canada, Latin America, and the Caribbean countries, which uses the Natural Heritage Methodology for ranking and preserving species and communities. Its database contains scientific information on two elements: species, and subspecies. This allows the program to rank relative degree of imperilment of these elements, rank populations or occurrences of each according to their level of health or quality, and delineate and rank potential conservation areas (http://nhnm.unm.edu/).

H.11.4 Sevilleta Long Term Ecological Research Station (LTER)

The Sevilleta LTER is located near Albuquerque, New Mexico and is comprised mostly of the Sevilleta National Wildlife Refuge. Originally acquired by The Nature Conservancy, the refuge lands were turned over in 1973 to the U.S. Fish and Wildlife Service. In a cooperative effort with University of New Mexico the refuge became host to a LTER in 1988 – one of twenty-four nation-wide sites where research focuses

on global warming trends and other environmental concerns. The LTER lands encompass subalpine mixed-conifer forest, riparian cottonwood communities, desert grasslands, mesquite and sand dunes, and Great Basin shrub and part of the Rio Grande river valley (http://sev.lternet.edu/).

H.11.5 Southwestern Museum of Biology, Curation of Biological Survey Collection

In 1994, United States Geological Survey (USGS) scientific collections of western vertebrates were moved from Fort Collins, CO, to Albuquerque, NM, where they joined a larger collection at the Museum of Southwestern Biology. This project creates and maintains electronic databases and curates the USGS collections, which consist of amphibians and reptiles, fishes, birds and mammals, mostly from the Rocky Mountains and Intermountain West. The collection is rich in bats and rodents, and a general research emphasis has been to document mammal species from public lands in the West. Vouchers from CHDN herpetological inventories are housed here.

Appendix I. Chihuahuan Desert Network Prioritization Workshop Report

I.1 Overview

The CHDN Vital Signs Prioritization Workshop was held June 14–15, 2006 in El Paso, Tx. This two-day workshop was attended by 64 people and continued the process of developing a long-term ecological monitoring program for natural resources in the Chihuahuan Desert Inventory and Monitoring Network (CHDN). This workshop was preceded in 2004 and 2005 by: 1) CHDN-held scoping sessions with park managers from each CHDN park, 2) review of peer-reviewed literature and gray literature, and 3) initiation of development of conceptual models for the three major terrestrial ecosystems in CHDN. In the fall of 2005, CHDN held one separate workshop, in Las Cruces, New Mexico, exclusively dealing with water-quality issues and potential aquatic resources vital signs as the network headed into development of its Phase II Water Quality Assessment report. This process resulted in a list of 35 potential vital signs for consideration in our water-quality and long-term monitoring programs:

1. Groundwater dynamics (flow patterns, rates, levels, groundwater interaction with surface water)
2. Endemic spring species
3. Spring flow in regional groundwater flow system
4. Water quality in large rivers
5. Contaminants
6. Microorganisms
7. Water chemistry
8. Water quality of other large surface flows (rivers)
9. Persistence of the spring (flows) at a location
10. Spring dependent biota (i.e. aquatic macroinvertebrates, etc.)
11. Groundwater level (local & regional flow systems)
12. Surface water dynamics (hydroperiods, flow rates)
13. Water quality of springs
14. Water quality of springs
15. Cave groundwater dynamics
16. Relict communities
17. Water quality in cave systems
18. Native fish communities & other key components (mussels, amphibians, sliders)
19. Water quality in reservoir
20. Nutrient dynamics
21. Water quality of groundwater
22. Aquatic macroinvertebrates
23. Streamflow, including arroyos
24. Contaminant levels in fish
25. Animal utilization
26. Exotic plants and animals in springs
27. Visitor use at springs & seeps
28. Water quantity of reservoir
29. Water quantity in cave systems
30. Siltation rates in reservoir
31. Extreme storm events

32. Water levels at Lake Lucero
33. Salinity levels at Lake Lucero
34. Groundwater chemistry in the unsaturated zone
35. Flood events on the Rio Grande

The objectives of the workshop were to:

- Review candidate vital signs;
- Identify justification sources for each vital sign by ecosystem;
- Score the Ecological Significance (ES) for each vital sign by ecosystem;
- Add new vital signs as appropriate;
- For the top 25% of vital signs, identify potential measures and monitoring partners; and
- Develop a prioritized list of vital signs ranked according to ecological significance.

The goal of the prioritization workshop was to create a prioritized list of vital signs. Prior to the prioritization workshop, park superintendents, technical committee members, and all natural resource staff from each park scored the vital signs to be reviewed at the workshop (Table I.1-1) according to management significance. At the workshop, participants were divided into five workgroups: animals, aquatic resources, landscape- level issues, plants and soils, and unique (subterranean caves and dunes) (see Table I.1-2 for a complete list of participants and break-out group assignments). Each group reviewed a set of potential vital signs. Each vital sign that was retained was reviewed in four areas: 1) a justification source was indicated for each of seven major ecosystems, 2) ecological significance was scored, 3) potential partners were noted, and 4) potential measures were indicated. Following the workshop, a total score for each potential vital sign was calculated using ecological and management significance scores and a justification source weighting score (see Section 4). This process resulted in a prioritized list of vital signs for CHDN.

Table I.1-1. The 97 Vital Signs (Phase I) that made up the database for the VS Prioritization Workshop (Phase II).

Level 1	Level 2	Vital Sign
Air and Climate	Air Quality	Air quality in caves
		Atmospheric deposition of mercury
		Ozone
		Visibility and particulate matter
		Wet deposition chemistry (pH, NO3-, SO4=), cont sulfur dioxide (SO2)
	Weather and Climate	Carbon balance in soil
		Cave microclimate
		General meteorological conditions (precip, wind, RH, T, snow pack, soil moisture)
Geology and Soils	Geomorphology	Dune formation and stability
		Dune reactivation
		Geomorphology/channel characteristics of perennial rivers and streams
		Reservoir siltation
		Soil budget/movement (inflow/outflow)
		Soil erosion index
	Soil Quality	Cave floor chemistry
		Nutrient levels
		Soil chemistry
		Soil erosion index (wind and water)
		Soil health (stability, compaction, infiltration)
	Subsurface Geologic Processes	Cave/karst processes
		Caves/karst features
		Water volume of pools
Water	Hydrology	Groundwater dynamics (flow patterns, rates, levels, groundwater interaction with surface water)
		Groundwater dynamics in cave systems
		Groundwater dynamics in dune systems
		Lake elevation for Amistad Reservoir - AMIS only
		Persistence of springs & seeps
		Regional groundwater flow systems
		Surface water dynamics (hydroperiods, flow rates and quantity) of rivers and other perennial waters
		Water quantity and shoreline shape of Lake Lucero - WHSA only
		Water quantity of non-reservoir aquatic systems
		Waterflow in dry arroyos

Appendix I. Chihuahuan Desert Network Prioritization Workshop report, cont.

Level 1	Level 2	Vital Sign
	Water Quality	Contaminants in fish (primarily heavy metals)
		Core parameters (T, DO, conductivity, pH, turbidity, flow)
		Groundwater chemistry in the unsaturated zone
		Microbiotic components (esp. E. coli)
		Nutrient loading (ammonia, nitrites, nitrates, total P)
		Water chemistry (acidification)
		Water quality (core parameters: T, DO, cond, pH) of cave pools
		Water quality of regional groundwater systems
Biological Integrity	At-risk Biota	Collecting/poaching of species, esp. special concern
		Distribution & relative abundance of animal species of concern
		Distribution & reproduction of plant species of concern
	Focal Species or Communities	Animal communities in special/relic plant communities
		Biological soil crusts
		Black bear abundance & distribution
		Composition of algal communities
		Composition of wetland vegetation communities
		Distribution & composition of vegetation communities/ecosystems
		Distribution of broad-ranging species (mt. lion, mule deer)
		Distribution of oak motts & other special woodlands (dune field cottonwoods)
		Historic cottonwood grove - FODA only
		Mutation frequencies in amphibians
		Neotropical migrant bird communities
		Phenology (leaf out/drop, flowering)/Tree growth bands
		Relative abundance of bats
		Size & age structure of tournament caught fish - AMIS only
		Small to moderate-sized carnivores
		Soil microbes and other soil biota
		Species richness & diversity of amphibians
		Species richness & diversity of aquatic invertebrates in perennial streams & rivers
		Species richness & diversity of cave biota
		Species richness & diversity of cave microbial communities
		Species richness & diversity of dune biota, esp. white-coloration species
		Species richness & diversity of native fish, mussels & turtles in perennial streams & rivers, esp. endemics
		Species richness & diversity of native species in reservoirs, esp. endemics

Appendix I. Chihuahuan Desert Network Prioritization Workshop report, cont.

Level 1	Level 2	Vital Sign
		Species richness & diversity of non-vascular plants
		Species richness & diversity of reptile community
		Species richness & diversity, composition of riparian vegetation communities
		Species richness & diversity, relative abundance of aquatic invertebrates of springs and seeps, esp. endemics
		Species richness & diversity-invertebrates, esp. endemics
		Species richness & diversity of cave pool biota
	Invasive Species	Distribution & composition of invasive/exotic plant associated with aquatic systems
		Distribution & abundance of invasive/non-native plants
		Distribution of hydrilla (recreation issue) - AMIS only
		Distribution of invasive/exotic aquatic invertebrates
		Distribution of non-native animals
		Distribution of non-native fish
		Feral cats
		Golden algae (Prymnesium parvum) distribution - exotic
Human Use	Consumptive Use	Distribution of mineral, oil and gas extraction sites
	Point Source Human Effects	Human-caused fire
		Visitor use at springs and seeps
	Visitor and Recreation Use	Effects of park visitors on natural resources
		Impacts of air quality on visitor satisfaction
		Visitor satisfaction relative to feature attractions (i.e. bats at the caverns)
Landscapes	Extreme Disturbance Events	Distribution & characterization of extreme disturbance events (fire, insect/pathogen outbreaks, floods)
	Fire and Fuel Dynamics	Fire and fuel dynamics
	Landscape Dynamics	Degradation of desert ecosystems (including hydrologic function)
		Land use changes adjacent to parks
		Land use changes within Chihuahuan Desert
		Landscape dynamics (land cover, pattern & patch sizes changes) in parks-
		Landscape fragmentation and connectivity
		Vegetation patch dynamics (microscale)
	Soundscape	Soundscape, especially in wilderness areas
	Viewscape	Night skies
		Viewsheds

Table I.1-2. List of Vital Signs Prioritization (Phase II) Workshop participants.

Name	Organization	Position	Group/Function	NPS Participants
Animal Group				
Bustos, David	White Sands National Monument	Biologist	Animals	NPS
Foster, Danielle	Carlsbad Caverns National Park	Biologist	Animals	NPS
Goode, Matt	School of Natural Resources, University of Arizona	Assistant Research Scientist	Animals	
Harris, Art	Centennial Museum, Laboratory for Environmental Biology	Director	Animals	
Heiner, John	Fort Davis National Historic Site	Chief of Interpretation	Animals	NPS
Kelly, Jeff	Oklahoma Biological Survey, University of Oklahoma	Heritage Zoologist/Assistant Professor	Animals-Facilitator	
Mendez-Gonzalez, Cesar	New Mexico State University, Fishery & Wildlife Sciences	Doctoral Student	Animals	
Metzler, Eric	Research Associates	Entomologist	Animals	
Mueller, Jim	Tarleton State University, Department of Animal Sciences	Assistant Professor	Animals	
Skiles, Raymond	Big Bend National Park	Wildlife Biologist	Animals	NPS
Smith, Jackie	Natural Heritage Program, University of New Mexico	Assistant Zoologist	Note Taker	
West, Steve	Carlsbad, New Mexico	Biologist	Animals	
Wobbenhorst, Jan	Guadalupe Mountains National Park	Chief Ranger	Animals	NPS
Aquatic Resources and Water Quality Group				
Bennett, Jeff	Big Bend National Park	Physical Scientist	Aquatics	NPS
Briggs, Mark	Mark Briggs Consulting	Restoration Ecologist	Aquatics	
Huff, Rick	USGS, New Mexico Water Resources	Hydrologist	Aquatics	
Groeger, Al	Texas State University-San Marcos	Associate Professor, Dept. of Biology	Aquatics	

Name	Organization	Position	Group/Function	NPS Participants
Keeshen, Rebecca	Natural Heritage Program, University of New Mexico	Office Manager	Note Taker	
Lambert, Becky	US Geological Survey	Water Quality Coordinator	Aquatics	
Langman, Jeff	USGS, New Mexico Water Science Center	Hydrologist	Aquatics	
Longley, Glenn	Texas State University-San Marcos	Professor of Aquatic Biology	Aquatics	
Lougheed, Vanessa	University of Texas at El Paso	Aquatic Biologist	Aquatics	
Moring, Bruce	US Geological Survey, Research and Investigations Section	Senior Biologist	Aquatics	
Roemer, Dave	Carlsbad Caverns National Park	GIS Specialist/Biologist	Aquatics	NPS
Rosenlieb, Gary	I&M, Water Resources Division, National Park Service	Hydrologist	Aquatics	NPS, I&M
Shanks, W.C. “Pat”	US Geological Survey	Research Geologist	Aquatics	
Slade, Rick	Amistad National Recreation Area	Chief of Education and Resource Management	Aquatics-Facilitator	NPS
Walsh, Elizabeth “Liz”	University of Texas-El Paso	Assistant Professor, Dept. of Biology	Aquatics	
Landscape Issues Group				
Atchley-Montoya, Jennifer	World Wildlife Fund	Senior Program Officer	Landscape	
Bailey, Derek	Chihuahuan Desert Rangeland Research Center/NMSU Animal and Range Sciences	Director/Associate Professor	Landscape	
Davila, Vidal	Big Bend National Park	Chief of Science & Resource Management	Landscape	NPS
Gatewood, Richard	NPS, Chihuahuan Desert & Southern Plains Fire Program	Fire Ecologist	Landscape	NPS
Marin, Rebecca	University of Texas-El Paso	Doctoral Candidate	Landscape	
Mills, Helen	Yale University	Doctoral Candidate	Landscape	
Neville, Teri	Natural Heritage Program, University of New Mexico	GIS Coordinator	Note Taker	

Appendix I. Chihuahuan Desert Network Prioritization Workshop report, cont.

Name	Organization	Position	Group/Function	NPS Participants
Noojibail, Gopaul	Carlsbad Caverns National Park	Chief of Resource Stewardship and Science	Landscape-Facilitator	NPS
Porter, Ellen	National Park Service, I&M Air Resources	Biologist	Landscape	NPS, I&M
Sikula, Nicole	The Nature Conservancy	Monitoring Coordinator	Landscape	
White, Joseph	Baylor University	Associate Professor of Biology	Landscape	
Whitford, Walt	USDA ARS, Jornada Experimental Range	Ecologist	Landscape	
Plants and Soil Resources Group				
Anderson, Dave	White Sands Missile Range	Botanist	Plants/Soil	
Armstrong, Fred	Guadalupe Mountains National Park	Resource Management Specialist	Plants/Soil	NPS
Biggam, Pete	NPS I&M Geological Resources Division	Soils Program Manager	Plants/Soil	NPS, I&M
Corral, Rafael	Fort Bliss	Botanist	Plants/Soil	
Florez, Lou	EPMT-CHDN & SOPN	Exotic Plant Management Specialist	Plants/Soil	NPS
Herrick, Jeff	USDA ARS, Jornada Experimental Range	Soil Scientist	Plants/Soil	
Hotchkin, Paul	University of Texas at El Paso	Doctoral Student	Plants/Soil	
Johnson, Kris	Natural Heritage Program, UNM	Director/Research Associate Professor	Plants/Soil-Facilitator	
McDaniel, Kirk	New Mexico State University	Professor of Range Science	Plants/Soil	
Monger, Curtis	New Mexico State University	Professor of Pedology/Environmental Science	Plants/Soil	
Powell, Missy	I&M Chihuahuan Desert Network	Biological Science Technician	Note Taker	NPS, I&M
Rice, Kathleen “Kathy”	Desert Botanical Garden	Curator of Seeds	Plants/Soil	
Sirotnak, Joe	Big Bend National Park	Botanist/Ecologist	Plants/Soil	NPS
Sivinski, Bob	New Mexico Department of Forestry and Minerals	T&E Botanist	Plants/Soil	
Warnock, Bonnie	Sul Ross State University	Assistant Professor of Natural Resource Management	Plants/Soil	
West, Renee	Carlsbad Caverns National Park	Supervisory Biologist	Plants/Soil	NPS

Appendix I. Chihuahuan Desert Network Prioritization Workshop report, cont.

Name	Organization	Position	Group/Function	NPS Participants
Worthington, Richard	University of Texas-El Paso	Associate Professor of Biological Sciences	Plants/Soil	
Unique Systems Issues Group				
Barton, Hazel	Northern Kentucky University	Assistant Professor	Unique Systems	
Bell, Gorden	Guadalupe Mountains National Park	Geologist	Unique Systems	NPS
Gill, Tom	University of Texas-El Paso, Geological Sciences	Associate Professor	Unique Systems	
Langford, Rip	University of Texas-El Paso, Geological Sciences	Associate Professor	Unique Systems	
Hennrich, Marchelle	NMSU International Programs Office	Student Worker	Note Taker	
Pate, Dale	Carlsbad Caverns National Park	Supervisory Physical Scientist	Unique Systems	NPS
Perkins, Dusty	I&M Southern Plains Network	Network Program Coordinator	Unique Systems-Facilitator	NPS, I&M
White, Diane	White Sands National Monument	Resources Specialist	Unique Systems	NPS
Additional Participants				
Harris, Rick	Chamizal National Memorial	Superintendent	Rover – Day 2 only	NPS
Lujan, John	Guadalupe Mountains National Park	Superintendent/Vice-Chair CHDN Board of Directors	Rover	NPS
Reiser, Hildy	I&M Chihuahuan Desert Network	Program Coordinator	Rover	NPS, I&M
Richie, Tom	I&M Chihuahuan Desert Network	Data Manager	Database/Equipment Management	NPS, I&M
Ward, Pat	USDA ARS, Jornada Experimental Range	Research Ecologist	Rover	

I.2 Prioritization Process

The workshop started with a welcome from John Lujan, Superintendent at Guadalupe Mountains National Park. CHDN Network Coordinator Hildy Reiser then presented an overview of the Inventory and Monitoring Program, the CHDN, and the workshop process (Table I.2-1). She emphasized that in ranking ecological significance the workgroups should stick to the pre-set criteria. Each criterion and the scoring system were reviewed as a group to minimize differences in definitions and interpretations between groups. Pat Ward then presented an overview of CHDN Conceptual Modeling process. The workshop was then divided into five break-out groups, with a facilitator and note taker in each group. The facilitators were familiar with the Inventory and Monitoring program and the vital signs process. All vital signs and scores were contained in an Access database.

Table I.2-1. Vital Signs Prioritization (Phase II) Workshop agenda.

Wednesday June 14, 2006 – Camino Real Hotel, El Paso, Texas			
Time	**Subject**	**Leader**	**Comments**
7:45–8:30	Continental Breakfast		Kohlberg Room
8:30–8:40	Welcome	John Lujan	Kohlberg Room
8:40–8:50	Group Introductions	Hildy Reiser	Kohlberg Room
8:50–9:30	Overview of I&M and CHDN; and Workshop Objectives	Hildy Reiser	Kohlberg Room
9:30–10:30	Overview of CHDN Conceptual Modeling Process	Pat Ward	Kohlberg Room
10:30–10:50	Break		
10:50–11:10	Discussion - Conceptual Model and Potential Vital Signs	Participants	Kohlberg Room
11:10–12:30	Breakout Sessions – Evaluation of Potential Vital Signs	Facilitators	
	Landscape Level Issues	Gopaul Noojibail – Facilitator	Rio Grande Room
	Plants and Soils	Kris Johnson – Facilitator	Kohlberg Room
	Unique Systems	Dusty Perkins - Facilitator	Hereford A Room
	Aquatic Resources and Water Quality	Rick Slade – Facilitator	Santa Fe Room
	Animals	Jeff Kelly – Facilitator	Angus Room
12:30–1:30	Lunch		
1:30–3:00	Breakout Sessions – Evaluation of Potential Vital Signs	Facilitators	Assigned Rooms
3:00–3:20	Break		Kohlberg Room
3:20–5:00	Resume Breakout Sessions		Assigned Rooms
Thursday, June 15, 2006 – Camino Real Hotel, El Paso, Tx			
7:45–8:30	Continental Breakfast		Kohlberg Room
8:30–8:45	Day's Objectives	Hildy Reiser	Kohlberg Room
8:45–12:00	Breakout Sessions – Evaluation of Potential Vital Signs and review of	Facilitators	Breaks as needed; See room assignments from

Wednesday June 14, 2006 – Camino Real Hotel, El Paso, Texas			
	group list		June 14
12:00–1:00	Lunch		
1:00–2:00	Breakout Sessions Continue	Facilitators	Assigned Rooms
2:00–2:30	Presentation of Prioritized Vital Signs List + Discussion	Hildy Reiser	Kohlberg Room
2:30–3:00	Wrap-Up and Future Plans	Hildy Reiser	Kohlberg Room

Each break-out group worked through its list, one vital sign at a time, and reviewed fields containing information on justifications, potential measures, and partners. Each break-out group participant was provided with a tally sheet that allowed each participant to track his or her scores by ecosystem for each vital sign. This allowed members to give full attention to the discussions and not worry about remembering scores. CHDN staff set up a spreadsheet ahead of time, whereby the note taker could quickly enter each group member's ecological significance score by ecosystem. The average, median, and mode were calculated for each vital sign by ecosystem. If the group felt the average value was not representative, a consensus score was provided via discussion. This was necessary when individual scores were bimodal. For example, if half indicated that the ecological significance score should be a 1 or 2, and the other half indicated 4 or 5, then the discrepancy was discussed before a final score was assigned. Median and modal values that were quite different from the average value provided a good indication that the mean value was not representative and that a refined score should be produced through consensus. Each break-out group was allowed to add vital signs to the list. Thirty-seven 'new' vital signs (generated by renaming of original vital signs, combining multiple vital signs into a newly titled vital sign, splitting original vital signs, and generating completely new vital signs) were added from the five break-out groups evaluating seven ecosystems. This data set was reduced to a total of 86 potential vital signs (Table I.2-2). Vital signs lists were also produced for each ecosystem (Tables J.2-3–J.2-9), see color key at the end of each table). The rankings of the vital signs in Tables J.2-3–J.2-9 are based on the rankings for only the ecosystem referenced in the table.

The break-out groups were also encouraged to write additional comments for each vital sign that pertained to scoring, justifications, monitoring objectives, measures, or other. All break-out groups also had suggestions for merging and combining vital signs (see the following links to the break-out group databases: Animals, Aquatics, Landscape, Plants and Soils, and Unique.

Table I.2-2. All CHDN vital signs ranked at the Vital Signs Prioritization Workshop (Phase II).

Final ID	Level 1	Level 2	Level 3	Vital Sign	Ranked Score
86	Water	Hydrology	Groundwater Dynamics	Groundwater dynamics in dune systems	8
84	Water	Hydrology	Groundwater Dynamics	Groundwater dynamics (flow patterns, rates, levels, groundwater interaction with surface water)	7.53
129	New-Water	New-Hydrology	New-Surface Water Dynamics	Watershed hydrology	7.44
56	Geology and Soils	Geomorphology	Windblown Features and Processes	Dune reactivation	7.2
122	New-Water	New-Water Quality	New-Water Quality	Water quality (surface and groundwater)	7.129
112	Biological Integrity	Invasive Species	Invasive/Exotic Animals	Distribution of non-native animals	6.87
78	Landscapes	Landscape Dynamics	Land Cover and Use	Landscape dynamics (land cover, pattern & patch sizes changes)	6.8
114	New-Biological Integrity	New-Focal Species or Communities	New-Cave Communities	Microbial biofilm formation	6.765
110	Biological Integrity	Invasive Species	Invasive/Exotic Plants	Distribution & abundance of invasive/non-native plants	6.71
55	Geology and Soils	Geomorphology	Windblown Features and Processes	Dune formation and stability	6.67
126	New-Biological Integrity	New-Focal Species or Communities	New-Soil Communities	Lichen/mosses as biomonitors	6.67
111	Biological Integrity	Focal Species or Communities	Terrestrial Complex	Phenology (leaf out/drop, flowering)/tree growth bands	6.656
7	Air and Climate	Weather and Climate	Weather and Climate	General meteorological conditions (precip, wind, RH, T, snow pack, soil moisture)	6.64
105	Water	Hydrology	Surface Water Dynamics	Lake elevation for Amistad Reservoir	6.64
75	Landscapes	Extreme Disturbance Events	Extreme Disturbance Events	Distribution & characterization of extreme disturbance events (fire, insect/pathogen outbreaks, floods)	6.6
28	Biological Integrity	Focal Species or Communities	Riparian communities	Bird communities	6.555

Appendix I. Chihuahuan Desert Network Prioritization Workshop report, cont.

Final ID	Level 1	Level 2	Level 3	Vital Sign	Ranked Score
115	New-Water	New-Water Quality	New-Water Chemistry	Sediment quality	6.52
79	Landscapes	Landscape Dynamics	Land Cover and Use	Vegetation patch dynamics (microscale)	6.5
116	New-Air and Climate	New-Air Quality	New-Visibility and Particulate Matter	Visibility	6.5
24	Biological Integrity	Focal Species or Communities	Mammals	Relative abundance of bats	6.465
107	Landscapes	Landscape Dynamics	Land Cover and Use	Landscape fragmentation and connectivity	6.4
108	Landscapes	Landscape Dynamics	Land Cover and Use	Land use changes within Chihuahuan Desert	6.4
139	New-Water	New-Hydrology	New-Surface Water Dynamics	Surface water dynamics (hydroperiods, flow rates and quantity)	6.376
119	New-Biological Integrity	New-Focal Species or Communities	New-Vegetation Complex	Plant community composition	6.36
132	New-Biological Integrity	New-Focal Species or Communities	New-Freshwater Invertebrates	Invertebrates in aquatic systems	6.34
135	New-Biological Integrity	New-Focal Species or Communities	New-Sparsely Vegetated Communities	Bare ground	6.24
10	Biological Integrity	At-risk Biota	T&E Species and Communities	Distribution & relative abundance of animal species of concern	6.215
103	Water	Hydrology	Surface Water Dynamics	Persistence of springs & seeps	6.215
123	New-Air and Climate	New-Air Quality	New-Wet and dry Deposition	Atmospheric wet/dry deposition	6.181
120	New-Air and Climate	New-Air Quality	New-Visibility and Particulate Matter	Particulate matter	6.18
130	New-Biological Integrity	New-Focal Species or Communities	New-Fishes	Native and non-native fish in aquatic systems	6.142
76	Landscapes	Fire and Fuel Dynamics	Fire and Fuel Dynamics	Fire and fuel dynamics	6.073

Appendix I. Chihuahuan Desert Network Prioritization Workshop report, cont.

Final ID	Level 1	Level 2	Level 3	Vital Sign	Ranked Score
137	New-Geology and Soils	New-Soil Quality	New-Soil Function and Dynamics	Soil erosion (wind and water)	5.993
16	Biological Integrity	Focal Species or Communities	Dune Communities	Species richness & diversity of dune biota, esp. white-coloration species	5.865
102	Biological Integrity	Focal Species or Communities	Amphibians and Reptiles	Species richness & diversity of amphibians	5.845
62	Water	Water Quality	Water Chemistry	Water quality (core parameters: T, DO, cond, pH) of cave pools	5.8
54	Geology and Soils	Geomorphology	Stream/River Channel Characteristics	Geomorphology/channel characteristics of perennial rivers and streams	5.793
133	New-Biological Integrity	Focal Species or Communities	New-Vegetation Complex	Elevational/latitudinal shifts in plant distribution	5.75
35	Biological Integrity	Focal Species or Communities	Desert Community	Biological soil crusts	5.745
65	Air and Climate	Weather and Climate	Weather and Climate	Cave microclimate	5.7
127	New-Biological Integrity	New-Focal Species or Communities	New-Freshwater Communities	Vertebrates other than fish in aquatic systems	5.696
117	New-Biological Integrity	New-Focal Species or Communities	New-Vegetation Complex	Plant community distribution	5.695
134	New-Geology and Soils	New-Geomorphology	New-Soil Function and Dynamics	Sedimentation alluvial and aeolian	5.615
136	New-Biological Integrity	New-Focal Species or Communities	New-Riparian Communities	Riparian vegetation communities	5.585
80	Geology and Soils	Soil Quality	Soil Function and Dynamics	Nutrient levels	5.576
124	New-Biological Integrity	New-Invasive Species	New-Invasive/Exotic Animals	Distribution of non-native terrestrial insects	5.57
3	Air and Climate	Air Quality	Ozone	Ozone	5.5
138	New-Biological Integrity	New-Focal Species or Communities	New-Freshwater Communities	Algal communities	5.5

Appendix I. Chihuahuan Desert Network Prioritization Workshop report, cont.

Final ID	Level 1	Level 2	Level 3	Vital Sign	Ranked Score
26	Biological Integrity	Focal Species or Communities	Mammals	Distribution of broad-ranging species (black bears, mt. lion, mule deer)	5.455
95	Water	Water Quality	Microorganisms	Microbiotic components (esp. E. coli)	5.43
128	New-Landscapes	New-Landscape Dynamics	New-Land Cover and Use	Animal metapopulations and movement	5.38
125	New-Biological Integrity	New-Focal Species or Communities	New-Vegetation Complex	Plant species richness	5.36
60	Geology and Soils	Soil Quality	Soil Function and Dynamics	Soil health (stability, compaction, infiltration)	5.3
118	New-Biological Integrity	New-Focal Species or Communities	New-Terrestrial Invertebrates	Richness and diversity of terrestrial insects esp. endemics	5.23
131	New-Biological Integrity	New-Focal Species or Communities	New-Desert Communities	Pollinator-mediated plant reproductive success	5.205
14	Biological Integrity	Focal Species or Communities	Cave Communities	Species richness & diversity of cave pool biota	5.2
140	New-Biological Integrity	New-At-risk Biota	New-Freshwater Invertebrates	Contaminants in aquatic or semi-aquatic vertebrates	5.079
85	Water	Hydrology	Groundwater Dynamics	Groundwater dynamics in cave systems	4.946
33	Biological Integrity	Focal Species or Communities	Soil Communities	Soil microbes and other soil biota	4.945
59	Geology and Soils	Soil Quality	Soil Function and Dynamics	Soil chemistry	4.935
1	Air and Climate	Air Quality	Air contaminants	Atmospheric deposition of mercury	4.884
15	Biological Integrity	Focal Species or Communities	Cave Communities	Species richness & diversity of cave microbial communities	4.83
121	New-Biological Integrity	New-Focal Species or Communities	New-Cave Communities	Cave invertebrate populations	4.7
71	Human Use	Visitor and Recreation Use	Visitor use	Effects of park visitors on natural resources	4.613
6	Air and Climate	Weather and Climate	Weather and Climate	Carbon balance in soil	4.535

Appendix I. Chihuahuan Desert Network Prioritization Workshop report, cont.

Final ID	Level 1	Level 2	Level 3	Vital Sign	Ranked Score
12	Biological Integrity	Focal Species or Communities	Amphibians and Reptiles	Species richness & diversity of reptile community	4.43
13	Biological Integrity	Focal Species or Communities	Cave Communities	Species richness & diversity of cave biota	4.2
8	Biological Integrity	At-risk Biota	T&E Species and Communities	Collecting/poaching of species, esp. special concern	4.051
42	Biological Integrity	Focal Species or Communities	Terrestrial Complex	Animal communities in special/relic habitats	4
69	Human Use	Point Source Human Effects	Point Source Human Effects	Visitor use at springs and seeps	3.935
9	Biological Integrity	At-risk Biota	T&E Species and Communities	Distribution & reproduction of plant species of concern	3.73
53	Geology and Soils	Geomorphology	Lake Features and Processes	Reservoir siltation	3.283
74	Human Use	Visitor and Recreation Use	Visitor Use	Visitor satisfaction relative to feature attractions (i.e. bats at the caverns)	3.15
11	Biological Integrity	Focal Species or Communities	Amphibians and Reptiles	Mutation (=malformation) frequencies in amphibians	2.8
27	Biological Integrity	Focal Species or Communities	Mammals	Small to moderate-sized carnivores	2.3
51	Biological Integrity	Invasive Species	Invasive/Exotic Plants	Distribution of hydrilla (recreation issue)	1.836
82	Landscapes	Viewscape	Viewscape/Dark Night Sky	Night skies	1.796
63	Geology and Soils	Subsurface Geologic Processes	Cave/Karst	Water volume of pools	1.68
70	Human Use	Point Source Human Effects	Point-Source Human Effects	Human-caused fire	1.6
67	Geology and Soils	Subsurface Geologic Processes	Cave/Karst Features and Processes	Caves/karst features	1.48
2	Air and Climate	Air Quality	Air contaminants	Air quality in caves	1.468
104	Water	Hydrology	Surface Water Dynamics	Water quantity and shoreline shape of Lake Lucero	1.424
81	Landscapes	Soundscape	Soundscape	Soundscape, especially in wilderness areas	1.36
50	Biological Integrity	Invasive Species	Invasive/Exotic Plants	Golden algae (Parmesium parvum) distribution - exotic	1.352

Appendix I. Chihuahuan Desert Network Prioritization Workshop report, cont.

Final ID	Level 1	Level 2	Level 3	Vital Sign	Ranked Score
29	Biological Integrity	Focal Species or Communities	Terrestrial Invertebrates	Terrestrial non-insect invertebrates	1.286
40	Biological Integrity	Focal Species or Communities	Riparian Community	Historic cottonwood grove	1.2

	Top ranked VS group
	VS in group after top ranked VS (1st break)
	VS in group after 2nd major break
	VS in group after 3rd or "sharpest" break
	New VS identified by the 5 Break Out Groups from Vital Signs Workshop. In most cases the new VS combined one or more original VSs, or renamed an original VS. The renamed VS was considered a more appropriate description of the intent of the VS.

Table I.2-3. CHDN vital signs for the Desert Ecosystem ranked at the vital signs prioritization workshop.

Final ID	Network Vital Sign	Ranked Score
84	Groundwater dynamics (flow patterns, rates, levels, groundwater interaction with surface water)	7.530
129	Watershed hydrology	7.440
121	Water quality (surface and groundwater)	7.195
111	Phenology (leaf out/drop, flowering)/tree growth bands	6.875
112	Distribution of non-native animals	6.870
78	Landscape dynamics (land cover, pattern & patch sizes changes)	6.800
110	Distribution & abundance of invasive/non-native plants	6.710
126	Lichen/mosses as biomonitors	6.670
7	General meterological conditions (precip, wind, RH, T, snow pack, soil moisture)	6.640
75	Distribution & characterization of extreme disturbance events (fire, insect/pathogen outbreaks, floods)	6.600
28	Bird communities	6.555
115	Sediment quality	6.520
79	Vegetation patch dynamics (microscale)	6.500
116	Visibility	6.500
107	Landscape fragmentation and connectivity	6.400
108	Land use changes within Chihuahuan Desert	6.400
24	Relative abundance of bats	6.385
139	Surface water dynamics (hydroperiods, flow rates and quantity)	6.375
119	Plant community composition	6.360
132	Invertebrates in aquatic systems	6.318
122	Atmospheric wet/dry deposition	6.278
135	Bare ground	6.240
10	Distribution & relative abundance of animal species of concern	6.215
103	Persistence of springs & seeps	6.215
120	Particulate matter	6.180
137	Soil erosion (wind and water)	6.010
54	Geomorphology/channel characteristics of perennial rivers and streams	5.910
130	Native and non-native fish in aquatic systems	5.858
102	Species richness & diversity of amphibians	5.845
133	Elevational/latitudinal shifts in plant distribution	5.750
35	Biological soil crusts	5.745

Appendix I. Chihuahuan Desert Network Prioritization Workshop report, cont.

Final ID	Network Vital Sign	Ranked Score
127	Vertebrates other than fish in aquatic systems	5.695
76	Fire and fuel dynamics	5.640
117	Plant community distribution	5.640
134	Sedimentation alluvial and aeolian	5.615
136	Riparian vegetation communities	5.585
124	Distribution of non-native terrestrial insects	5.570
138	Algal communities	5.500
128	Animal metapopulations and movement	5.380
125	Plant species richness	5.360
3	Ozone	5.300
60	Soil health (stability, compaction, infiltration)	5.300
118	Richness and diversity of terrestrial insects esp. endemics	5.230
80	Nutrient levels	5.220
131	Pollinator-mediated plant reproductive success	5.205
33	Soil microbes and other soil biota	4.945
59	Soil chemistry	4.935
1	Atmospheric deposition of mercury	4.765
26	Distribution of broad-ranging species (mt. lion, mule deer)	4.610
71	Effects of park visitors on natural resources	4.555
6	Carbon balance in soil	4.535
12	Species richness & diversity of reptile community	4.430
8	Collecting/poaching of species, esp. special concern	4.420
140	Contaminants in aquatic or semi-aquatic vertebrates	4.256
42	Animal communities in special/relic habitats	4.000
69	Visitor use at springs and seeps	3.935
9	Distribution & reproduction of plant species of concern	3.730
74	Visitor satisfaction relative to feature attractions (i.e. bats at the caverns)	3.150
11	Mutation (=malformation) frequencies in amphibians	2.800
27	Small to moderate-sized carnivores	2.300
82	Night skies	1.796
70	Human-caused fire	1.600
104	Water quantity and shoreline shape of Lake Lucero - WHSA only	1.424
81	Soundscape, especially in wilderness areas	1.360
29	Terrestrial non-insect invertebrates	1.286

Appendix I. Chihuahuan Desert Network Prioritization Workshop report, cont.

Final ID	Network Vital Sign	Ranked Score
	Top ranked VS group	
	VS in group after top ranked VS (1st break)	
	VS in group after 2nd major break	
	VS in group after 3rd or "sharpest" break	
	New VS identified by the 5 Break Out Groups from Vital Signs Workshop. In most cases the new VS combined one or more original VSs, or renamed an original VS. The renamed VS was considered a more appropriate description of the intent of the VS.	

Table I.2-4. CHDN vital signs for the Foothill Ecosystem ranked at the vital signs prioritization workshop.

Final ID	Network Vital Sign	Ranked Score
84	Groundwater dynamics (flow patterns, rates, levels, groundwater interaction with surface water)	7.530
129	Watershed hydrology	7.440
122	Water quality (surface and groundwater)	7.195
111	Phenology (leaf out/drop, flowering)/tree growth bands	6.875
112	Distribution of non-native animals	6.870
78	Landscape dynamics (land cover, pattern & patch sizes changes)	6.800
110	Distribution & abundance of invasive/non-native plants	6.710
126	Lichen/mosses as biomonitors	6.670
7	General meterological conditions (precip, wind, RH, T, snow pack, soil moisture)	6.640
75	Distribution & characterization of extreme disturbance events (fire, insect/pathogen outbreaks, floods)	6.600
28	Bird communities	6.555
115	Sediment quality	6.520
79	Vegetation patch dynamics (microscale)	6.500
116	Visibility	6.500
107	Landscape fragmentation and connectivity	6.400
108	Land use changes within Chihuahuan Desert	6.400
24	Relative abundance of bats	6.385
139	Surface water dynamics (hydroperiods, flow rates and quantity)	6.375
119	Plant community composition	6.360
132	Invertebrates in aquatic systems	6.318
25	Black bear abundance & distribution	6.300
123	Atmospheric wet/dry deposition	6.278
135	Bare ground	6.240
10	Distribution & relative abundance of animal species of concern	6.215
103	Persistence of springs & seeps	6.215
76	Fire and fuel dynamics	6.190
120	Particulate matter	6.180
35	Biological soil crusts	6.025
137	Soil erosion (wind and water)	6.010
54	Geomorphology/channel characteristics of perennial rivers and streams	5.910
130	Native and non-native fish in aquatic systems	5.858

Appendix I. Chihuahuan Desert Network Prioritization Workshop report, cont.

Final ID	Network Vital Sign	Ranked Score
102	Species richness & diversity of amphibians	5.845
133	Elevational/latitudinal shifts in plant distribution	5.750
127	Vertebrates other than fish in aquatic systems	5.698
117	Plant community distribution	5.640
134	Sedimentation alluvial and aeolian	5.615
136	Riparian vegetation communities	5.585
124	Distribution of non-native terrestrial insects	5.570
138	Algal communities	5.500
128	Animal metapopulations and movement	5.380
125	Plant species richness	5.360
3	Ozone	5.300
60	Soil health (stability, compaction, infiltration)	5.300
118	Richness and diversity of terrestrial insects esp. endemics	5.230
80	Nutrient levels	5.220
131	Pollinator-mediated plant reproductive success	5.205
33	Soil microbes and other soil biota	4.945
59	Soil chemistry	4.935
1	Atmospheric deposition of mercury	4.815
26	Distribution of broad-ranging species (mt. lion, mule deer)	4.610
71	Effects of park visitors on natural resources	4.555
6	Carbon balance in soil	4.535
12	Species richness & diversity of reptile community	4.430
8	Collecting/poaching of species, esp. special concern	4.420
140	Contaminants in aquatic or semi-aquatic vertebrates	4.256
42	Animal communities in special/relic habitats	4.000
69	Visitor use at springs and seeps	3.935
9	Distribution & reproduction of plant species of concern	3.730
74	Visitor satisfaction relative to feature attractions (i.e. bats at the caverns)	3.150
11	Mutation (=malformation) frequencies in amphibians	2.800
27	Small to moderate-sized carnivores	2.300
82	Night skies	1.796
70	Human-caused fire	1.600
81	Soundscape, especially in wilderness areas	1.360
29	Terrestrial non-insect invertebrates	1.286

Final ID	Network Vital Sign	Ranked Score
40	Historic cottonwood grove	1.200

	Top ranked VS group
	VS in group after top ranked VS (1st break)
	VS in group after 2nd major break
	VS in group after 3rd or "sharpest" break
	New VS identified by the 5 Break Out Groups from Vital Signs Workshop. In most cases the new VS combined one or more original VSs, or renamed an original VS. The renamed VS was considered a more appropriate description of the intent of the VS.

Table I.2-5. CHDN vital signs for the Montane Ecosystem ranked at the vital signs prioritization workshop.

Final ID	Network Vital Sign	Ranked Score
84	Groundwater dynamics (flow patterns, rates, levels, groundwater interaction with surface water)	7.530
129	Watershed hydrology	7.440
122	Water quality (surface and groundwater)	7.195
112	Distribution of non-native animals	6.870
78	Landscape dynamics (land cover, pattern & patch sizes changes)	6.800
110	Distribution & abundance of invasive/non-native plants	6.710
126	Lichen/mosses as biomonitors	6.670
7	General meterological conditions (precip, wind, RH, T, snow pack, soil moisture)	6.640
75	Distribution & characterization of extreme disturbance events (fire, insect/pathogen outbreaks, floods)	6.600
28	Bird communities	6.555
115	Sediment quality	6.520
79	Vegetation patch dynamics (microscale)	6.500
116	Visibility	6.500
107	Landscape fragmentation and connectivity	6.400
108	Land use changes within Chihuahuan Desert	6.400
76	Fire and fuel dynamics	6.390
24	Relative abundance of bats	6.385
139	Surface water dynamics (hydroperiods, flow rates and quantity)	6.375
119	Plant community composition	6.360
25	Black bear abundance & distribution	6.300
123	Atmospheric wet/dry deposition	6.278
132	Invertebrates in aquatic systems	6.278
135	Bare ground	6.240
10	Distribution & relative abundance of animal species of concern	6.215
103	Persistence of springs & seeps	6.215
120	Particulate matter	6.180
3	Ozone	6.100
35	Biological soil crusts	6.025
137	Soil erosion (wind and water)	6.010
111	Phenology (leaf out/drop, flowering)/tree growth bands	6.000
102	Species richness & diversity of amphibians	5.845

Appendix I. Chihuahuan Desert Network Prioritization Workshop report, cont.

Final ID	Network Vital Sign	Ranked Score
133	Elevational/latitudinal shifts in plant distribution	5.750
117	Plant community distribution	5.640
134	Sedimentation alluvial and aeolian	5.615
124	Distribution of non-native terrestrial insects	5.570
138	Algal communities	5.500
127	Vertebrates other than fish in aquatic systems	5.475
128	Animal metapopulations and movement	5.380
125	Plant species richness	5.360
60	Soil health (stability, compaction, infiltration)	5.300
118	Richness and diversity of terrestrial insects esp. endemics	5.230
80	Nutrient levels	5.220
131	Pollinator-mediated plant reproductive success	5.205
33	Soil microbes and other soil biota	4.945
59	Soil chemistry	4.935
1	Atmospheric deposition of mercury	4.815
26	Distribution of broad-ranging species (mt. lion, mule deer)	4.610
71	Effects of park visitors on natural resources	4.555
6	Carbon balance in soil	4.535
12	Species richness & diversity of reptile community	4.430
8	Collecting/poaching of species, esp. special concern	4.085
42	Animal communities in special/relic habitats	4.000
69	Visitor use at springs and seeps	3.935
9	Distribution & reproduction of plant species of concern	3.730
74	Visitor satisfaction relative to feature attractions (i.e. bats at the caverns)	3.150
11	Mutation (=malformation) frequencies in amphibians	2.800
27	Small to moderate-sized carnivores	2.300
82	Night skies	1.796
70	Human-caused fire	1.600
81	Soundscape, especially in wilderness areas	1.360
29	Terrestrial non-insect invertebrates	1.286

	Top ranked VS group
	VS in group after top ranked VS (1st break)
	VS in group after 2nd major break

Final ID	Network Vital Sign	Ranked Score
	VS in group after 3rd or "sharpest" break	
	New VS identified by the 5 Break Out Groups from Vital Signs Workshop. In most cases the new VS combined one or more original VSs, or renamed an original VS. The renamed VS was considered a more appropriate description of the intent of the VS.	

Table I.2-6. CHDN vital signs for the Reservoir Ecosystem ranked at the vital signs prioritization workshop.

Final ID	Network Vital Sign	Ranked Score
84	Groundwater dynamics (flow patterns, rates, levels, groundwater interaction with surface water)	7.530
129	Watershed hydrology	7.440
122	Water quality (surface and groundwater)	6.925
112	Distribution of non-native animals	6.870
76	Landscape dynamics (land cover, pattern & patch sizes changes)	6.800
110	Distribution & abundance of invasive/non-native plants	6.710
24	Relative abundance of bats	6.665
105	Lake elevation for Amistad Reservoir - AMIS only	6.640
7	General meterological conditions (precip, wind, RH, T, snow pack, soil moisture)	6.640
75	Distribution & characterization of extreme disturbance events (fire, insect/pathogen outbreaks, floods)	6.600
28	Bird communities	6.555
115	Sediment quality	6.520
132	Invertebrates in aquatic systems	6.515
116	Visibility	6.500
108	Land use changes within Chihuahuan Desert	6.400
107	Landscape fragmentation and connectivity	6.400
119	Plant community composition	6.360
103	Persistence of springs & seeps	6.215
10	Distribution & relative abundance of animal species of concern	6.215
120	Particulate matter	6.180
78	Nutrient levels	6.050
123	Atmospheric wet/dry deposition	5.940
137	Soil erosion (wind and water)	5.910
130	Native and non-native fish in aquatic systems	5.858
102	Species richness & diversity of amphibians	5.845
127	Vertebrates other than fish in aquatic systems	5.695
117	Plant community distribution	5.640
134	Sedimentation alluvial and aeolian	5.615
138	Algal communities	5.500
95	Microbiotic components (esp. E. coli)	5.430
128	Animal metapopulations and movement	5.380

Appendix I. Chihuahuan Desert Network Prioritization Workshop report, cont.

Final ID	Network Vital Sign	Ranked Score
125	Plant species richness	5.360
140	Contaminants in aquatic or semi-aquatic vertebrates	5.078
1	Atmospheric deposition of mercury	5.065
12	Species richness & diversity of reptile community	4.430
71	Effects of park visitors on natural resources	4.368
69	Visitor use at springs and seeps	3.935
53	Reservoir siltation	3.283
74	Visitor satisfaction relative to feature attractions (i.e. bats at the caverns)	3.150
11	Mutation (=malformation) frequencies in amphibians	2.800
51	Distribution of hydrilla (recreation issue) - AMIS only	1.836
82	Night skies	1.796
81	Soundscape, especially in wilderness areas	1.360
50	Golden algae (Parmesium parvum) distribution - exotic	1.352

	Top ranked VS group
	VS in group after top ranked VS (1st break)
	VS in group after 2nd major break
	VS in group after 3rd or "sharpest" break
	New VS identified by the 5 Break Out Groups from Vital Signs Workshop. In most cases the new VS combined one or more original VSs, or renamed an original VS. The renamed VS was considered a more appropriate description of the intent of the VS.

Table I.2-7. CHDN vital signs for the River Ecosystem ranked at the vital signs prioritization workshop.

Final ID	Network Vital Sign	Ranked Score
84	Groundwater dynamics (flow patterns, rates, levels, groundwater interaction with surface water)	7.530
129	Watershed hydrology	7.440
122	Water quality (surface and groundwater)	6.925
112	Distribution of non-native animals	6.870
78	Landscape dynamics (land cover, pattern & patch sizes changes)	6.800
110	Distribution & abundance of invasive/non-native plants	6.710
105	Lake elevation for Amistad Reservoir - AMIS only	6.640
7	General meterological conditions (precip, wind, RH, T, snow pack, soil moisture)	6.640
75	Distribution & characterization of extreme disturbance events (fire, insect/pathogen outbreaks, floods)	6.600
28	Bird communities	6.555
115	Sediment quality	6.520
116	Visibility	6.500
108	Land use changes within Chihuahuan Desert	6.400
107	Landscape fragmentation and connectivity	6.400
24	Relative abundance of bats	6.385
139	Surface water dynamics (hydroperiods, flow rates and quantity)	6.375
119	Plant community composition	6.360
132	Invertebrates in aquatic systems	6.343
25	Black bear abundance & distribution	6.300
123	Atmospheric wet/dry deposition	6.278
103	Persistence of springs & seeps	6.215
10	Distribution & relative abundance of animal species of concern	6.215
120	Particulate matter	6.180
80	Nutrient levels	6.050
137	Soil erosion (wind and water)	6.010
54	Geomorphology/channel characteristics of perennial rivers and streams	5.910
130	Native and non-native fish in aquatic systems	5.858
102	Species richness & diversity of amphibians	5.845
127	Vertebrates other than fish in aquatic systems	5.695
117	Plant community distribution	5.640
134	Sedimentation alluvial and aeolian	5.615

Appendix I. Chihuahuan Desert Network Prioritization Workshop report, cont.

Final ID	Network Vital Sign	Ranked Score
136	Riparian vegetation communities	5.585
138	Algal communities	5.500
95	Microbiotic components (esp. E. coli)	5.430
128	Animal metapopulations and movement	5.380
125	Plant species richness	5.360
140	Contaminants in aquatic or semi-aquatic vertebrates	5.078
1	Atmospheric deposition of mercury	5.065
71	Effects of park visitors on natural resources	4.555
12	Species richness & diversity of reptile community	4.430
69	Visitor use at springs and seeps	3.935
9	Distribution & reproduction of plant species of concern	3.730
53	Reservoir siltation	3.283
74	Visitor satisfaction relative to feature attractions (i.e. bats at the caverns)	3.150
11	Mutation (=malformation) frequencies in amphibians	2.800
51	Distribution of hydrilla (recreation issue) - AMIS only	1.836
82	Night skies	1.796
81	Soundscape, especially in wilderness areas	1.360
50	Golden algae (Parmesium parvum) distribution - exotic	1.352

	Top ranked VS group
	VS in group after top ranked VS (1st break)
	VS in group after 2nd major break
	VS in group after 3rd or "sharpest" break
	New VS identified by the 5 Break Out Groups from Vital Signs Workshop. In most cases the new VS combined one or more original VSs, or renamed an original VS. The renamed VS was considered a more appropriate description of the intent of the VS.

Table I.2-8. CHDN vital signs for the Caves Ecosystem ranked at the vital signs prioritization workshop.

Final ID	Network Vital Sign	Ranked Score
129	Watershed hydrology	7.440
122	Water quality (surface and groundwater)	7.235
114	Microbial biofilm formation	6.765
7	General meterological conditions (precip, wind, RH, T, snow pack, soil moisture)	6.640
75	Distribution & characterization of extreme disturbance events (fire, insect/pathogen outbreaks, floods)	6.600
108	Land use changes within Chihuahuan Desert	6.400
24	Relative abundance of bats	6.385
123	Atmospheric wet/dry deposition	6.278
85	Groundwater dynamics in cave systems	6.238
103	Persistence of springs & seeps	6.215
9	Distribution & relative abundance of animal species of concern	6.215
120	Particulate matter	6.180
80	Nutrient levels	6.050
62	Water quality (core parameters: T, DO, cond, pH) of cave pools	5.800
65	Cave microclimate	5.700
134	Sedimentation alluvial and aeolian	5.615
95	Microbiotic components (esp. E. coli)	5.430
128	Animal metapopulations and movement	5.380
14	Species richness & diversity of cave pool biota	5.200
71	Effects of park visitors on natural resources	5.050
15	Species richness & diversity of cave microbial communities	4.830
1	Atmospheric deposition of mercury	4.830
121	Cave invertebrate populations	4.700
13	Species richness & diversity of cave biota	4.200
8	Collecting/poaching of species, esp. special concern	3.665
74	Visitor satisfaction relative to feature attractions (i.e. bats at the caverns)	3.150
27	Small to moderate-sized carnivores	2.300
63	Water volume of pools	1.680
70	Human-caused fire	1.600
67	Caves/karst features	1.480
2	Air quality in caves	1.468

Appendix I. Chihuahuan Desert Network Prioritization Workshop report, cont.

Final ID	Network Vital Sign	Ranked Score
81	Soundscape, especially in wilderness areas	1.360
	Top ranked VS group	
	VS in group after top ranked VS (1st break)	
	VS in group after 2nd major break	
	VS in group after 3rd or "sharpest" break	
	New VS identified by the 5 Break Out Groups from Vital Signs Workshop. In most cases the new VS combined one or more original VSs, or renamed an original VS. The renamed VS was considered a more appropriate description of the intent of the VS.	

Table I.2-9. CHDN vital signs for the Dune Ecosystem ranked at the vital signs prioritization workshop.

Final ID	Network Vital Sign	Ranked Score
86	Groundwater dynamics in dune systems	8.000
129	Watershed hydrology	7.440
122	Water quality (surface and groundwater)	7.235
56	Dune reactivation	7.200
111	Phenology (leaf out/drop, flowering)/tree growth bands	6.875
112	Distribution of non-native animals	6.870
78	Landscape dynamics (land cover, pattern & patch sizes changes)	6.800
110	Distribution & abundance of invasive/non-native plants	6.710
126	Lichen/mosses as biomonitors	6.670
55	Dune formation and stability	6.670
24	Relative abundance of bats	6.665
7	General meterological conditions (precip, wind, RH, T, snow pack, soil moisture)	6.640
75	Distribution & characterization of extreme disturbance events (fire, insect/pathogen outbreaks, floods)	6.600
28	Bird communities	6.555
116	Visibility	6.500
79	Vegetation patch dynamics (microscale)	6.500
108	Land use changes within Chihuahuan Desert	6.400
107	Landscape fragmentation and connectivity	6.400
119	Plant community composition	6.360
132	Invertebrates in aquatic systems	6.270
135	Bare ground	6.240
103	Persistence of springs & seeps	6.215
10	Distribution & relative abundance of animal species of concern	6.215
120	Particulate matter	6.180
137	Soil erosion (wind and water)	6.010
123	Atmospheric wet/dry deposition	5.940
16	Species richness & diversity of dune biota, esp. white-coloration species	5.865
102	Species richness & diversity of amphibians	5.845
133	Elevational/latitudinal shifts in plant distribution	5.750
35	Biological soil crusts	5.745
117	Plant community distribution	5.640

Appendix I. Chihuahuan Desert Network Prioritization Workshop report, cont.

Final ID	Network Vital Sign	Ranked Score
134	Sedimentation alluvial and aeolian	5.615
124	Distribution of non-native terrestrial insects	5.570
128	Animal metapopulations and movement	5.380
125	Plant species richness	5.360
60	Soil health (stability, compaction, infiltration)	5.300
3	Ozone	5.300
118	Richness and diversity of terrestrial insects esp. endemics	5.230
80	Nutrient levels	5.220
131	Pollinator-mediated plant reproductive success	5.205
33	Soil microbes and other soil biota	4.945
59	Soil chemistry	4.935
1	Atmospheric deposition of mercury	4.830
71	Effects of park visitors on natural resources	4.653
26	Distribution of broad-ranging species (mt. lion, mule deer)	4.610
12	Species richness & diversity of reptile community	4.430
42	Animal communities in special/relic habitats	4.000
9	Distribution & reproduction of plant species of concern	3.730
8	Collecting/poaching of species, esp. special concern	3.665
74	Visitor satisfaction relative to feature attractions (i.e. bats at the caverns)	3.150
11	Mutation (=malformation) frequencies in amphibians	2.800
27	Small to moderate-sized carnivores	2.300
82	Night skies	1.796
81	Soundscape, especially in wilderness areas	1.360
29	Terrestrial non-insect invertebrates	1.286

	Top ranked VS group
	VS in group after top ranked VS (1st break)
	VS in group after 2nd major break
	VS in group after 3rd or "sharpest" break
	New VS identified by the 5 Break Out Groups from Vital Signs Workshop. In most cases the new VS combined one or more original VSs, or renamed an original VS. The renamed VS was considered a more appropriate description of the intent of the VS.

I.3 Vital Signs Prioritization Workshop – Scoring Criteria

The following subsections provide the documentation for the vital signs scoring process.

I.3.1 Ranked scores for vital signs

The rank score for each of the 86 unique vital signs was calculated using the formula:

$$(ES + [1/2 * MS]) \times JS_{max}$$

where ES was the Ecological Significance Score provided at the prioritization workshop (possible value range 1-5), the MS was the Management Significance Score value provided prior to the prioritization workshop (possible value range 1-6), and JS was the Justification Score which was a weight assigned according to the type of source used to justify the vital sign's ecological or management significance (values: 0.4, 0.7, or 1.0). The maximum JS was applied for each ecosystem. This allowed for a range of Rank Scores of 0.6 to 8.0. See Sections 4.2, 4.3 and 4.4 for the specific criteria.

As previously stated, the consolidated list included some newly titled vital signs per the recommendations of the group participants at the prioritization workshop. If more than one group ranked an existing or related new vital sign, those scores were averaged to produce the rank score given in the consolidated list. Likewise, if a vital sign was considered applicable to more than one ecosystem, then the rank score given in the consolidated list is an average score among the ecosystems.

For each list of vital signs and associated rank scores (consolidated and by ecosystem), a graph shows the descending order of ranks. These graphs provided a means for visualizing natural breaks in the rank scores and hence a means for grouping the highest ranked vital signs. Groupings of the vital signs in all lists have been color-coded. These groupings and represented prioritization provided a template for discussing the important vital signs that may eventually be monitored.

I.3.2 Justification sources

In order to justify the selection of all vital signs that are ultimately monitored, it was important for us to know *why* any given vital sign was suggested and the *source* of information that provided the explanation (see Table I.3.2). To facilitate compilation of potential vital signs, justifications, and associated sources during these two days, participants were asked to prepare prior to attending the workshop. They were asked to develop their own top list of vital signs from the unique vital signs produced from the Phase I process. They were also asked to provide a list of references that would help justify the selection of those vital signs, and they were asked to bring supporting information for those vital signs.

Table I.3.2. Justification sources for use in the Chihuahuan Desert Network Prioritization Workshop.

Class Name	Definition and Examples	Example Citation
Legally Mandated	A vital sign that should be monitored because of an existing or legal mandate from Congress. For example, monitoring of a Threatened or Endangered Species. The name of the act or regulation identifier could be given.	ESA (1974; Fed. Reg. (1993)
Management Priority	Chosen because there is a non-legally binding management need to understand trends in this vital sign. NPS or acronym of a particular unit could be used along with a year or date of established policy (if present) to identify this source.	NPS (2002); CAVE
Personal Observation	Recommended vital sign based on personal observations, professional judgment, or unpublished data analysis. Patterns that have been established through repeated or occasional, casual observation. Last name of observer and abbreviation for personal observation should be used to identify this source.	Davila (pers. obs.)
Non-peer Reviewed Literature	Information that has not undergone specific review for scientific process or content accuracy. This category can include reports, models, articles, and books. Cite according to last name(s) of author(s) and year produced.	Reiser et al. (2006)
Peer-reviewed	Information that has undergone specific review for scientific process or content accuracy. This category can include journal articles, edited books, and published models.	Havstad et al. (2002)

Weightings of justification sources were not revealed to participants at the time of the workshop in order to avoid bias in their responses. The weightings were applied after the workshop, and the data were exported into MSQL for data analysis. Justification source scores were applied as the maximum score for each vital sign by each ecosystem. The weightings were broken down as follows:

1.0– Peer-reviewed Literature or Legally Mandated

0.7 – Non-peer Reviewed Literature or Management Priority

0.4 – Personal Observation

I.3.3 Ecological significance scores

Each vital sign was also ranked according to possible influence on the function of a given ecosystem (Ecological Significance). Seven ranking criteria were used to by each participant determine the scoring. The note taker entered a number (with up to 1 decimal place) for the ecological significance score.

The ranking questions were as follows:

For this potential vital sign, how many of the following statements do you STRONGLY AGREE with?

- There is a strong, defensible linkage between the vital sign and the ecological function or critical resource it is intended to represent (supported by ecological literature or knowledge of system).

- The vital sign provides an early warning of changes to ecosystems or signifies an impending change in the ecological system. [Note: replace the term ecosystem with landscape or population, as appropriate.]

- The vital sign responds to change in a predictable and explainable matter.

- The vital sign has low natural variability (high signal to noise ratio).

- There are reference conditions that exist within the region and/or threshold values that could be determined to assess deviance from a natural condition.

- The vital sign reflects the capacity of key ecosystem processes to resist or recover from change induced by exposure to natural disturbances and/or anthropogenic stressors. [Note: replace the term ecosystem with landscape or population, as appropriate.]

- The vital sign represents a resource or function of high ecological importance based on the supporting ecological literature and knowledge of the system.

The final score was tabulated based on total number of statements the reviewer agreed with. Scores were broken down as follows:

Scores:

- **5** = Participant agrees that 6-7 statements apply to proposed vital sign
- **4** = Participant agrees that 4-5 statements apply to proposed vital sign
- **3** = Participant agrees that 3 statements apply to proposed vital sign
- **2** = Participant agrees that 2 statements apply to proposed vital sign
- **1** = Participant agrees that 1 statement apply to proposed vital sign
- **0** = Participant agrees that none of these statements apply

I.3.4 Management Significance Scores

The final score was the average of all respondents' scores for a particular vital sign. For 'new' vital signs generated from the workshop, only the technical committee members provided management significance scores, but they were allowed to discuss their scores with other park staff. The final management significance score was an average for all six parks.

The eight ranking criteria for management concern score (MC) were included in a handout that was used by park staff and the Technical Committee for scoring original and 'new' vital signs:

For this potential vital sign, how many of the following statements do you STRONGLY AGREE with?

- There is an obvious, direct application of the data to a key management decision, or for evaluating the effectiveness of past management decisions.

- The vital sign will produce results that are clearly understood and accepted by park managers, other policy makers, research scientists, and the general public.

- Monitoring results are likely to provide early warning of resource impairment, and will save park resources and money if a problem is discovered early.

- In cases where data will be used primarily to influence external decisions, the decisions will affect key resources in the park, and there is a great potential for the park to influence the external decisions.

- Data are of high interest to the public.

- For species-level monitoring, involves species that are harvested, endemic, invasive, or at-risk biota.

- There is an obvious, direct application of the data to performance (GPRA) goals.

- Contributes to increased understanding that ultimately leads to better management.

The final score was tabulated based on the number of statements the reviewer agreed with. Scores were broken down as follows:

Scores:

- **6** = Participants agree that 7-8 statements apply to proposed vital sign
- **5** = Participants agree that 5-6 statements apply to proposed vital sign
- **4** = Participants agree that 4 statements apply to proposed vital sign
- **3** = Participants agree that 3 statements apply to proposed vital sign
- **2** = Participants agree that 2 statement apply to proposed vital sign
- **1** = Participants agree that 1 statement applies to proposed vital sign
- **0** = Participants agree that none of these statements apply

Appendix J. Chihuahuan Desert Network Protocol Development Summaries

J.1 Introduction

This section includes 10 protocol development summaries (PDS) that address 21 Chihuahuan Desert Network (CHDN) vital signs. Some PDSs address multiple vital signs and include the list of vital signs addressed and justifications for combining them. Others address only a single vital sign. Each summary contains a list of the parks in which the protocol will be implemented, a justification and description for each vital sign, specific monitoring objectives to be addressed, the protocol development approach, opportunities for integration with other protocols, information on the lead developers, NPS leads, and a development schedule.

This network's monitoring plan emphasizes sharing protocols with other I&M networks and integrating vital signs monitoring for efficiency. Shared protocols are identified by network, as are opportunities within each protocol to address some aspect of another vital sign. To highlight these opportunities, we have included, in each PDS, (1) the secondary vital sign(s) that may be addressed by the protocol (as indicated by parentheses in the Vital Signs Addressed section) and (2) specific identification of the opportunities for integration. Supporting references have been combined for all PDSs and are presented at the end of this appendix. Protocols follow the order presented in the NPS Ecological Monitoring Framework.

J.2 Air Quality

J.2.1 Vital signs included

- Ozone
- Wet and dry deposition
- Visibility and particulate matter

J.2.2 Parks where protocol will be implemented

- BIBE (ozone, wet and dry deposition, visibility and particulate matter)
- CAVE (ozone)
- GUMO (ozone, wet and dry deposition, visibility and particulate matter)

J.2.3 Justification/Issues being addressed

Diminishing air quality is a concern in a number of national parks (NPS-ARD 2002), and can significantly affect visitor experience. Although most CHDN parks are located some distance from urban centers in Texas and Mexico, significant oil and gas development near several network parks in southeastern New Mexico and West Texas, and coal-fired power plants in Central Texas, will likely increase pollution by nitrates and sulfates. CHDN parks affected by pollution from these cities and energy development projects (whether nearby or distant) experience poor air quality due to ozone, nitrogen oxides, sulfur dioxide, volatile organic compounds, particulate matter, and toxins. Influenced by weather patterns, atmospheric pollutants are carried by the wind, broken down by high temperatures and radiation, and then deposited as wet and dry particles in the air, water, soil, vegetation, and on wildlife and humans. Atmospheric deposition of nitrogen and sulfur compounds can alter soil processes (e.g., soil nutrient cycling), affect plant species composition, directly injure vegetation, affect stability of biological systems,

and impair water quality (Fenn et al. 2003). Air pollutants that decrease visibility also can affect human health, impair viewsheds, and degrade the aesthetic appeal of a national park (Malm 1999). Consequently, protection of air quality has become a priority in national parks, and a core vital sign for monitoring in many networks (Maniero 2001).

Under the Clean Air Act of 1970 (as amended in 1977 and 1990), protection of air quality is required in all U.S. national parks greater than 5,000 ac (labeled as Class I areas). The Clean Air Act gives non-attainment Class I areas the greatest protection against further deterioration and requires monitoring to confirm that air quality and visibility improve or, at minimum, do not further degrade. In addition, according to each NPS park's GPRA mandate, land managers in Class I parks are required to provide recommendations on how to protect air, natural, and cultural resources in the park. To evaluate these hazards to ecosystem and human health, it is important to monitor air quality conditions and their interactions with the physical and biological components of ecosystems. Additionally, monitoring these vital signs will provide information for assessing temporal trends in air quality of individual Class I CHDN parks and generalized trends for broader regions (NPS-ARD 2002).

J.2.4 Monitoring objectives addressed by the protocol

Air quality parameters are monitored in CHDN park units by the NPS in cooperation with national air quality monitoring programs. Air quality data are summarized and analyzed for conditions and trends by both the NPS Air Resources Division (NPS-ARD) and those national programs. Therefore, it is not the CHDN's objective to replicate these analyses. Instead, the network aims to compile the data summaries performed by these groups and provide them in a concise report to be analyzed in conjunction with other CHDN vital signs. In addition, the CHDN seeks to see how ozone, nitrogen deposition, sulfur deposition, and visibility-reducing pollutants vary with associated vital signs (e.g., climate, plant composition). CHDN air quality monitoring objectives are:

1. Report on the seasonal and annual trends in concentrations of nitrogen and sulfur from wet deposition at BIBE and GUMO.
2. Report on the seasonal and annual trends in dry deposition chemistry at BIBE.
3. Report on the seasonal and annual trends in ozone concentration at BIBE, CAVE, and GUMO.
4. Report on seasonal and annual trends in visibility-reducing pollutants at BIBE and GUMO.
5. Determine patterns of among year variability and long-term trends in air quality vital signs in CHDN parks in order to detect changes in air quality that correlate with changes in other CHDN vital signs.

J.2.5 Measures

Concentration of wet deposition, concentrations of dry deposition, ozone concentration, particulate matter concentrations by particle size, and transmissometer readings

J.2.6 Basic approach

Four existing monitoring programs currently provide trend data for Class I parks in the CHDN. The NPS-ARD monitors ground-level ozone concentrations continuously as an hourly average at BIBE, CAVE, and GUMO. Precipitation is collected weekly at BIBE and GUMO and analyzed for wet deposition of atmospheric pollutants, including pH, sulfate, nitrate, ammonium, chloride, calcium, magnesium, potassium, and sodium, by the National Atmospheric Deposition Program (NADP). Filters are collected weekly and analyzed for pollutants falling as dry deposition, including sulfate, sulfur dioxide, nitrate, ammonium, and nitric acid from Clean Air Status and Trends Network (CASTNet) stations at BIBE. The Interagency Monitoring of Protected Visual Environments (IMPROVE) Program measures visibility at BIBE and GUMO. Field collection of air quality samples and data is mostly automated, except for the

changing of filter bucket collectors. Field collection, routine maintenance, and calibration are performed primarily by park staff.

The Sonoran Desert Network is currently coordinating with air quality programs (e.g., NPS-ARD) to identify procedures for uploading and archiving datasets from different monitoring stations. The CHDN will adopt the same procedures. The procedures for dataset and metadata acquisition and storage, data validation and verification, and data analysis and reporting will be described in future Standard Operating Procedures (SOPs). The workload for the CHDN staff will likely consist of downloading, archiving, and analyzing monitoring data, as well as preparing an annual air quality summary report.

The existing programs do not require field data collection or development of a new protocol by CHDN personnel. Ozone, deposition of nitrogen and sulfur, and visibility are measured with automated collectors and sensors at existing reference sites according to procedures described by the NPS-ARD (2004, 2005, 2006). These procedures have been incorporated as standard operating procedures (SOPs) of an approved Air Quality Protocol (Mau-Crimmins and Porter 2007). The Northern Colorado Plateau Network (NCPN) is also near completion of its Air Quality Monitoring Protocol (NPS 2008). Accordingly, the CHDN will adopt these protocols, with modifications if needed, to monitor air quality in CHDN parks. The focus of this protocol is to compile data summaries and provide them in a concise report to be analyzed in conjunction with other CHDN vital signs. If critical data gaps are identified, the CHDN may recommend expanding monitoring station capabilities for CAVE.

J.2.7 Opportunities for integration

The data from this protocol will be integrated with other vital signs protocols to understand better how localized and regional trends in air quality conditions vary with other vital signs in CHDN parks.

J.2.8 Principal investigators and NPS lead

- Lead developer: Andy Hubbard
- Network contact: Kirsten Gallo; Chihuahuan Desert Inventory and Monitoring Network, 575.646.5294, kirsten_gallo@nps.gov
- Other support: Ellen Porter (NPS Air Resources Division, Denver Colorado, 303.969.2617, ellen_porter@nps.gov)

J.2.9 Development schedule and budget

The CHDN will follow SODN's lead on developing air quality protocols. A draft protocol should be prepared by the end of 2010 and implemented in 2011. The budget should include CHDN staff time for reviewing and implementing the protocol.

J.3 Climate

J.3.1 Vital signs included

Basic meteorology

J.3.2 Parks where protocol will be implemented

AMIS, BIBE, CAVE, FODA, GUMO, WHSA

J.3.3 Justification/Issues being addressed

Climate consists of the prevailing weather conditions in a given region averaged over a long series of years. Because of its crucial role in driving or regulating many biological and physical processes at the landscape scale, climate has been identified as a vital sign for all CHDN parks. Rainfall and temperature

are the primary factors that limit an ecosystem's structure and function. Secondary limiting factors include long-term climate patterns: the length and intensity of weather events, seasons in which they occur, and amount of variability between and among years. Together, these dynamics greatly influence the types of plant species that occur, and where; the ways in which nutrients are cycled; and the relationships between soil, plants, and water availability. Accordingly, climate is a fundamental determinant of plant and animal distributions, productivity, and ultimately biodiversity (Rehfeldt et al. 2006). They can also affect the susceptibility of an ecosystem to disturbance.

Two climate-related meteorological conditions that have shown profound influence on Chihuahuan Desert systems are the intensity and persistence of rainfall, and the frequency and duration of prolonged periods of drought (Davey et al. 2007). Intense rainfall affects the transport and distribution of energy and materials through arid and semi-arid systems (Whitford 2002). Runoff also affects the hydrology and quality of aquatic systems, such as the Rio Grande and Amistad International Reservoir. Prolonged drought often leads to diminished productivity in many species of plants and animals. Loss of vegetation cover, in turn, leads to greater vulnerability of soil erosion (Okin et al. 2006).

Long-term climate change generated by a proliferation of heat-storing (greenhouse) gases in Earth's atmosphere may have the most profound impact on ecological systems of any other human-induced stressor. Monitoring of basic meteorological measures over long periods of time can indicate whether attributes of climate are changing at CHDN park units (Davey et al 2007). When climate monitoring is co-measured with the phenology or productivity of plants or animals, the interpretation of observed meteorological trends is enhanced. For example, changes in climate that accelerate or expand growing seasons might be reflected by earlier onset of plant leaf-out or flowering which, in turn, can influence plant–animal interactions (Schwartz and Reiter 2000, Marra et al. 2005, Cleland et al. 2007, Studer et al. 2007, Khanduri et al. 2008).

Monitoring weather conditions in combination with other vital signs is one way to evaluate and anticipate changes observed in CHDN ecosystems. Monitoring of basic meteorological attributes will provide knowledge for understanding the magnitude of change in this key system driver within CHDN park units. Existing efforts by several regional and national networks of weather/climate stations, including weather stations in CHDN parks, collect these data. Parks are then provided with monthly and annual summaries of variables such as air temperature, precipitation, wind speed and direction, solar radiation, fuel temperature, and moisture. Davey et al. (2007) also identified gaps in current weather/climate monitoring and collection of data for other variables (i.e., soil moisture) at network parks. The CHDN will continue to discuss how to address those needs.

J.3.4 Monitoring objectives addressed by the protocol

1. Report on status and trends of monthly, seasonal, and annual common meteorological variables (i.e., temperature, precipitation) at existing monitoring stations in, and nearby, CHDN parks.

2. Determine patterns of among year variability and long-term trends in common meteorological variables in CHDN parks in order to detect changes in climate that correlate with changes in other CHDN vital signs.

J.3.5 Measures

Common weather parameters, including air temperature and precipitation, wind speed and direction, relative humidity, solar radiation, and soil moisture

J.3.6 Basic approach

The protocol will use meteorological data from existing programs (weather stations in or nearby to all park units). National Oceanic and Atmospheric cooperative weather stations exist in all park units, except AMIS. Multiple stations are located at BIBE (Davey et al. 2007). The types of measures recorded at existing stations vary, but at a minimum include precipitation and ambient temperature. In addition, weather sensors required for estimating air quality measures exist at BIBE, CAVE, and GUMO.

The existing programs do not require field data collection or development of a new protocol by CHDN personnel. There is an existing protocol for recording some of the measures that will be sampled in CHDN park units (Sousanes 2004). The Sonoran Desert Network, in coordination with the Southern Plains, Greater Yellowstone, Rocky Mountain, and Northern Colorado Plateau networks, is in the process of drafting climate protocols. The CHDN has joined this collaboration, and these protocols will be adopted for monitoring meteorological attributes in the CHDN.

In the CHDN, a majority of weather data (temperature, precipitation, wind speed and direction, relative humidity, solar radiation) are tracked by (1) Remote Automated Weather Stations (RAWS), administered by the National Interagency Fire Center, and (2) the National Weather Service's Cooperative Observer Program (COOP). Because COOP and/or RAWS stations have continuously monitored weather data within the CHDN, this historic information can be used to generate baseline data, assess long-term trends, and aid in detecting major/minor fluctuations or changes. For most weather stations, field collection and recording of weather data are automated and directly transmitted to receiving agencies; however, routine maintenance and calibration are performed by park staff. For the manual COOP stations, park staff record daily observations and phone or enter data via the worldwide web.

CHDN staff will analyze weather data for baseline information as well as long-term trends and patterns, calculate standard indices, identify variations and extreme conditions, and display spatial and temporal information using GIS, if these analyses are not provided elsewhere. After climate and other vital signs monitoring information are spatially and temporally overlaid, the relationships between vital signs within an ecosystem can be observed and modeled.

The workload for CHDN staff will consist of downloading and analyzing data, as well as preparing an annual climate summary report. This summary report will consist of (1) seasonal and annual status and trends of weather data at existing monitoring stations, (2) assessments of climatic measures in the context of historical trends (e.g., extremes), (3) a comparison of key climate attributes among various CHDN ecosystems and parks, and (4) a summary of climate monitoring efforts (i.e., links to other vital signs monitoring).

J.3.7 Opportunities for integration

This protocol will be integrated with other vital signs protocols to improve our understanding of how local and regional trends in weather and climate vary with other vital signs in CHDN parks (e.g., vegetation and animal communities, invasive plant trends).

J.3.8 Principal investigators and NPS lead

- Lead developer: Andy Hubbard
- Network contact: Kirsten Gallo; Chihuahuan Desert Inventory and Monitoring Network, 575.646.5294, kirsten_gallo@nps.gov
- Other support: Western Regional Climate Center

J.3.9 Development schedule and budget

Draft protocol development should be completed in 2010, and a final peer-reviewed protocol completed in 2011. Implementation will also start in 2011. No cost beyond CHDN staff salaries is expected for reviewing and implementing the protocol.

J.4 Dune Dynamics

J.4.1 Vital signs included

- Dune formation and stability
- Dune morphology

J.4.2 Parks where protocol will be implemented

WHSA, GUMO (if resources permit)

J.4.3 Justification/Issues being addressed

WHSA was established in 1933, in order to preserve the largest gypsum dune field known globally. The park encompasses about half of the dune field. An understanding of the dynamics of the dunes lies at the core mission of the park. Dune dynamics are taken here to include a broad spectrum of dune and dune-field aspects: dune formation/destruction, surface processes, migration rate, characteristic behavior, dune-dune interactions, and dune-substrate interactions. Because dune-substrate interactions are partly driven by the height of the water table, the groundwater quantity vital sign is also indirectly addressed. This vital sign, along with groundwater quantity, are the two priority vital signs for WHSA.

J.4.4 Monitoring objectives addressed by the protocol

1. Characterize single-dune dynamics on a seasonal and composite yearly basis for baseline condition.

2. Determine long-term trends in dune dynamics at the dunefield scale at 5–10 year intervals.

3. Determine seasonal and composite yearly trends in the sediment budget at the dunefield scale at 5–10 year intervals.

J.4.5 Measures

Single and time-series LiDAR surveys, wind data (speed, direction, duration), water-table monitoring, substrate erosion/deposition rates, dune height, type, volume, and migration rates

J.4.6 Basic approach

The approach for these protocols includes (1) single and timeseries LIDAR surveys, (2) distillation of wind data, (3) in-field measurement of flux at saturation levels for various wind speeds, (4) water-table monitoring, (5) substrate erosion/deposition monitoring, and (6) field work to compare the decadal record of dune behavior to the LiDAR results.

The initial LiDAR survey (June 2007) was followed by surveys in June 2008 (NPS-funded), January 2009 (non-NPS funded), and June 2009. Additional surveys will be conducted in the summers of 2010 and 2011. Each survey revisits the same ~15 mi^2 area, extending from Alkali Flat in the dune migration direction to the vegetated downwind terminus of the field. This area samples a representative portion of the crescentic dune field, but does not include the far less active parabolic dunes to the south. Each survey will yield a digital elevation model (DEM) that will be used to deduce how similar dunes are to each other in size and shape at any one time. Comparison of the June 2007 and June 2008 surveys to the January

2009 survey, which occurred near the ends of the two most significant wind seasons (i.e., late spring, winter), will allow for comparisons of dune shape, size, and seasonal migration rates as a function of each major component of the total wind regime. These data, combined with subsequent surveys, allow for the establishment of migration rates, documentation of dune–dune interactions, and identification of any morphologic/dynamic trends in the streamwise direction. Trends evident for the heavily visited dunes near the "Heart of the Dunes Loop" will be compared to those for the remainder of the field in order to establish human impacts. Trends evident for the vegetated dunes near the downwind terminus of the field can similarly be compared to the remainder of the field to gauge the impact of vegetation.

A distillation of wind data (reduced to 16 sectors of the compass for flows above threshold value) from weather stations at Holloman Air Force Base will be used to determine potential transport capability of the wind, and compared to dune migration rates, which represents the actual bedform sediment transport rate. In order to calibrate the flux for sand-saturation conditions at a variety of wind speeds, in-field measurements will be made using a combination sand trap and anemometer (hot-wire or sonic type).

Water-table and substrate erosion/deposition monitoring will be conducted monthly along five piezometers situated within the LiDAR-surveyed area and placed in interdune areas along a streamwise trend from Alkali Flat to the terminus of the field. The piezometer located on Alkali Flat will provide an indication of new influx to the field via salt-flat deflation, whereas the interior piezometers will allow for estimates of the sediment exchange between the dunes and the substrate. This exchange can be compared to changes in the water table measured at the same points. Additional data on water-table fluctuations will be collected from existing NPS wells. A comprehensive comparison between temporal changes in dune volume and substrate erosion/deposition (integrated over the survey area) will yield the total sediment budget of the system which, in turn, can be considered as a function of the wind regime and the water table.

High-resolution aerial images will be used with in-field mapping of eroded cross-strata to determine the decadal migration and behavior history of selected dunes within the LiDAR survey area. This longer-term data will be compared to that derived from the LiDAR surveys.

Initial results from the first two LiDAR surveys have been processed. The first LiDAR timeseries of the dunes in the surveyed area and construction of a "difference map" have also occurred. These results have been combined with work on aerial photos spanning about 40 years in order to estimate initially long-term dune-migration rates. Detailed statistical analysis of the dunes from the June 2007 LiDAR also continues. The most significant aspect of the ongoing research is the documentation of newly discovered dune interactions that seem to characterize the entire field (Kocurek 2008).

J.4.7 Opportunities for integration

This protocol will be integrated with other hydrological vital signs protocols to improve our understanding of how dune dynamics vary with other WHSA vital signs (e.g., trends in groundwater depth).

J.4.8 Principal investigators and NPS lead

- Lead developer: Dr. Gary Kocurek, University of Texas at Austin, 512.471.5855, garyK@mail.utexas.edu
- Network contact: Kirsten Gallo; Chihuahuan Desert Inventory and Monitoring Network, 575.646.5294, kirsten_gallo@nps.gov
- Other support: Ryan Ewing, University of Texas at Austin, 512.917.4267, rce@mail.utexas.edu
  David Mohrig, University of Texas at Austin, 512.471.2282, mohrig@mail.utexas.edu
  Rip Langford, University of Texas – El Paso, 915.747.5968, langfore@utep.edu

Mike Story, NPS Natural Resource Program Center, Office of Inventory, Monitoring and Evaluation, 303.969.2746, mike_story@nps.gov
David Bustos, White Sands National Monument, 575.679.2599, ext. 223; david_bustos@nps.gov

J.4.9 Development schedule and budget

This protocol was initially funded by the CHDN and NPS Natural Resource Program Center, Office of Inventory, Monitoring and Evaluation ($14,900 and $4,500 respectively) and the University of Texas at Austin ($5,000) to aid with the June 2007 pilot LiDAR survey and drafting this PDS. In FY08, the NPS NRPC provided $43,000 to conduct a second summer LiDAR survey, and CHDN provided $73,500 (through Cooperative Agreement No. H5000 02 0271) to process and interpret the summer (2008) and winter (2009) LiDAR images, and to initiate monitoring protocol development. An independent (non-NPS) grant funded the January 2009 survey. The draft protocol specific to dune dynamics should be completed by December 2010. Several oral and poster papers have been presented at conferences in the last two years, and two annual project reports have been written. Two peer-reviewed journal articles were submitted in 2009. No additional funds are anticipated for protocol development.

J.5 River Channel Morphology

J.5.1 Vital signs included

River channel characteristics

J.5.2 Parks where protocol will be implemented

- BIBE, AMIS *(if resources permit),* RIGR (*if resources permit*)

J.5.3 Justification/Issues being addressed

Management and restoration activities in riparian and aquatic ecosystems of the lower Rio Grande in Big Bend National Park (BIBE), the Rio Grande Wild and Scenic River (RIGR), and Amistad National Recreation Area (AMIS) are hindered by a vague understanding of the magnitude of changes in channel morphology. Flow depletions in the northern branch of the Rio Grande in the United States and in the Rio Conchos, in Mexico, have caused significant reduction in channel-forming discharges in the Rio Grande in BIBE. These hydrologic changes have resulted in channel aggradation; channel narrowing and development of inset floodplains; reduction in aquatic habitats, especially native fish and freshwater mollusks; increase in invasive/non-native riparian vegetation; and reduction in the quality of recreational boating (Schmidt et al. 2003).

J.5.4 Monitoring objectives addressed by the protocol

Determine long-term trends in channel location and characteristics of selected reaches of active river channels at approximately 5-year intervals.

J.5.5 Measures

Selected metrics (sinuosity, channel width, channel geometry, longitudinal profiles), cross-sections, and mapping of selected reaches

J.5.6 Basic approach

Methodologies described in Allred and Schmidt (1999) will be used to measure changes in river channel morphology. Additionally, data available from various existing U.S. Geological Survey, International Boundary Water Commission, and Texas Commission on Environmental Quality gaging stations of the lower Rio Grande, and use of aerial photographic analysis within GIS, will be used to develop a temporally precise record of channel change. These measurements will allow us to identify the timing and

onset of changes in channel cross-section and the relation of these changes to flow conditions. Stratigraphic analysis of the identified inset deposits and dendrochronology allows further dating of sediments and understanding of the rate of channel aggradation. Protocol development will also rely on modified Rosgen protocols that have been developed for the arid and semi-arid Southwest (Rosgen 1996).

J.5.7 Opportunities for integration

This protocol will be integrated with other vital signs (e.g., weather, vegetation communities, invasive plant trends, groundwater hydrology, surface water quality) in three CHDN parks (AMIS, BIBE, RIGR) to better understand how trends in river channel morphology vary with other vital signs.

J.5.8 Principal investigators and NPS lead

- Lead developer: Dr. John "Jack" C. Schmidt, Utah State University, 435.797.1791, jack.schmidt@usu.edu
- Network contact: Kirsten Gallo; Chihuahuan Desert Inventory and Monitoring Network, 575.646.5294, kirsten_gallo@nps.gov
- Other support: Jeff Bennett, Big Bend National Park, 432.477.1141, Jeffrey_Bennett@nps.gov

J.5.9 Development schedule and budget

A CESU task agreement with Utah State University was funded for $15,179 in FY10 to develop a monitoring plan for the Rio Grande using existing peer-reviewed protocols in a cost-share partnership with Big Bend National Park. Monitoring will largely be conducted by BIBE base funding, with small supplements by CHDN I&M funds if needed. The CHDN will focus primarily on data management and reporting. The protocols should be completed in 2010 and implemented in 2011.

J.6 Groundwater Quantity

J.6.1 Vital signs included

Groundwater quantity

J.6.2 Parks where protocol will be implemented

AMIS, BIBE, CAVE, FODA, GUMO, WHSA

J.6.3 Justification/Issues being addressed

An integrated approach to monitoring ground- and surface water is desired because the majority of CHDN surface water sources are closely tied to groundwater discharge, and because the regional use of groundwater resources is accelerating. Groundwater dynamics ranked first throughout the entire vital signs selection process.

Water sustains life, and its amount and quality can profoundly influence the function and services provided by ecological systems (Baron et al. 2002). Consequently, aquatic biological communities are structured according to and respond to spatial and temporal changes in the quality and quantity of water resources (Bunn and Arthington 2002, Valett et al. 2005, Thorp et al. 2006). Surface water resources are sparsely distributed in the semi-arid and arid terrestrial ecosystems of the CHDN, but are critical for supporting native biota. Although limited in extent, these microcosms can add considerably to the biodiversity of arid and semi-arid landscapes. The quantity of subsurface water is a prominent issue for CHDN parks. Every CHDN park is dependent on groundwater that discharges from springs, is pumped from local aquifers, or both (Porter et al. 2009). Groundwater is also a source of potable water for human subsistence near CHDN parks, as well as the discharge component of springs and seeps.

By definition, springs are sites of groundwater discharge. The ecological characteristics of individual springs are strongly affected by the quantity and quality of the groundwater outflow through those springs. CHDN springs are of three general types that reflect differences in the quantity and quality of groundwater discharge from regional, local, and perched aquifers. The latter two types are typically supported by groundwater outflow from relatively small aquifers with dynamics determined primarily by short-term climatic patterns. In contrast, the regionally extensive aquifers—such as the Capitan Reef and Associated Limestones aquifer (GUMO) and the Edwards-Trinity aquifer (RIGR)—typically show the effects of relatively distant conditions of groundwater recharge determined by comparatively long-term climatic trends.

In particular, the Edwards-Trinity aquifer, in Terrell County, Texas, discharges to springs and seeps that sustain streamflow in the lower reaches of the Rio Grande. Anticipated increases in groundwater withdrawals could significantly impact the region's surface-water resources (Porter et al. 2009). AMIS and WHSA, on the other hand, exhibit the effects of comparatively isolated conditions associated with unique hydrogeologic settings. While the groundwater-level variations near AMIS have been distinctly buffered by water levels in Lake Amistad, the shallow groundwater regime at WHSA is perched above and hydraulically isolated from the regional, basin-fill aquifer of the larger Tularosa Basin by an areally extensive remnant of an ancient (Pleistocene) lake bed (Porter et al. 2009). More broadly, the alteration of surface-water resources within desert ecosystems has profound ecological and management implications, including loss of species diversity, extinction or extirpation of special-status and endemic species, alteration in the composition and distribution of aquatic, riparian, and terrestrial plant and animal communities, and inability of parks to meet legal and policy mandates.

Therefore, CHDN park staffs are very concerned about the degradation of both ground- and surface-water resources. A primary cause of degradation to springs is the overdrafting of upgradient groundwater resources. Other impacts to springflow and surface-water biota include current and historical alterations to the hydrology (e.g., construction of spring boxes), current and historical grazing impacts, invasive plant species (especially *Tamarix* spp.), and non-native vertebrates (fish, turtles, and frogs).

J.6.4 Monitoring objectives addressed by the protocol

Determine the seasonal and annual status and longer-term trends in groundwater resources (as estimated from existing wells) in or adjacent to all CHDN park units.

J.6.5 Measures

Depth to groundwater

J.6.6 Basic approach

IMR Hydrologist Colleen Filippone is working on a protocol to measure groundwater quantity in the Sonoran Desert and Southern Plains networks. The CHDN will adopt this protocol.

Following review of monitoring protocols associated with data collection, acceptable existing databases will be used to document and quantify temporal trends in groundwater depth. Existing records of groundwater quantity data relevant to CHDN park units will also be inventoried for useful historical information. For each park with sufficient historical data, a tentative network of potential observation wells will be drafted, based on the longevity of a given well's historical record and apparent ability to reflect conditions most representative of local hydrogeologic conditions. Existing groundwater observation wells with significant historical data would be considered top candidates for continued monitoring as part of a cost-effective and hydrologically sound monitoring program with which to track future groundwater trends in each park unit. Following the electronic- and (or) field-checking of all candidate groundwater observations, a final groundwater-observation network will be presented, along

with recommended monitoring activities, associated guidelines, and appropriate protocols for the measurement, storage, and analysis of groundwater quality and quantity data (USEPA 1986; 1987, Koterba et al. 1995, Lapham et al. 1995, Drost 2005, Texas Water Development Board 2003, Wilde 2005). For parks with an insufficient number of representative wells providing access to groundwater-level measurements, potential sites of possible observation wells will be proposed, in addition to recommended well drilling and construction options for each park unit.

J.6.7 Opportunities for integration

To the extent possible, this protocol will be integrated with other protocols.

J.6.8 Principal investigators and NPS lead

- Lead developer: Colleen Filippone; Intermountain Region, 520.403.2527, colleen_filippone@nps.gov
- Network contact: Kirsten Gallo; Chihuahuan Desert Inventory and Monitoring Network, 575.646.5294, kirsten_gallo@nps.gov
- Other support: Bill Harrison, TCEQ, 512.239.4602, bharriso@tceq.state.tx.us
  Christine Kolbe, TCEQ, 512.239.5831, ckolbe@tceq.state.tx.us
  Gary Rosenlieb, NPS-WRD, 970.225.3518, gary_rosenlieb@nps.gov
  Dr. Liz Walsh, University of Texas at El Paso, 915.747.5421, ewalsh@utep.edu
  Rene Barker, Texas State University, 512.947.9609, rb42@txstate.edu
  Stephen Porter, Texas State University, 512.245.6176, sp31@txstate.edu
  Raymond Slade, Texas State University, 512.922.4488; raymond643@aol.com
  Jeff Bennett, Big Bend National Park, 432.477.1141, Jeffrey_bennett@nps.gov
  Paul Burger, Carlsbad Caverns National Park, 575.785.3106, paul_burger@nps.gov
  Gorden Bell, Guadalupe Mountains National Park, 915.828.3251, ext. 249, gorden_bell@nps.gov
  David Bustos, White Sands National Monument, 575.679.2599, ext. 223, david_bustos@nps.gov

J.6.9 Development schedule and budget

Development of PDSs related to water quality and water quantity, and compilation of historical and trend data and analysis for surface water and groundwater resources in the Chihuahuan Desert Network, was conducted under a Cooperative Agreement (Dr. Glenn Longley) initiated in FY07 ($50,200). Two PDSs were developed, and a final report, "Historical perspective of surface water and groundwater resources in the Chihuahuan Desert Network, National Park Service" (Porter et al. 2009), was produced. A second Task Agreement ($54,000) was initiated in FY08 for development of the water resources-related monitoring protocols.

Analysis of existing aquatic invertebrate community data and recommendations for water quality monitoring through analysis of aquatic microinvertebrates and related biocriteria was conducted under a Cooperative Agreement ($3,550) by Dr. Liz Walsh, University of Texas at El Paso. Recommendations stemming from this agreement will be incorporated into the water quality and quantity monitoring protocol. A draft protocol should be ready for review in early spring 2010. Purchase and initial field testing of equipment will occur in FY 2010, and the protocol will be implemented in 2011.

J.7 Surface Water Quality and Surface Water Dynamics

J.7.1 Vital signs included

- Surface water dynamics
- Persistence of springs
- Surface water quality

- Aquatic invertebrates

J.7.2 Parks where protocol will be implemented

AMIS, BIBE, CAVE, GUMO

J.7.3 Justification/Issues being addressed

Seeps, springs, perennial streams, and certain intermittent streams provide important sources of water for park biota and human visitors. Although limited in extent, these microcosms can add considerably to the biodiversity of arid and semi-arid landscapes. However, most streams in the network are intermittent and small, difficult to sample, or perceived as having relatively low monitoring priority. In contrast, several perennial streams in BIBE and GUMO (e.g., McKittrick Creek), though not officially designated as Outstanding Natural Resource Waters (ONRWs), are considered critically important to their respective parks. The quality of water in the Rio Grande is of particular concern, given its economic and ecological role in the border region and recent exposure to pollutants (International Boundary and Water Commission 1994, Lee and Wilson, 1997, Van Metre et al. 1997). Monitoring the relevant vital signs will demonstrate whether or not park water quality is being protected or maintained and indicate whether restoration is required. The only impaired water in CHDN under Section 303(d) of the Clean Water Act occurs on Segments 2306 and 2307 of the Rio Grande. Additionally, chlorophyll *a* and total phosphorus are listed as Concern Levels for Segment 2306, and nitrate is listed as a Concern Level for Sement 2305 (Amistad Reservoir) (http://www.tceq.state.tx.us/compliance/monitoring/water/quality/data/08twqi/twqi08.html).

Lake Amistad (a Rio Grande reservoir) is the largest and most heavily used water body in the network. This reservoir receives significant levels of monitoring (including continuous lake elevation) by other agencies and programs within NPS. Thus, we do not plan to sample Lake Amistad, but we will report on trends of appropriate data sets.

J.7.4 Monitoring objectives addressed by the protocol

Regulatory and Park Critical Objectives

1. Report on seasonal and annual status and long-term trends for core water quality vital signs for Segments 2306 and 2307 of the Rio Grande, classified as an impaired water under Section 303(d) of the Clean Water Act.

2. Determine seasonal and annual status and long-term trends for core water quality vital signs at selected sites in water resources classified as critically important by each park in AMIS, BIBE, CAVE, and GUMO.

Surface Water Quality and Surface Water Dynamics Objectives

1. Determine the seasonal and annual status and long-term trends in water quantity and core water quality measures for select sites in the Rio Grande in BIBE and RIGR, and report on these trends from existing stations.

2. Determine the seasonal and annual status and long-term trends in water quality and quantity measures at selected sites for perennial streams in BIBE, CAVE, and GUMO.

3. Determine the seasonal and annual status and long-term trends in measures of wetness in select springs and seeps in BIBE, CAVE, and GUMO.

4. Determine the status and long-term trends in measures of aquatic invertebrate communities in selected sites of the rivers, perennial streams in BIBE, CAVE, and GUMO, and report on these trends from existing stations.

5. Determine the status and long-term trends of aquatic invertebrate communities at select springs in BIBE, CAVE, and GUMO.

6. Report on status of monthly, seasonal, and annual reservoir levels and long-term trends from existing International Boundary Water Commission (IBWC) stations in AMIS.

J.7.5 Measures

- Surface water quality (including core parameters): pH, water temperature, dissolved oxygen, specific conductance, fecal-indicator bacteria (at select sites), common dissolved inorganic constituents, discharge rate

- Aquatic macroinvertebrate communities: taxa richness, EPT richness, estimate of the number of pollution-sensitive taxa, Benthic Macroinvertebrate Rapid Bioassessment Index of Biotic Integrity (BRBIBI), functional feeding groups, dominance.

- Surface water sources (springs): measure of wetted perimeter (extent), mean depth, spring length

J.7.6 Basic approach

Monitoring of water quality, benthic macroinvertebrates, and geomorphology is already being conducted on the Rio Grande by BIBE, in conjunction with the Texas Commission on Environmental Quality. This protocol will focus on seeps, springs, and flowing waters other than the Rio Grande. A multi-network (CHDN, SODN, SCPN, NCPN, MOJN) effort is underway to develop sampling protocols for water quality, macroinvertebrates, hydrologic parameters, morphology, and vegetation. The protocols will be based on approved protocols developed by the USGS, NPS-WRD, and others. The CHDN will adopt these protocols and focus on developing the study design.

A large number of springs are known for BIBE, with much fewer numbers in other CHDN parks. A spatially balanced sample with random component (after considering accessibility) of known springs in BIBE will be selected for visitation to determine presence of surface water and flow and to accurately document (georeference) the location. Depending on the number identified, springs known for other CHDN parks will be treated as reference sites and censused or treated as a target population and sampled. High-resolution remote sensing data will be examined to determine our ability to detect a highly correlated wetness index at the visited spring or seep locations. If correlation falls below an acceptable limit, then automated sensing at a subsample of sites will be implemented in lieu of more frequent and costly direct visitation. Otherwise, a much smaller sample of reference sites will be monitored over time through direct visitation. Annual trends during the two driest periods (normally late-winter/early spring and post-monsoonal fall) will be quantified and, hence, will be the target periods for visitation. Measures of water quality and aquatic (macro) invertebrates will also be gathered from springs with adequate-sized pools. Standard Operating Procedures for determining presence of water and flow at springs and seeps will have to be developed, as existing monitoring programs are unknown or have not developed monitoring programs.

J.7.7 Opportunities for integration

To the extent possible, this protocol will be integrated with other protocols, and sampling locations will be co-located with sampling locations for the Integrated Uplands and Landbirds protocols in riparian habitats.

J.7.8 Principal investigators and NPS lead

- Lead developer: Kirsten Gallo; Chihuahuan Desert Inventory and Monitoring Network, 575.646.5294, kirsten_gallo@nps.gov
- Network contact: Kirsten Gallo; Chihuahuan Desert Inventory and Monitoring Network, 575.646.5294, kirsten_gallo@nps.gov
- Other support: Bill Harrison, TCEQ, 512.239.4602, bharriso@tceq.state.tx.us
  Christine Kolbe, TCEQ, 512.239.5831, ckolbe@tceq.state.tx.us
  Gary Rosenlieb, NPS-WRD, 970.225.3518, gary_rosenlieb@nps.gov
  Dr. Liz Walsh, University of Texas at El Paso, 915.747.5421, ewalsh@utep.edu
  Rene Barker, Texas State University, 512.947.9609, rb42@txstate.edu
  Stephen Porter, Texas State University, 512.245.6176, sp31@txstate.edu
  Raymond Slade, Texas State University, 512.922.4488; raymond643@aol.com
  Jeff Bennett, Big Bend National Park, 432.477.1141, Jeffrey_bennett@nps.gov
  Paul Burger, Carlsbad Caverns National Park, 575.785.3106, paul_burger@nps.gov
  Gorden Bell, Guadalupe Mountains National Park, 915.828.3251, ext. 249, gorden_bell@nps.gov

J.7.9 Development schedule and budget

Development of PDSs related to water quality and water quantity, and compilation of historical and trend data and analysis for surface water and groundwater resources in the Chihuahuan Desert Network, was conducted under a Cooperative Agreement (Dr. Glenn Longley) initiated in FY07 ($50,200). Two PDSs were developed, and a final report, "Historical perspective of surface water and groundwater resources in the Chihuahuan Desert Network, National Park Service" (Porter et al. 2009), was produced. A second Task Agreement ($54,000) was initiated in FY08 for development of the water resources-related monitoring protocols.

Analysis of existing aquatic invertebrate community data and recommendations for water quality monitoring through analysis of aquatic microinvertebrates and related biocriteria was conducted under a Cooperative Agreement ($3,550) by Dr. Liz Walsh, University of Texas at El Paso. Recommendations stemming from this agreement will be incorporated into the water quality and quantity monitoring protocol. A draft protocol should be ready for review in late summer 2010. Purchase and initial field testing of equipment will occur in late 2010, and the protocol will be implemented in 2011.

J.8 Invasive/Non-Native Plants

J.8.1 Vital signs included

Invasive/non-native plants (*Integrated Uplands*)

J.8.2 Parks where protocol will be implemented

AMIS, BIBE, CAVE, FODA, GUMO, WHSA

J.8.3 Justification/Issues being addressed

Biological invasions are second only to direct habitat destruction in terms of threats to indigenous biodiversity (Mack et al. 2000, NRC 2002). Colonization and spread of some invader species is a direct consequence of disturbance, while other plants are able to colonize into undisturbed communities (Hobbs

and Huenneke 1992, Mack et al. 2000, Larson 2003, Rejmanek et al. 2005). Ecological and system effects depend on the rate and amount of spread, site characteristics, and the biology of organisms in infected areas (Hupy et al. 2004, Welch 2007a). Prolonged occupancy by non-native species can alter entire ecosystems through fundamental changes to ecosystem processes (D'Antonio and Vitousek 1992). An obvious example is salt cedar, which has spread rapidly throughout the western U.S. in riparian areas, roadsides, and drainage canals. This species can alter local hydrology of riparian zones and prevent native riparian vegetation from establishing (Kennedy and Hobbie 2004). Some species of invasive non-native plants can become prevalent enough to alter fire regimes (D'Antonio and Vitousek 1992, Brooks et al. 2004).

Invasive non-native and exotic plant species are challenging the protection and management of resources in national parks throughout the United States (Lodge et al. 2006, Welch 2007b). As such, the management and control of invasive non-native species has been identified as a high-priority issue within the NPS (e.g., National Invasive Species Council 2008), and reduction of invasive plants is a goal for all CHDN park units under the Government Performance and Results Act of 1993. Executive Order 13112 (Invasive Species) further identifies and strengthens the obligations of federal agencies to address significant economic and biological threats posed by non-native species. Additionally, the NPS has emphasized the importance of invasive species issues and their associated impacts by identifying non-native species as one of three major areas of focus under the Natural Resource Challenge. More recently, NPS Management Policies 2006 (NPS 2006) stated, "high priority will be given to managing exotic species that have, or potentially could have, a substantial impact on park resources, and that can reasonably be expected to be successfully controllable."

In the CHDN, invasive plants, most of which are non-native species, pose one of the greatest threats to natural resources, and have been identified as a high-priority vital sign. Highway and park road margins and banks along watercourses are common conduits for dispersal by invasive non-native plants in the CHDN. Hydrological function and high-value indigenous biodiversity in riparian areas are threatened by woody invaders, such as tamarisk (*Tamarix* spp.). Other non-native species that are impacting riparian areas include Russian olive (*Elaeagnus angustifolia*) and giant reed (*Arundo donax*). Exotic grass species, such as buffelgrass (*Cenchrus ciliaris*) and Lehmann lovegrass (*Eragrostis lehmanniana*), are impacting endangered cacti by altering fire regimes.

National Park Service policy and current best management practices in invasion ecology promote the use of early warning efforts to combat invasive species (Rejmanek and Pitcairn 2002, Klinger and Brooks 2008). Early warning of approaching invasive species, or early detection before extensive spread, are critical when managing to reduce or minimize the effects of non-native invasive plants (Westbrook 2004, Welch 2007c). After an aggressive non-native species has spread over large areas, restoration is often improbable in national parks due to poor access and limited funds (Welch 2007a). Monitoring efforts that provide early warning of approaching non-native plant species will help prevent costly restoration efforts and the spread of new invasive species into CHDN park units. Monitoring the distribution and spread of existing non-natives can also help park managers to assess the success of attempted restoration projects. Unfortunately, regular comprehensive monitoring of the distribution and abundance of all exotic plant species within the CHDN is beyond the fiscal capabilities of the network and parks. Thus, the network will develop a cost-effective approach to early detection and trend evaluation of a prioritized list of target incipient and established species by integrating information from existing park programs, other network-sponsored vegetation monitoring efforts (e.g., Integrated Uplands monitoring), and monitoring proposed in this PDS.

J.8.4 Monitoring objectives addressed by the protocol

1. Detect the initial occurrence for any of a subset of high-priority species in areas of high and low invasion probability.

2. Determine changes in the status and trend (density, abundance, or extent) of a subset of high-priority species in areas of high and low invasion probability.
3. Determine changes in species composition of a subset of high-priority species in areas of high and low invasion probability, taking into account any management treatments that occurred between sampling intervals.

J.8.5 Measures

Presence and relative abundance of target plants

J.8.6 Basic approach

The CHDN will adopt the early detection protocol developed by the SOPN (also used by the SODN). This protocol involves sampling along vectors that serve as corridors for plant invasion (e.g., roads, arroyos).

J.8.7 Opportunities for integration

Opportunities for integration include the use of common field crews with the Integrated Uplands protocol, and possible co-location of samples.

J.8.8 Principal investigators and NPS lead

- Lead developers: Rob Bennetts, Southern Plains Inventory and Monitoring Network, 719.846.4663, robert_bennetts@nps.gov
- Network contact: Kirsten Gallo; Chihuahuan Desert Inventory and Monitoring Network, 575.646.5294, kirsten_gallo@nps.gov
- Other support: Dr. Joe Sirotnak, Big Bend National Park, 432.477.1148, joe_sirotnak@nps.gov
  Renee West, Carlsbad Caverns National Park, 575.785.3099, renee_west@nps.gov
  Fred Armstrong, Guadalupe Mountains National Park, 915.828.3251, fred_armstrong@nps.gov
  David Bustos, White Sands National Monument, 575.679.2599, ext. 223, david.bustos@nps.gov

J.8.9 Development schedule and budget

The protocol has already been developed and implemented in the SOPN. The CHDN will adopt the protocol and begin pilot testing in late 2010.

J.9 Landbirds

J.9.1 Vital signs included

Bird communities

J.9.2 Parks where protocol will be implemented

Birds of grassland, shrubland, and riparian, communities will be monitored at AMIS, BIBE, CAVE, FODA, GUMO, WHSA

J.9.3 Justification/Issues being addressed

The opportunity to see wildlife attracts many visitors to CHDN parks. The geographic location and arid and semi-arid environment of these parks provide suitable habitat for a variety of desert, woodland, and montane species of the southwestern United States. In particular, desert riparian and grassland communities provide important habitats for migrating and wintering birds in the Southwest despite a reduction in quality and quantity during the past 100 years (Ffolliott et al. 2004, Merola-Zwartjes 2005,

Skagen et al. 2005). The relatively less-disturbed systems in CHDN parks provide refugia for avian species seeking these habitats and enhance regional biodiversity. For certain birds, properties of faunal assemblages and populations are important indicators of environmental change because they serve a great diversity of ecological functions that affect ecosystem productivity, resilience, and sustainability (Marcot 1996, Bryce et al. 2002, Sullivan et al. 2007). Similar conservation issues affect landbirds in the southwestern U.S. and northwest Mexico, making bird monitoring an important international issue, as well (Rich et al. 2004).

Birds are also desirable subjects for long-term ecological monitoring because they have widespread public appeal, and changes in park fauna are likely to garner a high level of public interest and generate support for corrective or remedial management actions. CHDN parks are well-positioned to contribute to regional and national bird monitoring initiatives (e.g., with the adjacent Sonoran Desert, Southern Colorado Plateau, and Southern Plains I&M networks; Partners in Flight; Rocky Mountain Bird Observatory, parks in adjacent Chihuahua and Coahuila, Mexico) that will provide insight into changes of this important focal resource.

This protocol will address obligate breeding bird species for Chihuahuan Desert grasslands and riparian areas. Seventeen bird species of continental importance (>75% of their breeding population occurs in this biome) are found in CHDN parks, including verdin (*Auriparus flaviceps*), pyrrhuloxia (*Cardinalis sinuatus*), scaled quail (*Callipepla squamata*), and Bell's vireo (*Vireo bellii*). This protocol will also provide information on many other bird species that use these habitats during the breeding season.

We will monitor breeding bird populations associated with desert grasslands, shrublands, and riparian areas. Riparian birds associated with vegetation in intermittently flooded washes and arroyos will not be addressed by this protocol. Monitoring riparian areas during other seasons (spring and fall migration, winter) may be addressed by the CHDN as a future project. Integration with the Integrated Uplands protocol will enable vegetation trends to be used in the analysis and interpretation of bird trends.

J.9.4 Monitoring objectives addressed by the protocol

1. Provide occupancy and trend in occupancy estimates for breeding landbirds.
2. Estimate species richness, composition, and associated parameters of landbird community dynamics.
3. Where feasible, estimate population density and trend estimates for common breeding landbirds.
4. Where feasible, incorporate vegetation monitoring from Integrated Uplands protocol to augment landbird sampling and increase efficiency.

J.9.5 Measures

Occupancy estimates; community dynamics measures, such as species richness and composition.

J.9.6 Basic approach

The CHDN will adopt the landbird protocol developed by the SOPN, which has been implemented in the SOPN and SODN. The Rocky Mountain Bird Observatory (RMBO) conducts surveys for SOPN and SODN, and the CHDN will also use RMBO, resulting in efficiency in contract administration, data management, and reporting.

J.9.7 Opportunities for integration

If possible, bird sampling will be co-located and co-visited with the sampling points selected for the Integrated Uplands protocol.

J.9.8 Principal investigators and NPS lead

- Lead developer: David Hanni, Rocky Mountain Bird Observatory, 970.482.1707, ext. 13, david.hanni@rmbo.org
- Network contact: Kirsten Gallo; Chihuahuan Desert Inventory and Monitoring Network, 575.646.5294, kirsten_gallo@nps.gov
- Other support: Rob Bennetts, Southern Plains Inventory and Monitoring Network, 719.846.4663, robert_bennetts@nps.gov
  Raymond Skiles, Big Bend National Park, 432.477.1145, raymond_skiles@nps.gov

J.9.9 Development schedule and budget

A two-year Cooperative Agreement (approximately $73,000) for FY08–09 was provided to RMBO for assistance in adapting existing monitoring protocols for the CHDN, developing appropriate sampling designs, developing SOPs, and pilot testing in a subset of parks. An additional $40,000 was added to the agreement in 2009. Pilot work for testing was conducted in April–June 2009. Implementation will begin in 2010. Future expenses are expected to be about $40,000 per year for monitoring.

J.10 Integrated Upland (Soils and Vegetation)

J.10.1 Vital signs included

- Bare ground
- Biological soil crusts
- Soil erosion (wind and water)
- Soil hydrologic function
- Plant community composition
  (Invasive/Non-native Plants, Landscape Patterns and Dynamics)

J.10.2 Parks where protocol will be implemented

BIBE, CAVE, FODA, GUMO, WHSA

J.10.3 Justification/Issues being addressed

Soils and plants provide the foundation for productivity in terrestrial ecosystems. In the arid and semi-arid ecosystems of the CHDN, soil type, topographic position, and condition have direct influence on rates of mineralization, nutrient cycling, moisture retention, and susceptibility to erosion (Monger and Bestlemeyer 2006, Schlesinger et al. 2006, Snyder et al. 2006, Duniway et al. 2007). In turn, these processes influence plant production, distribution, water runoff, and sedimentation loads in surface waters (Wondzell et al. 1996, McAuliffe 2003). Soil and plant communities provide the structural template and habitats for a wide array of fauna and are key resources that affect biotic diversity.

The arid and semi-arid Desert Ecosystem comprises approximately 77% of total CHDN park area. Throughout the last century, the predominance of desert grasslands has diminished and woody-dominated communities have expanded in the Chihuahuan Desert as a complex and interactive function of land use, climate, and species interactions (Van Devender 1995, Peters 2001, Peters et al. 2006). Regionwide losses of grass-dominated communities have resulted in habitat loss for grassland-obligate species and changes in fire regimes at a landscape level. Continued loss of grass-dominated communities could lead to overall loss of biotic diversity, particularly as grassland-shrubland ecotones disappear and desert plant communities become less heterogeneous in CHDN parks.

Conservation of soils is essential for long-term protection of biotic productivity. Monitoring attributes that relate information about soil condition and process, along with structure and composition of key plant

communities at the micro- (plot level) and sub-landscape scales, will help identify the potential for maintaining biological integrity and function in CHDN park units (Herrick et al. 2002).

This protocol will establish long-term monitoring plots that will quantify network- and park-wide changes in key plant communities and their associated soil properties in upland communities. These monitoring plots are not manipulative and, therefore, do not address causal relationships or functional questions about the ecosystems. Rather, they establish a basis for quantifying changes in the soils and vegetative communities.

Although CHDN parks encompass a wide range of plant communities, from desert grasslands to saltbush, mesquite, and creosotebush at low elevations to mixed-conifer communities at the highest elevations, financial and logistical constraints require that we limit our objectives to a subset of these communities. We propose to conduct long-term monitoring on desert grasslands, desert shrub communities, and the grassland-shrubland ecotone within network parks because this physiognomic class collectively represents a large proportion of each park, captures several focal communities of interest, and provides a common theme among all parks (as opposed to a disjointed set of favorites at each park), thereby increasing our ability to discern landscape-scale changes in upland vegetation and soils arising from drought, fire, exotic plant invasions, and other biotic and abiotic disturbances.

The data developed from these plots will provide (1) a quantifiable framework upon which to build adaptive management policies, and (2) a baseline from which to establish additional scientific studies, for example, those addressing cause and effect relationships. Without a basic understanding of the resources and processes present within park boundaries, land managers cannot hope to make informed decisions about how to conserve these resources into the future.

Although the invasive-plants vital sign is predominantly addressed through another protocol (Invasive Plants), data collected through this protocol will also contribute toward evaluating status and trends of invasive plants. Fixed-plot methods used in this protocol will provide data on shifts in spatial distribution, abundance, and persistence of invasive plant species in the plant communities of interest to CHDN parks.

J.10.4 Monitoring objectives addressed by the protocol

1. Determine the status and long-term trends in soil stability, bare ground, magnitude and extent of soil erosion, and soil hydrologic function within selected grassland and shrubland communities of the Desert and Foothill ecosystems of BIBE, CAVE, FODA, GUMO, and WHSA.
2. Determine long-term trends in the composition, structure, and relative abundance of dominant and subdominant perennial plant species and biological soil crusts within selected grassland and shrubland communities in the Desert and Foothill ecosystems of BIBE, CAVE, FODA, GUMO, and WHSA.

J.10.5 Measures

- Specific vegetation parameters include perennial species composition, cover, and relative abundance, and community structure of dominant and subdominant perennial species and biological soil crusts.
- Soil measurements include penetration resistance and infiltration rates, length of bare ground.

J.10.6 Basic approach

The overall goal is to establish permanent vegetation/soil monitoring plots throughout grassland and shrubland communities of CHDN parks that provide robust data through cost-effective sampling designs. We will follow procedures developed by the Sonoran Desert Network. Sampling will be stratified

according to ecological sites most likely to have the target plant communities. If use of ecological sites becomes prohibitive, we will delineate sample frames using elevation, landform (e.g., valley bottom to upper piedmont), soils, or other relatively static features. A generalized random tessellation stratified (GRTS) sample will be assigned to each domain of ecological sites. We will also incorporate other practical concerns into our sampling design, such as excluding areas of limited accessibility (e.g., large distance from roads) or safety concern (e.g., steep slopes).

Using the existing SODN protocol provides several advantages to CHDN monitoring efforts. Data entry and summarization interfaces are currently available. Training programs for data collection have been established and the time required for measuring relevant attributes in selected environments have been estimated.

In addition to the GRTS sampling locations, this protocol will also be measured at all weather monitoring sites. In BIBE, because of the nearly 60 years of legacy data from Ecological Survey of Big Bend permanent plots and efforts in change detection by the USDA Agricultural Research Station-Jornada Experimental Range (Las Cruces, New Mexico), we will pursue the use of technologies such as remote sampling and digital photo sampling to minimize costs and reduce soil and vegetation disturbance due to repeat sampling. These additional efforts will enhance interpretation of observed trends.

J.10.7 Opportunities for integration

This protocol will be integrated with other related vital signs protocols, including Invasive Plants, Surface Water Quality and Dynamics, and Landscape Patterns and Dynamics (e.g., detecting shifts in plant community distribution). During the design phase of protocol development, opportunities for field integration, such as co-location of sample sites, concurrent sampling, and the use of a common field crew, will be discussed.

J.10.8 Principal investigators and NPS lead

- Lead developer: Andy Hubbard, Sonoran Desert Network, 520.429.8147, andy_hubbard@nps.gov
- Network contact: Kirsten Gallo; Chihuahuan Desert Inventory and Monitoring Network, 575.646.5294, kirsten_gallo@nps.gov
- Other support: Dr. Este Muldavin, New Mexico Natural Heritage Program, 505.277.3822, ext. 228, muldavin@unm.edu
  Dr. Steve Wondzell, USFS Pacific Northwest Research Station, 360.753.7691, swondzell@fs.fed.us
  Dr. John Ludwig, +61 [07] (4091 8837, john.ludwig@csiro.au
  Dr. Brandon Bestelmeyer, USDA Agricultural Research Station-Jornada Experimental Range, 575.646.5139, bbestelm@nmsu.edu
  Dr. Joe Sirotnak, Big Bend National Park, 432.477.1148, joe_sirotnak@nps.gov

J.10.9 Development schedule and, budget

The protocol has already been developed and implemented in the SODN. The CHDN will adopt the protocol and begin pilot testing in late 2010.

J.11 Landscape Patterns and Dynamics

J.11.1 Vital signs included

- Land cover

- Land-use changes
  (Integrated Uplands, Invasive/Non-native Plants)

J.11.2 Parks where protocol will be implemented

All CHDN park units (AMIS, BIBE, CAVE, FODA, GUMO, RIGR, WHSA)

J.11.3 Justification/Issues being addressed

Ecosystem processes occur at multiple scales, but most notably over ecologically long time periods (decades to centuries) and large spatial extents (e.g., tens to hundreds of kilometers). Monitoring of ecosystem change, therefore, benefits from a landscape-level perspective. Change in landscape use, both inside and outside NPS boundaries, can identify impending issues, such as future loss and fragmentation of wildlife habitats, isolation of park resources, potential for water scarcity and pollution, and invasion of non-native species (Hacsic and Wu 2006, NARSEC 2007, Young and Schrader 2007). Change in landscape composition (e.g., land cover classes, severity classes of past fires, indices of wetness) can also provide valuable information on large-scale changes in resources that may be associated with shifting climate and temperature feedbacks (Saunders et al. 1998, Quattrochi and Luvall 1999, Smith and Johnson 2004). Substantial changes in these land-cover attributes occur in response to natural and anthropogenic processes. Natural disturbance regimes are largely driven by climatic factors (e.g., Swetnam and Betancourt 1998), and expected changes in climatic conditions may elevate the frequency and/or severity of natural disturbances, such as wildfire and insect and disease outbreaks. Energy-development sites (e.g., wind farms, oil and gas development) are increasing in the CHDN region (e.g., near CAVE and GUMO). Increased habitat fragmentation is a likely outcome of this growth.

The NPS has long been aware of the implications and consequences of large-scale changes in land cover. More than 10 years ago, the National Park System Advisory Board recommended that "resource management should be addressed in broader context," and specifically recognized the impact of activities outside park boundaries (NPS 1993). The majority of parks are dependent on adjacent lands simply because their boundaries fail to completely encompass the habitats (e.g., riparian corridors) and processes (e.g., migratory species, fire regimes) of the greater ecosystem (Myers 1972, Western 1982, Curry-Lindahl 1972, Garratt 1984). Therefore, threats from outside park boundaries can significantly modify biodiversity within parks—and are doing so (NPCA 1979, Garratt 1984, Sinclair 1998).

In the CHDN, landscape-level issues of greatest concern include understanding how, where, and over what time periods land uses, such as energy and human developments, are changing. The ability to detect major shifts in vegetation zones (e.g., desert grassland/shrubland ecotone) or conversion of particular communities to altered states is an important objective of the CHDN monitoring plan. Development and implementation of a protocol to efficiently and cost-effectively monitor land-cover change (including measures of fragmentation and connectivity) within and around CHDN parks at multiple spatial scales will advance our current understanding of park-level ecosystem dynamics and allow for better management practices and decisionmaking in the future.

J.11.4 Monitoring objectives addressed by the protocol

Determine patterns and long-term trends in spatial and temporal landscape change within and adjacent to CHDN parks based on changes in land use (e.g., road density, building density, energy developments sites) and land-cover distribution (vegetation classes).

J.11.5 Measures

Candidate measures: energy development densities, housing densities, road densities, and general land cover types

J.11.6 Basic approach

Monitoring landscape dynamics will be a matter of repeating measures of landscape condition over appropriate time intervals. The CHDN will use aerial photography and satellite imagery (collectively, remote sensing) to monitor the spatial extent of changes in land cover (see Tatem et al. [2008] for an overview of the availability and uses of different types of satellite imagery). Benefits of this monitoring approach (i.e., using remotely sensed data) include complete spatial coverage of large sampling areas and substantially reduced sampling time compared to ground-based sampling within plots. Additionally, remote sensing is often used as an alternative to ground-based sampling, allowing collection of certain survey data (e.g., vegetation cover) in areas considered too remote to visit on the ground. This additional data, not otherwise available through standard survey methods, facilitates the extrapolation of point measurements across landscapes.

Although maps and mapping are inherently interesting for the purpose of developing comprehensive inventories, monitoring requires the derivation of meaningful information from those maps to interpret the nature and context of changes occurring among sampling dates. Two approaches to landscape interpretation will be pursued: (1) pattern analysis, which uses metrics of landscape pattern derived from categorical maps, and (2) descriptive change detection via map-to map or image-to-image comparisons. Both approaches identify land areas that have been significantly altered. Such information will inform more focused management efforts and/or support additional, intensive, ground-based monitoring.

Selecting an adequate scale at which to evaluate the effects of land-cover change and fragmentation is difficult without first identifying what is being managed (e.g., what species or processes; Beatley 2000), and the scales of disturbance to which those species/processes respond. One of the first tasks associated with this protocol will be to determine the appropriate temporal and spatial (grain size and map extent) resolutions for mapping and analyzing land cover in and adjacent to the parks.

Several national and regional NPS efforts are underway to develop land-cover change protocols. The Landscape Dynamic Monitoring Project, led by John Gross, will identify, evaluate, and report on a small set of landscape-level measures for all I&M parks. Candidate measures include housing densities, road densities, and general land-cover types. The CHDN will adopt existing protocols to the extent possible. Various approaches have been presented by several networks, including the National Capital Region (Townsend et al. 2006), Appalachian Highlands, and North Coast Cascades (Kennedy et al. 2007) networks.

Additionally, the CHDN has access to long-term legacy data gathered from ground-measured plots in desert grassland, shrublands, and foothill woodlands of BIBE (Muldavin et al. 2002), foothill woodlands of GUMO, and at upper elevations proximal to CAVE (Jones and Hessler 1983) that could provide meaningful results from a change-detection analysis. Fine-scale changes in these data sets will be explored and compared to patterns generated from remote-sensing data to understand the sensitivity of changes detected by the coarser-scale remote-sensing data. Future sampling of soil- and vegetation-related vital signs may also aid interpretation of remote-sensing data in similar fashion, as long as sampling on the ground is temporally synchronized with remote sensing. A substantial focus during protocol development will be on the evaluation of existing approaches for use in CHDN parks.

J.11.7 Opportunities for integration

As other vital sign protocols are developed, landscape-level objectives will be identified. Opportunities for addressing these objectives through the Landscape Dynamics protocol will be discussed. Landscape-level objectives will likely be identified for several protocols, including Integrated Uplands and Invasive/Exotic Plants.

J.11.8 Principal investigators and NPS lead

- Lead developer: TBD
- Network contact: Kirsten Gallo; Chihuahuan Desert Inventory and Monitoring Network, 575.646.5294, kirsten_gallo@nps.gov
- Other support:
  Dr. John Gross, Servicewide I&M Program, 970.267.2111, john_gross@nps.gov
  Dr. Bruce Milne, University of New Mexico, 505.277.5356, bmilne@unm.edu

J.11.9 Development schedule, budget, and expected interim products

In early 2011, the network will re-examine objectives, discuss landscape-level objectives from other vital signs that may be incorporated into this protocol, and explore potential cooperators for development. By mid-2011, the network will identify a lead developer. Protocol development will begin in late 2011.

J.12 Literature Cited

Allred, T. M., and J. C. Schmidt 1999. Channel narrowing by vertical accretion along the Green River near Green River, Utah. Geological Society of America Bulletin 111:1757–1772.

Anderson, D. R., K. P. Burnham, and W. L. Thompson. 2000. Null hypothesis testing: Problems, prevalence, and an alternative. Journal of Wildlife Management 64:912–923.

Baron, J. S., N. L. Poff, P. L. Angermeier, C. N. Dahm, P. H. Gleick, N. G. Hairston, R. B. Jackson, C. A. Johnston, B. D. Richter, and A. D. Steinman. 2002. Meeting ecological and societal needs for freshwater. Ecological Applications 12:1247–1260.

Beatley, T. 2000. Preserving biodiversity: challenges for planners. Journal of the American Planning Association 66:5–21.

Brooks, M. L., C. M. D'Antonio, D. M. Richardson, J. B. Grace, J. E. Keeley, J. M. Ditomaso, R. J. Hobbs, M. Pellant, and D. Pyke. 2004. Effects of invasive alien plants on fire regimes. BioScience 54:677–688.

Brown, J. H., and E. J. Heske. 1990. Control of a desert-grassland transition by a keystone rodent guild. Science 250:1705–1707.

Bryce, S. A., R. M. Hughes, and P. R. Kaufmann. 2002. Development of a bird integrity index: Using bird assemblages as indicators of riparian condition. Environmental Management 30:294–310.

Buckland, S. T., D. R. Anderson, K. P. Burnham, and J. L. Laake. 1993. Distance sampling: Estimating abundance of biological populations. London: Chapman and Hall.

Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers and L. Thomas, eds. 2004. Advanced distance sampling: Estimating abundance of biological populations. Oxford, U.K.: Oxford University Press.

Bunn, S. E., and A. H. Arthington. 2002. Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. Environmental Management 30:492–507.

Cleland, E. E., I. Chuine, A. Menzel, H. A. Mooney, and M. D. Schwartz. 2007. Shifting plant phenology in response to global change. Trends in Ecology & Evolution 22:357–365.

Cook, R. P., K. M. Boland, and T. Dolbeare. 2004. Inventory of small mammals at Cape Code National Seashore with recommendations for long-term monitoring. Unpublished technical report, Cape Cod National Seashore, Wellfleet, Massachusetts.

Curry-Lindahl, K. 1972. Ecological research and management. Pages 197–213 *in* R. Osten, ed., World national parks: Progress and opportunities. Brussels, Belgium: World Conservation Union.

D'Antonio, C. M., and P. M. Vitousek. 1992. Biological invasions by exotic grasses, the grass/fire cycle, and global change. Annual Review of Ecology and Systematics 23:63–87.

Davey, C. A., K. T. Redmond, and D. B. Simeral. 2007. Weather and climate inventory, National Park Service, Chihuahuan Desert Network. Natural Resource Technical Report NPS/CHDN/NRTR—2007/034. National Park Service, Fort Collins, Colorado.

Daw, S., M. Beer, and S. L. Garman. 2004. Landbird monitoring protocol for the park units in the Northern Colorado Plateau Network (version 1.00). Unpublished technical report, National Park Service, Northern Colorado Plateau Network Inventory and Monitoring Program.

Drost, B. W., compiler. 2005. Quality-assurance plan for ground-water activities. U.S. Geological Survey, Washington Water Science Center. Open-File Report 2005–1126.

Duniway, M. C., J. E. Herrick, and H. C. Monger. 2007. The high water-holding capacity of petrocalcic horizons. Soil Science Society of America Journal 71:812–819.

Fenn, M. E., J. S. Baron, E. B. Allen, H. M. Rueth, K. R. Nydick, and others. 2003. Ecological effects of nitrogen deposition in the western United States. BioScience 53:404–420.

Ffolliott, P. F., C. M. Jones, and W. D. Jones. 2004. Chapter 8: Mammals, avifauna, and herpetofauna. Pages 169–192 *in* M. B. Baker, Jr., P. F. Ffolliot, L. F. DeBano, and D. G. Neary, eds., Riparian areas of the southwestern United States. Boca Raton, Fl.: Lewis Publishers.

Franklin, A. B. 2001. Exploring ecological relationships in survival and estimating rates of population change using program MARK. Pages 290–296 *in* R. Field, R. J. Warren, H. Okarma, and P. R. Sievert, eds., Wildlife, land, and people: Priorities for the 21st century. Proceedings of the Second International Wildlife Management Congress. The Wildlife Society, Bethesda, Maryland.

Garman, S. L., M. Beer, M. A. Powell, R. DenBleyker. 2004. Climate monitoring protocol for the park units in the Northern Colorado Plateau Network. National Park Service, Moab, Utah.

Garratt, K. 1984. The relationship between adjacent lands and protected areas: Issues of concern for the protected area manager. Pages 65–71 *in* J. A. McNeely, and K. R. Miller, eds., National parks, conservation and development: The role of protected areas in sustaining society. Proceedings of the World Congress on National Parks, Bali, Indonesia, October 11–22, 1982. Washington, D.C.: Smithsonian Institution Press.

Guo, Q. F., D. B. Thompson, T. J. Valone, and J. H. Brown. 1995. The effects of vertebrate granivores and folivores on plant community structure in the Chihuahuan Desert. Oikos 73:251–259.

Hacsic, I., and J. Wu. 2006. Land use and watershed health in the United States. Land Economics 82:214–239.

Hamada, Y., D. A. Stow, L. L. Coulter, J. C. Jafolla, and. L. W. Hendricks. 2007. Detecting Tamarisk species (*Tamarix* spp.) in riparian habitats of southern California using high spatial resolution hyperspectral imagery. Remote Sensing of the Environment 109:237–248.

Harrison, B. 2006. Development of biocriteria for the Southern Deserts and Southern Texas Plains Ecoregions. Unpublished technical teport. Texas Commission of Environmental Quality, Austin, Texas.

Herrick, J. E., J. R. Brown, A. J. Tugel, P. L. Shaver, and K. M. Havstad. 2002. Application of soil quality to monitoring and management: paradigms from rangeland ecology. Agronomy Journal 94:3–11.

Herrick, J. E., J. W. Van Zee, K. M. Havstad, L. M. Burkett, and W. G. Whitford. 2005. Monitoring manual for grassland, shrubland and savanna ecosystems. Volume II: Design, supplementary methods

and interpretation. USDA Agricultural Research Service, Jornada Experimental Range, Las Cruces, New Mexico and University of Arizona Press, Tucson, Arizona.

Hobbs, R. J., and L. F. Huenneke. 1992. Disturbance, diversity, and invasion: Implications for conservation. Conservation Biology 6:324–337.

Hupy, C. M., W. G. Whitford, and E. C. Jackson. 2004. The effect of dominance by an alien grass species, Lehmann lovegrass, *Eragrostis lehmanniana*, on faunal pedoturbation patterns in North American Desert grasslands. Journal of Arid Environments 58:321–334.

International Boundary and Water Commission. 1994. Binational study regarding the presence of toxic substances in the Rio Grande/Rio Bravo and its tributaries along the boundary portion between the United States and Mexico: Final report. U.S. Environmental Protection Agency, Dallas, Texas.

Jones, B., and C. Hessler. 1983. Fuel loading and inventory project. Unpublished technical report. National Park Service, Guadalupe Mountains and Carlsbad Caverns national parks.

Kennedy, R. E., W. B. Cohen, A. A. Kirschbaum, and E. Haunreiter. 2007. Protocol for Landsat-based monitoring of landscape dynamics at North Coast and Cascades Network Parks: U.S. Geological Survey Techniques and Methods 2–G1.

Kennedy, T. A., and S. E. Hobbie. 2004. Saltcedar (*Tamarix ramosissima*) invasion alters organic matter dynamics in a desert stream. Freshwater Biology 49:65–76.

Khanduri, V. P., C. M. Sharma, and S. P. Singh. 2008. The effects of climate change on plant phenology. Environmentalist DOI 10.1007/s10669-007-9153-1.

Klinger, R. C., and M. L. Brooks. 2008. Prioritization of non-native plants in the National Park Service Klamath Network using weighted criteria and measures of uncertainty. A technical report prepared for the National Park Service, Klamath Network.

Kocurek, G. 2008. LiDAR surveys of gypsum dune fields in White Sands National Monument, New Mexico. Unpublished annual report for FY07, National Park Service, Chihuahuan Desert Network, Las Cruces, New Mexico.

Koterba, M. T., F. D. Wilde, and W. W. Lapham. 1995. Ground-water data-collection protocols and procedures for the National Water Quality Assessment Program: collection and documentation of water-quality samples and related data. U.S. Geological Survey Open-File Report 95-399.

Lapham, W. W., F. D. Wilde, and M. T. Koterba. 1995. Ground-water data-collection protocols and procedures for the National Water Quality Assessment Program: Selection, installation, and documentation of wells, and collection of related data. U.S. Geological Survey Open-File Report 95-398.

Larson, D. L. 2003. Native weeds and exotic plants: relationships to disturbance in mixed-grass prairie. Plant Ecology 169:317–333.

Lazorchak, J. M., B. H. Hill, D. K. Averill, D.V. Peck, and D. J. Klemm, eds. 2000. Environmental Monitoring and Assessment Program-surface waters: Field operations and methods for measuring the ecological condition of non-wadeable rivers and streams. U.S. Environmental Protection Agency, Cincinnati, Ohio.

Lee, R. W., and J. T. Wilson. 1997. Trace elements and organic compounds associated with riverbed sediments in the Rio Grande/Rio Bravo basin, Mexico and Texas. U.S. Geological Survey Fact Sheet FS-098-97.

Leukering, T., M. Carter, A. Panjabi, D. Faulkner, and R. Levad. 2006. Rocky Mountain Bird Observatory point transect protocol. Unpublished technical report, Rocky Mountain Bird Observatory, Brighton, Colorado.

Lodge, D. M., S. Williams, H. J. Macisaac, K. R. Hayes, B. Leung, S. Reichard, R. N. Mack, P. B. Moyle, M. Smith, D. A. Andow, J. T. Carlton, and A. McMichael. 2006. ESA report. Biological invasions: Recommendations for U.S. policy and management. Ecological Applications 16:2035–2054.

Mack, R. N., D. Simberloff, W. M. Lonsdale, H. Evans, M. Clout, and F. A. Bazzaz. 2000. Biotic invasions: Causes, epidemiology, global consequences and control. Ecological Applications 10:689–710.

MacKenzie, D. I., J. D. Nichols, J. A. Royle, K. H. Pollock, J. E. Hines, and L. L. Bailey. 2006. Occupancy estimation and modeling: inferring patterns and dynamics of species occurrence. San Diego, Ca.: Elsevier Academic Press.

Malm, W. C. 1999. Introduction to visibility. National Park Service-Air Resources Division and Cooperative Institute for Research in the Atmosphere, Fort Collins, Colorado. http://www2.nature.nps.gov/air/Pubs/all.cfm. Last accessed February 18, 2010.

Maniero, T. 2001. Guidance on air quality and air quality related values, vital signs monitoring in national parks. Unpublished report. National Park Service-Air Resources Division, Denver, Colorado.

Marcot, B. 1996. An ecosystem context for bat management: A case study of the interior Columbia River Basin, USA. Pages 19–38 *in* R. M. R. Barclay and R. M. Brigham, eds., Bats and Forests Symposium. British Columbia Ministry of Forestry, Victoria, B.C., Canada.

Marra, P. P., C. M. Francis, R. S. Mulvihill, and F. R. Moore. 2005. The influence of climate on the timing and rate of spring bird migration. Oecologia 142:307–315.

Mau-Crimmins, T. M., H. R. Schussman, and E. L. Geiger. 2006. Can the invaded range of a species be predicted sufficiently using only native-range data? Lehmann lovegrass (*Eragrostis lehmanniana*) in the southwestern United States. Ecological Modelling 193:736–746.

Mau-Crimmins, T., and E. Porter. 2007. Air quality monitoring protocol and standard operating procedures for the Sonoran Desert Network. Natural Resource Report NPS/SODN/NRTR—2007/003. National Park Service, Fort Collins, Colorado.

McAuliffe, J. R. 2003. The interface between precipitation and vegetation: the importance of soils in arid and semiarid environments. Pages 9–27 *in* J. F. Weltzin and G. R. McPherson, eds., Changing precipitation regimes and terrestrial ecosystems. Tucson: University of Arizona Press.

McCallum, D. A. 2005. A conceptual guide to detection probability for point counts and other count-based survey methods. Pages 754–760 *in* C. J. Ralph and T. D. Rich, eds., Bird conservation implementation and integration in the Americas. Proceedings of the Third International Partners in Flight Conference, March 20–24 2002, Asilomar, California, volume 2. USDA Forest Service General Technical Report PSW-GTR-191.

McCune, B., and J. B. Grace. 2002. Analysis of ecological communities. MjM Software Design, Gleneden Beach, Oregon.

Merola-Zwartjes, M. 2005. Birds of southwestern grasslands: Status, conservation, and management. Pages 71–139 *in* D. M. Finch, ed., Assessment of grassland ecosystem conditions in the southwestern United States: Wildlife and fish, volume 2. USDA Forest Service General Technical Report RMRS-GTR-135, volume 2.

Monger, H. C., and B. T. Bestelmeyer. 2006. The soil-geomorphic template and biotic change in arid and semi-arid ecosystems. Journal of Arid Environments 65:207–218.

Moulton, S. R., II, J. G. Kennen, R. M. Goldstein, and J. A. Hambrook. 2002. Revised protocols for sampling algal, invertebrate, and fish communities as part of the National Water-Quality Assessment

Program. U.S. Geological Survey Open-File Report 02-150. http://water.usgs.gov/nawqa/protocols/OFR02-150/. Last accessed February 18, 2010.

Muldavin, E., S. Wondzell, and J. A. Ludwig. 2002. Forty years of vegetation change in desert grasslands of Big Bend National Park. Final report to the Big Bend Natural History Association and Big Bend National Park.

Myers, N. 1972. National parks in savannah Africa. Science 178:1255–1263.

National Invasive Species Council. 2008. 2008–2012 National invasive species management plan. http://www.invasivespeciesinfo.gov/council/mp2008.pdf. Last accessed March 26, 2010.

National Park Service-Air Resources Division (NPS-ARD). 2002. Air quality in the national parks. Second edition. National Park Service-Air Resources Division, Lakewood, Colorado.

——. 2004. Ozone monitoring protocol for the National Park Service. NPS D-1654. National Park Service-Air Resources Division, Denver, Colorado.

——. 2005. Wet deposition monitoring protocol: Monitoring atmospheric pollutants in wet deposition. NPS D-1655. National Park Service-Air Resources Division, Denver, Colorado.

——. 2006. Dry deposition monitoring protocol: Monitoring atmospheric pollutants in dry deposition. NPS D-1770. National Park Service-Air Resources Division, Denver, Colorado.

National Park Service. 2006. Management policies 2006: A guide to managing the National Park System. National Park Service, Washington, D.C. http://www.nps.gov/policy/mp/policies.html. Last accessed February 18, 2010.

——. 1993. Science and the national parks II: Adapting to change. Washington, D.C.: U.S. Government Printing Office.

——. 2008. (Draft) Air quality monitoring protocol and standard operating procedures for the Northern Colorado Plateau Network. Unpublished technical report. National Park Service, Northern Colorado Plateau Network, Moab, Utah.

National Parks and Conservation Association (NPCA). 1979. NPCA adjacent lands survey: No park is an island. National Parks and Conservation Magazine 53:4–9.

National Research Council. 2002. Predicting invasions of nonindigenous plants and plant pests. National Academy of Sciences, Washington, D.C.

North American Network for Remote Sensing Park Ecological Condition (NARSEC). 2007. Satellite remote sensing for monitoring and reporting the condition of national parks. Report for workshop proceedings, March 6–8, 2007, Santa Fe, New Mexico. North American Network for Remote Sensing Park Ecological Condition. http://science.nature.nps.gov/im/monitor/meetings/NARSEC_2007/docs/NARSEC_2007_Rpt_0606.pdf. Last accessed February 18, 2010.

Okin, G. S., D. A. Gillette, and J. E. Herrick. 2006. Multi-scale controls on and consequences of Aeolian processes in landscape change in arid and semi-arid environments. Journal of Arid Environments 65:253–275.

Otis, D. L., K. P. Burnham, G. C. White, and D. R. Anderson. 1978. Statistical inference from capture data on closed animal populations. Wildlife Monographs 62.

Peitz, D. G., S. G. Fancy, L. P. Thomas, G. A. Rowell, and M. D. DeBacker. 2004. Bird monitoring protocol for Agate Fossil Beds National Monument, Nebraska, and Tallgrass Prairie National Preserve, Kansas (version 1.01). Unpublished technical report, National Park Service, Prairie Cluster Prototype Monitoring Program.

Pellant, M., P. Shaver, D. A. Pyke, and J. E. Herrick. 2005. Interpreting indicators of rangeland health (version 4). Technical Reference 1734-6, BLM/WO/ST-00/001+1734/REV05. Bureau of Land Management, National Science and Technology Center, Denver, Colorado.

Peters, D. 2001. Plant species dominance at a grassland-shrubland ecotone: an individual-based gap dynamics model of herbaceous and woody species. Ecological Modeling 152:5–32.

Peters, D. P. C., B. T. Bestelmeyer, J. E. Herrick, E. L. Frederickson, H. C. Monger, and K. M. Havstad. 2006. Disentangling complex landscapes: new insights into arid and semiarid system dynamics. BioScience 56:491–501.

Porter, S. D., R. A. Barker, R. M. Slade, Jr., and G. Longley. 2009. Historical perspective of surface water and groundwater resources in the Chihuahuan Desert Network, National Park Service. Edwards Aquifer Research & Data Center Report R1-09. Texas State University, San Marcos, Texas.

Powell, B. F., A. D. Flesch, D. Angell, K. Beaupre, and W. L. Halvorson. 2007. Landbird monitoring protocol for the Sonoran Desert Network. Version 1.02. Unpublished technical report. National Park Service, Sonoran Desert Network, Tucson, Arizona.

Quattrochi, D. A., and L. C. Luvall. 1999. Thermal infrared remote sensing for analysis of landscape ecological processes: methods and applications. Landscape Ecology 14:577–598.

Rehfeldt, G. E., N. L. Crookston, M. V. Warwell, and J. S. Evans. 2006. Empirical analyses of plant-climate relationships for the western United States. International Journal of Plant Science 167:1123–1150.

Reichard, S. H., and C. W. Hamilton. 1997. Predicting invasions of woody plants introduced into North America. Conservation Biology 11:193–203.

Rejmánek, M., and M. J. Pitcairn. 2002. When is eradication of exotic pest plant a realistic goal? Pages 249–253 *in* C. R. Veitch and M. N. Clout, eds., Turning the tide: The eradication of invasive species. Gland, Switzerland and Cambridge, U.K.: International Union for Conservation of Nature.

Rejmanek, M., D. M. Richardson, S. I. Higgins, M. J. Pitcairn, and E. Grotkopp. 2005. Ecology of invasive plants: State of the art. Pages 104–161 *in* H. A. Mooney, R. N. Mack, J. A. McNeely, L. E. Neville, P. J. Schei, and J. K. Waage, eds., Invasive alien species: A new synthesis. Washington, D.C.: Island Press.

Rexstad, E. 1996. Small mammal sampling protocol for long-term ecological monitoring program, Denali National Park and Preserve. Unpublished technical report, Institute of Arctic Biology, University of Alaska, Fairbanks.

Rich, T. C., C. J. Beardmore, H. Berlanga., P. Blancher., M. S. W. Bradstreet, G. S. Buthcher, D. W. Demarest., E. H. Dunn, C. W. Hunter, E. E. Inigo-Elias, and others. 2004. Partners in Flight North American landbird conservation plan. Cornell Lab of Ornithology, Ithaca, New York.

Roberts, E. A., R. L. Sheley, and R. L. Lawrence. 2004. Using sampling and inverse distance weighted modeling for mapping invasive plants. Western North American Naturalist 64:312–323.

Rosgen, D. 1996. Applied river morphology. Wild Land Hydrology, Pagosa Springs, Colorado.

Saunders, S. C., J. Q. Chen, T. R. Crow, and K. D. Brosofske. 1998. Hierarchical relationships between landscape structure and temperature in a managed forest landscape. Landscape Ecology 13:381–395.

Schlesinger, W. H., S. L. Tartowski, and S. M. Schmidt. 2006. Nutrient cycling within an arid ecosystem. Pages 133–149 *in* K. M. Havstad, L. F. Heunneke, and W. H. Schlesinger, eds., Structure and function of a Chihuahuan Desert ecosystem. New York: Oxford University Press.

Schmidt, J. C., Everitt, B. L. and Richard, G. A. 2003. Hydrology and geomorphology of the Rio Grande and implications for river restoration. Pages 25–45 *in* G. P. Garrett and N. L. Allan, eds., Aquatic fauna of the northern Chihuahuan Desert. Museum of Texas Tech University, Special Publication Number 46.

Schwartz, M. D., and B. E. Reiter. 2000. Changes in North American spring. International Journal of Climatology 20:929–932.

Sinclair, A. R. E. 1998. Natural regulation of ecosystems in protected areas as ecological baselines. Wildlife Society Bulletin 26:399–409.

Skagen, S. K., J. F. Kelly, C. Van Riper, R. L. Hutto, D. M. Finch, D. J. Krueper, and C. P. Melcher. 2005. Geography of spring landbird migration through riparian habitats in southwestern North America. Condor 107:212–227.

Smith, D. L., and L. Johnson. 2004. Vegetation-mediated changes in microclimate reduce soil respiration as woodlands expand into grasslands. Ecology 85:3348–3361.

Snyder, K. A., K. A. Mitchell, and J. E. Herrick. 2006. Patterns and controls of soil water in the Jornada Basin. Pages 107–132 *in* K. M. Havstad, L. F. Heunneke, and W. H. Schlesinger, eds., Structure and function of a Chihuahuan Desert ecosystem. New York: Oxford University Press.

Sousanes, P. J. 2004. Climate monitoring protocol for the Central Alaska Network Denali National Park and Preserve, Yukon-Charley Rivers National Preserve, and Wrangell-St. Elias National Park and Preserve. National Park Service, Inventory and Monitoring Program, Denali National Park, Alaska.

Studer, S., R. Stockli, C. Appenzeller, and P. L. Vidale. 2007. A comparative study of satellite and ground-based phenology. International Journal of Biometeorology 51:405–414.

Sullivan, S. M. P., M. C. Watzin, and W. S. Keeton. 2007. A riverscape perspective on habitat associations among riverine bird assemblages in the Lake Champlain Basin, USA. Landscape Ecology 22:1169–1186.

Swetnam, T. W., and J. L. Betancourt. 1998. Mesoscale disturbance and ecological response to decadal climatic variability in the American Southwest. Journal of Climate 11:3128–3147.

Tatem, A. J., S. J. Goetz, and S. I. Hay. 2008. Fifty years of Earth-observation satellites. American Scientist 98:390–398.

Texas Commission on Environmental Quality. 2003. Surface water quality monitoring procedures, volume 1: Physical and chemical monitoring methods for water, sediment, and tissue. TCEQ RG-415. Texas Commission on Environmental Quality, Austin, Texas.

Texas Commission on Environmental Quality. 2006. Surface water quality monitoring procedures, volume 2: methods for collecting and analyzing biological assemblage and habitat data. TCEQ RG-416. Texas Commission on Environmental Quality, Austin, Texas.

Texas Water Development Board. 2003. A field manual for groundwater sampling. TWDB Report UM-51.

Thomas, L., S. T. Buckland, K. P. Burnham, D. R. Anderson, J. L. Laake, D. L. Borchers, and S. Strindberg. 2002. Distance sampling. Pages 544–552 *in* A. H. El-Shaarawi and W. W. Piegorsch, eds., Encyclopedia of environmetrics. Chichester, U.K.: John Wiley and Sons.

Thompson, W. T. 2002. Toward reliable bird surveys: accounting for individuals present but not detected. Auk 119:18–25.

Thorp, J, H., M. C. Thoms, and M. D. Delong. 2006. The riverine ecosystem synthesis: Biocomplexity in river networks across space and time. River Research and Applications 22:123–147.

Townsend, P. A., R. H. Gardner, T. R. Lookingbill, and C. C. Kingdon. 2006. Remote sensing and landscape pattern protocols for long-term monitoring of parks in the National Capital Region. Draft protocols report. January 2006. University of Maryland Center for Environmental Science, Appalachian Laboratory, Frostburg, Maryland.

U.S. Environmental Protection Agency. 1986. RCRA groundwater monitoring technical enforcement guidance document. U.S. Environmental Protection Agency, Washington, D.C.

——. 1987. A compendium of superfund field operations methods. EPA/540-P-87/001. U.S. Environmental Protection Agency Office of Emergency and Remedial Response, Washington, D.C.

Valett, H. M., M. A. Baker, J. A. Morrice, C. S. Crawford, M. C. Molles, C. N. Dahm, D. L. Moyer, J. R. Thibault, and L. M. Ellis. 2005. Biogeochemical and metabolic responses to the flood pulse in a semiarid floodplain. Ecology 86:220–234.

Van Devender, T. R. 1995. Desert grassland history: Changing climates, evolution, biogeography, and community dynamics. Pages 69–99 *in* M. P. McClaran, and T. R. van Devender, eds., The desert grassland. Tucson: University of Arizona Press.

Van Metre, P. C., B. J. Mahler, and E. Calender. 1997. Water-quality trends in the Rio Grande/Rio Bravo basin using sediment cores from reservoirs. U.S. Geological Survey Fact Sheet FS-221-96.

Welch, B. A. 2007a. The plant invasion process: Implications for land managers [DRAFT]. Chapter 2 *in* Early detection of invasive plant species handbook. U.S. Geological Survey/National Park Service, Washington, D.C. http://www.pwrc.usgs.gov/brd/invasiveHandbook.cfm.

——. 2007b. Introduction [DRAFT]. Chapter 1 *in*:Early detection of invasive plant species handbook. USDI US Geological Survey/National Park Service, Washington, D.C. http://www.pwrc.usgs.gov/brd/invasiveHandbook.cfm.

——. 2007c. Strategic approach to early detection [DRAFT]. Chapter 3 *in*: Early detection of invasive plant species handbook. U.S. Geological Survey/National Park Service, Washington, D.C. http://www.pwrc.usgs.gov/brd/invasiveHandbook.cfm.

Westbrook, R. G. 2004. New approaches for early detection and rapid response to invasive plants in the United States. Weed Technology 18 Supplement:1468–1471.

Western, D. 1982. Amboseli National Park: Enlisting landowners to conserve migratory wildlife. Ambio 11:302–308.

White, G. C., and K. P. Burnham. 1999. Program MARK: Survival estimation from populations of marked animals. Bird Study 46 Supplement:120–138.

White, G. C., D. R. Anderson, K. P. Burnham, and D. L. Otis. 1982. Capture-recapture and removal methods for sampling closed populations. Los Alamos National Laboratory Report LA-8787-NERP, Los Alamos, New Mexico.

Whitford, W. G. 2002. Ecology of desert systems. San Diego, Ca.: Academic Press.

Whitford, W. G., and B. T. Bestelmeyer. 2006. Chihuahuan Desert fauna: Effects on ecosystem properties and processes. Pages 247–265 *in* K. M. Havstad, L. F. Heunneke, and W. H. Schlesinger, eds., Structure and function of a Chihuahuan Desert ecosystem. New York: Oxford University Press.

Whitford, W. G., S. Dick-Peddie, D. Walters, and J. A. Ludwig. 1978. Effects of shrub defoliation on grass cover and rodent species in a Chihuahuan Desert ecosystem. Journal of Arid Environments 1:237–242.

Wilde, F. D. 2005. Book 9, Chapter A1: Preparations for water sampling, version 2.0. U.S. Geological Survey techniques of water-resources investigations. http://pubs.usgs.gov/twri/.

Wondzell, S. M., G. L. Cunningham, and D. Bachelet. 1996. Relationships between landforms, geomorphic processes, and plant communities on a watershed in the northern Chihuahuan Desert. Landscape Ecology 11:351–362.

Woodman, R. L., S. C. Thomas, B. J. Moore, and R. R. Byrd. 2004. A protocol for monitoring Allegheny woodrats (*Neotoma magister*) at Mammoth Cave National Park, version 1.00. Unpublished technical report, Mammoth Cave National Park, Mammoth Cave, Kentucky.

Young, K. E., and T. S. Schrader. 2007. Predicting risk of invasive species occurrence: Remote-sensing strategies [DRAFT]. Chapter 6 *in* Early detection of invasive plant species handbook. U.S. Geological Survey/National Park Service, Washington, D.C. http://www.pwrc.usgs.gov/brd/invasiveHandbook.cfm.

Young, K. E., T. S. Schrader, K. G. Boykin, C. Caldwell, and G. W. Roemer. 2007. Early detection of invasive species in Big Bend National Park: Remote sensing and GIS strategies. U. S. Geological Survey, New Mexico Cooperative Fish and Wildlife Research Unit, Las Cruces, New Mexico.

Appendix K. Chihuahuan Desert Network Data Management Plan

Appendix K is packaged with the pdf of this document.

National Park Service
U.S. Department of Interior

Natural Resource Program Center

Inventory and Monitoring Program

Data Management Plan for the Chihuahuan Desert Network

Natural Resource Report NPS/CHDN/NRR—2009/xxx

Appendix L. Charter of the Chihuahuan Desert Network Inventory and Monitoring Program

The Chihuahuan Desert Network's charter conforms to the February 2008 policy memo regarding roles and responsibilities of Board of Directors. The memo may be viewed at: http://www1.nrintra.nps.gov/im/monitor/docs/Operations_of_I&M_Networks.pdf.

Appendix L is packaged with the pdf of this document.

CHARTER OF THE CHIHUAHUAN DESERT NETWORK

INVENTORY AND MONITORING PROGRAM

May 10, 2007

Introduction

This is the first update of the Chihuahuan Desert Network (CHDN) charter since the fall of 2003.

The purpose of this charter is to describe the basic practices that will be used to plan, organize, manage, evaluate, and adapt the efforts of the Chihuahuan Desert Inventory and Monitoring (I&M) Network as it carries out the National Park Service Natural Resource Challenge with respect to the inventory of natural resources and monitoring of vital signs for the network. The Chihuahuan Desert Network comprises seven national park units in West Texas and southern New Mexico including:

Amistad National Recreation Area	AMIS
Big Bend National Park	BIBE
Carlsbad Caverns National Park	CAVE
Fort Davis National Historic Site	FODA
Guadalupe Mountains National Park	GUMO
Rio Grande Wild & Scenic River	RIGR
White Sands National Monument	WHSA

All parks in the network have active relationships with local entities including other state and federal government agencies, educational institutions, municipalities, the general public, and Mexican protected areas and communities. A successful network program will be fully integrated into park and cluster programs. Key to this success will be the development of communication systems that enhance the network's ability to collaborate within park programs and throughout the Southwest Cluster. The Chihuahuan Desert Network must be seen and must operate as an effective collaborative partner between the network parks, within the Southwest Cluster and with the Intermountain Region and Washington offices directing the Natural Resource Challenge.

Board of Directors

The Board of Directors will provide oversight of the network activities. The permanent, voting members on this Board are the six park superintendents of the network parks, and the Regional I&M Coordinator. Additional Ex-officio members include the Chihuahuan Desert Network (CHDN) Coordinator, the Desert Southwest Cooperative Ecosystem Studies Unit (DSCESU) Coordinator and the Chair of the Technical Committee.

The permanent voting Board members represent the network in carrying out the Natural Resource Challenge in the Chihuahuan Desert Network. Ex-officio members are called upon for specialty expertise and as links to the regional/Washington program. The Board of Directors recognizes the need for involvement and input from the scientific community and will seek the contributions from subject matter specialists as needed, especially during the planning phase of the monitoring program.

Responsibilities of the Board of Directors

The Board is committed to operate in an atmosphere of fairness, trust, and respect throughout the network. It is the intent of this charter to implement the I&M program in support of all the parks in the network using scientifically credible standards.

The major responsibilities of the Board of Directors are to:

- Provide leadership to conduct a credible I&M program for the benefit of the network.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 960/101911, April 2010

National Park Service
U.S. Department of the Interior

Natural Resource Program Center

Natural Resource Program Center
1201 Oak Ridge Drive, Suite 150
Fort Collins, Colorado 80525

www.nature.nps.gov

EXPERIENCE YOUR AMERICA™