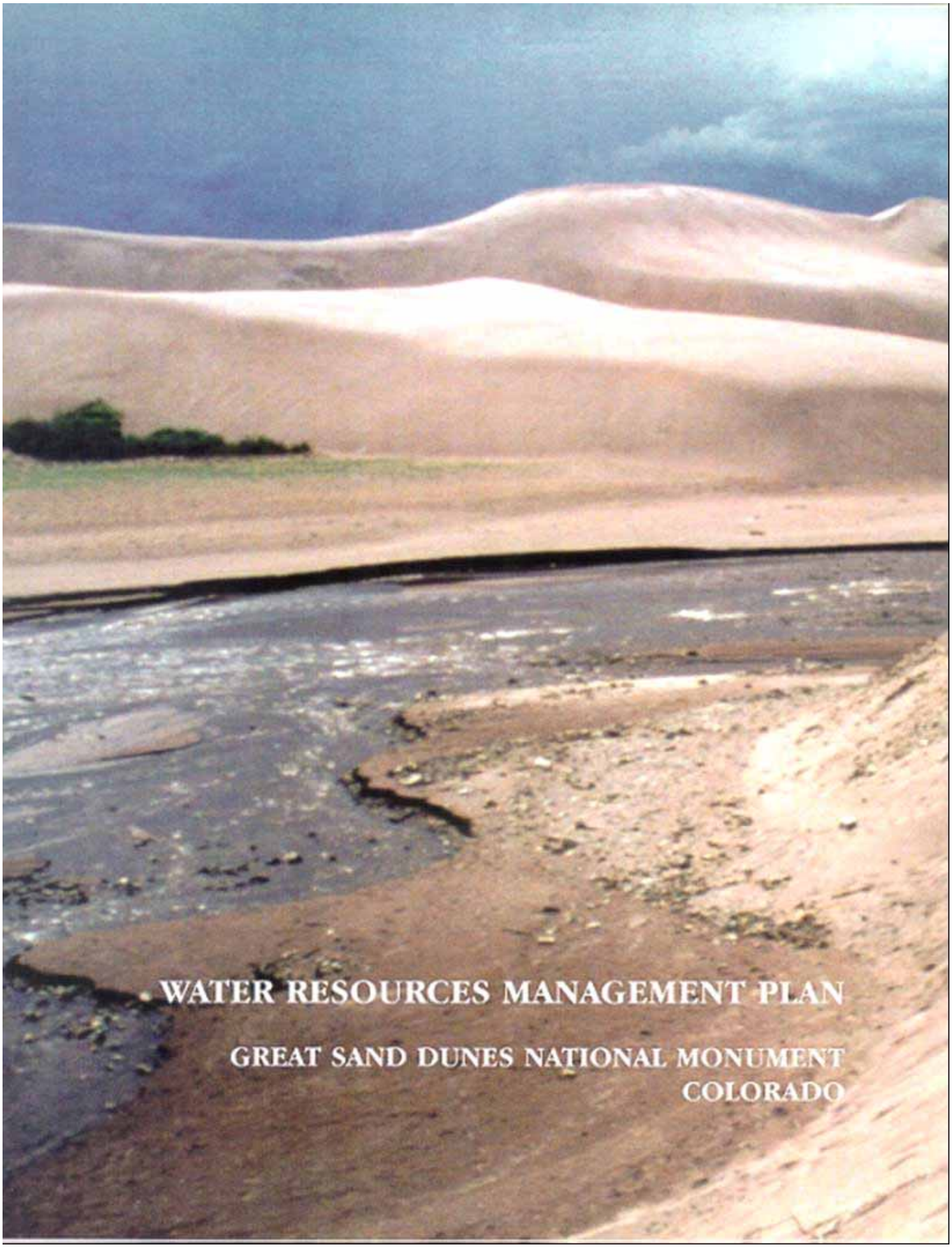

WATER RESOURCES MANAGEMENT PLAN

GREAT SAND DUNES NATIONAL MONUMENT
COLORADO

Water Resources Management Plan
Great Sand Dunes National Monument, Colorado

1997

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EXECUTIVE SUMMARY

Located in the south central Colorado, Great Sand Dunes National Monument contains the tallest dunes in North America, rising over 700 feet above the San Luis Valley floor. This dune system is very complex and provides excellent opportunities to witness eolian geology.

As incongruous as it might seem, these sand dunes are a water-dependent resource. Prevailing winds carry sand to the northeast, toward the mountains, while streams flowing from these mountains intercept the sand, carry it around the perimeter of the dunes, and deposit it on the upwind side. The transport of sand by water appears to occur at roughly the same rate as wind transport in the opposite direction, thus maintaining the dune field in equilibrium.

The lower reaches of Medano and Sand Creeks, the two major streams flowing around the dunes, are typically dry for some portion of the year. Surface flow - and the all important sand transport that it provides - can occur only when runoff is sufficient to fill shallow sandy aquifers faster than they can drain through the porous medium. Though there is considerable year-to-year variation, snowmelt each spring is typically sufficient to push the terminus of flow toward the valley floor and sustain it for a few months. While this is occurring, a very unusual flow pattern called "surge flow" is produced, a phenomena found only in steep wide sand-dominated channels. Medano Creek, and to a lesser extent Sand Creek, produce some of the worlds finest examples of surge flow and sand waves, of interest to the scientific community as well as visitors.

The system is complex to be certain. Whether it is resilient to changes in ground or surface water conditions remains to be determined. The disappearance over the last 60 years of most of the interdunal ponds and wetlands indicates a vulnerability to changes in hydrology. The greatest threat to water resources at this time are recurrent proposals to pump and export vast quantities of ground water from lands adjacent to the Monument. In an effort to acquire some legal protection from such activities, Federal reserved water rights have been adjudicated for the Monument, including instream flow rights for all the streams flowing into the Monument, and ground water needed for current and future visitor use.

This Water Resources Management Plan presents a description of the current state of knowledge of the water resources of the Monument, specific objectives and legal requirements for their management, a discussion of the issues facing the Monument, and a program to address those issues. It is expected that the approaches to the immediate concerns will continue to evolve, while the value of this plan as a reference will he more enduring. In recognizing the need for both a regional approach to water resources management, and the need for site specific studies and monitoring, several actions are proposed in this plan, including ten for which project statements have been developed to seek additional funding.

The Monument has instituted substantial ground and surface water monitoring programs as a result of the growing recognition of the importance of water to maintaining the dunes and other resources, and the need to document compliance with adjudicated water rights. This includes 23 monitoring wells, 13 sites for monitoring surface flow, and some monitoring of the terminus of flow in Sand and Medano Creeks. Though extensive among National Park System units, this monitoring network needs to be expanded in duration (to accommodate considerable annual variability), and location (to incorporate portions of the monument heretofore neglected). Three projects are proposed to address this issue including a continuation of the existing surface and ground water monitoring programs, expanding the well network to the sand sheet, main dune field and south boundary, and instituting regular monitoring of the terminus of flow of Sand and Medano creeks.

Two principal questions remain regarding the subsurface hydrology of the area. First, is determining the nature of permeable and impermeable layers underlying Medano Creek, which permits aquifers to fill to the

surface with each spring runoff and support surface flow, then empty when flows recede. The other is the connection between shallow groundwater, which is important in supporting most of the surface water features in the Monument, and deep groundwater, which is much sought after for sale and transport out of the basin. A project to investigate the hydrostratigraphy beneath Medano Creek proposes to shed some light on both of these questions.

Ponds are rare features within dune fields, and historic records show that the Monument's interdunal ponds are rapidly disappearing. Several possible reasons for this disappearance have been suggested, and a project
is proposed to investigate two of the most likely possibilities. Another project is proposed to review the body of literature that might shed some light on the biological function of these ponds as a prelude to more site specific investigations.

Concern over water quality centers around achieving a level of protection appropriate for a National Park System unit, and investigating fecal contamination where visitors are both the probable source and victims. An Outstanding Waters designation is sought by the National Park Service because it provides the highest level of regulatory protection available. A project is proposed to expand the meager water quality database so that it will be sufficient to demonstrate the superior water quality conditions required by the state for an Outstanding Waters Designation. Two projects are proposed to, (I) determine the effects of backcountry camping along streams and frontcountry water play on water quality, and (2) provide toilet facilities at two recreation sites where water quality evidence and field observations indicate a problem with human waste disposal.

Conveying the importance of hydrology to the formation and continued existence of the dunes is recognized in a project to enhance the interpretation of water resource issues in the monument. Actions are also proposed to pursue the possible purchase of lands containing Indian Springs and interdunal ponds currently located just outside the Monument's western boundary, along with continued work to restore native fishes to streams in the Monument.

The Monument currently devotes about 1.1 positions of park staff and management to water resources management. Based on the importance of water to preserving resources and recreation opportunities, and the hydrologic and political complexity of its management, the plan identifies the need to add a full-time Hydrologic or Physical Sciences Technician to the staff, raising the commitment to water management to a total of 2.0 full-time positions.

INTRODUCTION

Water plays a major role in maintaining the sand dune field in the Great Sand Dunes National Monument. Moisture stabilizes individual dunes by dampening dune surfaces and at times freezing. Surface flow stabilizes the overall dune field by capturing and transporting blown sand, which would otherwise escape into the Sangre de Cristo Mountains, back into the windward side of dune field. Water also is important in recharging shallow aquifer layers beneath the dunes and supporting related wetlands. Those roles operate in a delicate balance that is made all the more critical considering that the area is a desert, with only 10 inches to 11 inches of annual precipitation.

Great Sand Dunes National Monument, Colorado, was established on March 17, 1932 by Presidential Proclamation No. 1994 to preserve the nation's tallest inland sand dunes and "additional features of scenic, scientific and educational interest." The Monument occupies an area of 38,662.18 acres (60.4 mi^2) on the San Luis Valley floor in Saguache and Alamosa Counties (Figure 1). This acreage includes four inholdings totaling about 2,240 acres (Figure 2).

The Sangre de Cristo Mountains are immediately adjacent to the Monument and a small part of the foothills of that range are inside the eastern part of the Monument boundary. But it is the Great Sand Dunes, an active sand dune field occupying 39 mi^2 and containing an estimated 5 trillion yd^3 of sand, that are the predominant feature. The remainder of the Monument acreage is a sand sheet, which is of a deep but unknown total thickness.

There is one paved road in the Monument between the southeastern corner of the Monument and Piñon Flats Campground, to the north. From that point northward, a four-wheel-drive, single lane, dirt road extends for another 4 miles to the northeastern part of the Monument and then crosses over into the Rio Grande National Forest. Nearly all Monument land west of that road, with the exception of the inholdings, is now part of the National Wilderness Preservation System.

Surrounding the Monument are several types of public lands, including the Rio Grande National Forest along the northeast and east, which is mostly managed as the Sangre de Cristo Wilderness. To the south and west are mostly State of Colorado lands subject to leasing, lesser amounts of U.S. Bureau of Land Management holdings, and a small amount (less than 1.25 mi^2) of private land. To the northwest is a large tract of private land, comprised mostly of the 100,000-acre Luis Maria Cabeza de Baca No. 4 Grant (the Baca Grant) (Figures 1 and 2). The leased and private lands to the south, west, and northwest are used a ranches, including the Medano and Zapata Ranches of Rocky Mountain Bison, Inc. on which buffalo are grazed, and the Baca Ranch (on the Baca Grant), formerly used for cattle grazing.

Purpose of this Water Resources Management Plan

Water Resources Management Plans (WRMPs) are prepared in NPS units where the water resource issues are particularly important, complex, or controversial. A Water Resources Management Plan provides an enhancement of the Natural and Cultural Resources Management Plan, wherein the history of water management and study, and current water issues can be examined in much greater detail. They are not required for every National Park System unit because many lack the baseline information necessary for planning, or face water issues dominated by one or two key concerns which are easily identified, and can be addressed adequately in their Natural and Cultural Resource Management Plans.

This Water Resources Management Plan begins with a description of the water and water-related resources of the Monument, based on a fairly extensive body of literature, data and observations. This chapter entitled Description of Water Resources and Water Rights is intended to provide a basis for planning and to serve as a reference for the condition of water resources at this time. Water Resources Issues and Recommendations are presented in the third chapter. Where a proposed action requires additional funding or staff, a project statement is developed and presented in Appendix A.

Legislation and Purpose of Great Sand Dunes National Monument

The purposes for which Great Sand Dunes National Monument was established are set forth in Presidential Proclamation Number 1994, which established the Monument when it was signed by

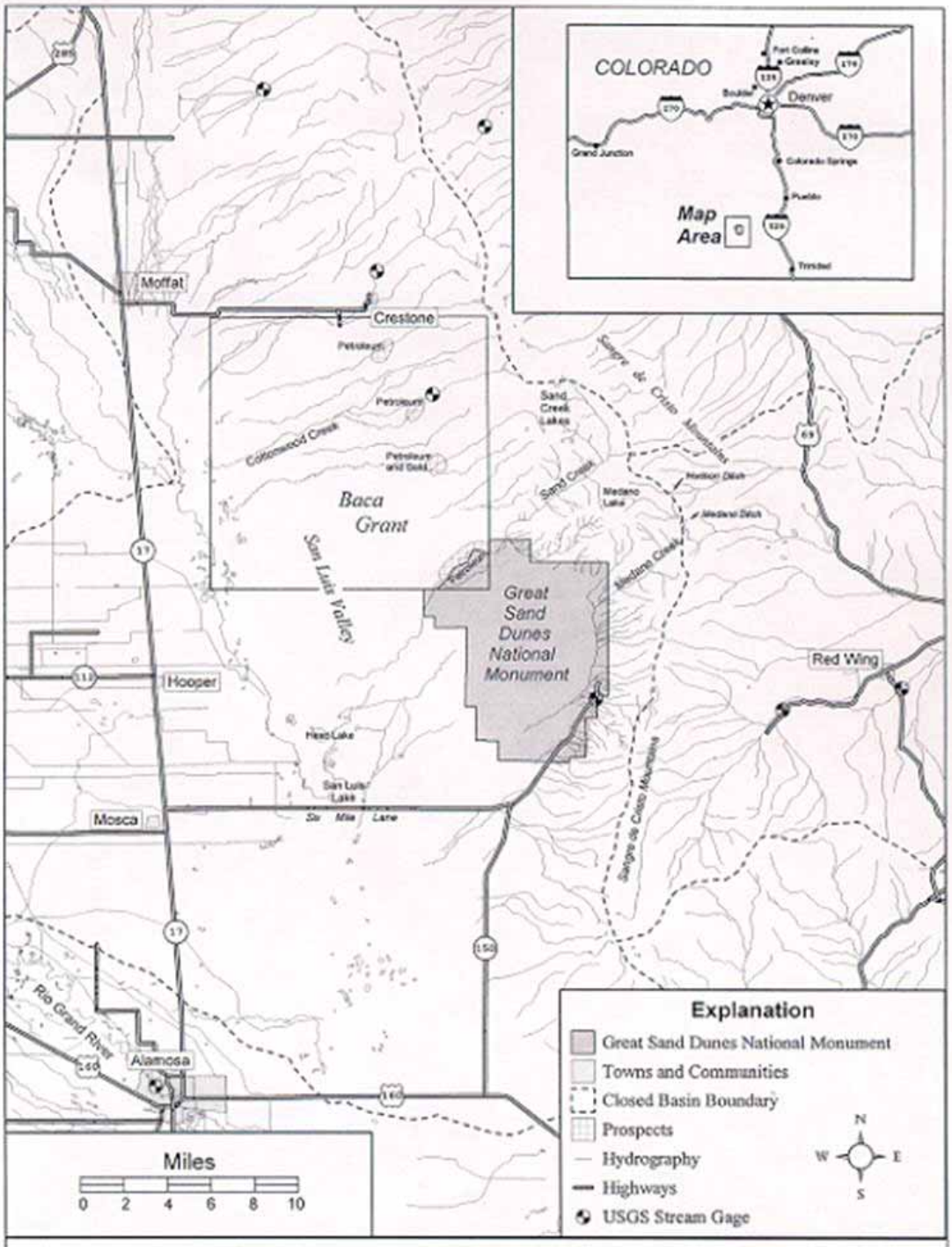

Figure 1. Location map of Great Sand Dunes National Monument with regional hydrography.

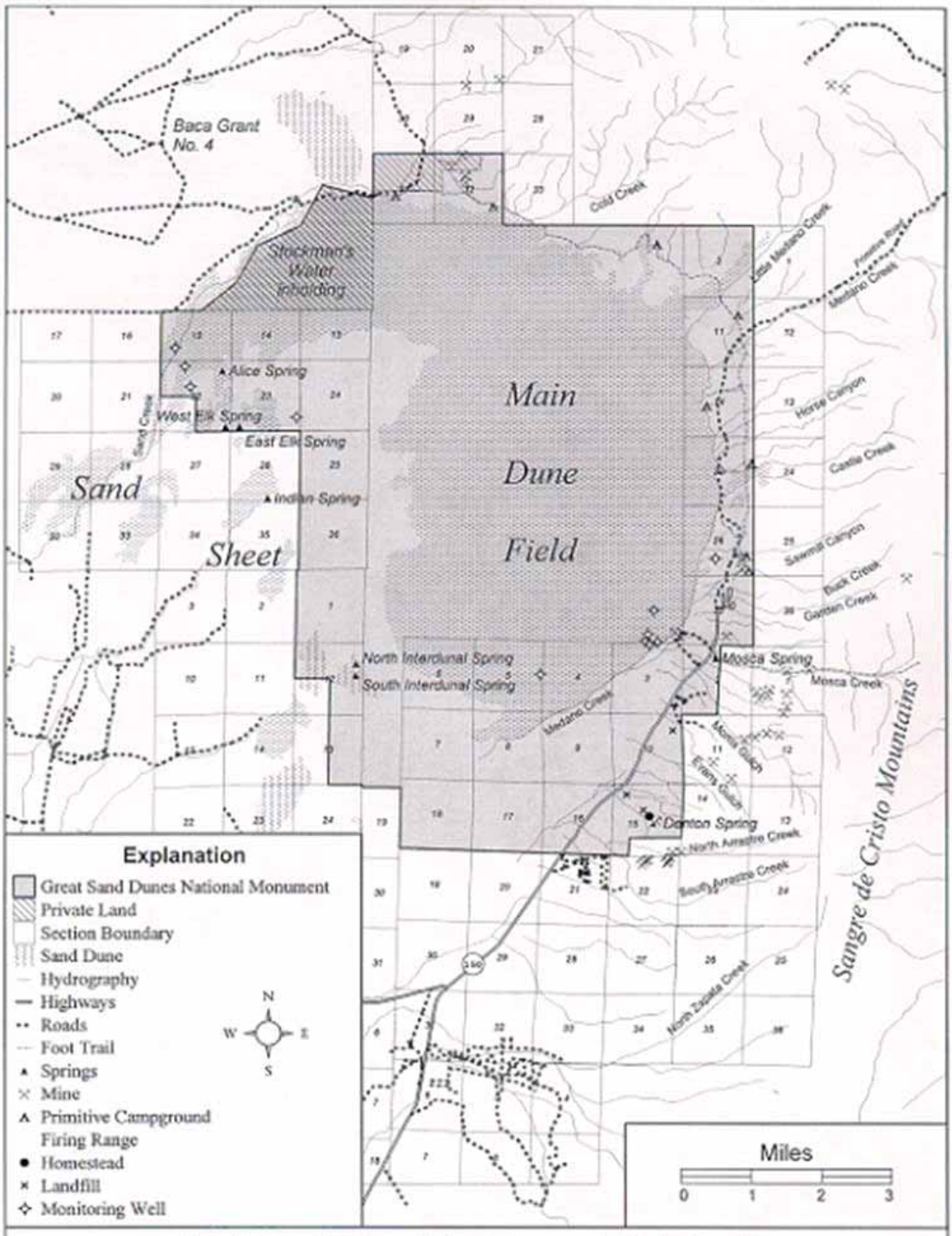

Figure 2. Great Sand Dunes National Monument, showing hydrography, land status, the dune field, and other features related to water resources.

President Herbert Hoover on March 17, 1932. It states that the Monument was established "... for the preservation of the great sand dunes and additional features of scenic, scientific, and educational interest." Two additional proclamations in 1946 and 1956, and Acts in 1978 and 1979 revised the boundaries of the Monument, but were silent regarding its purposes.

In 1976, roughly 86% of the Monument (33,450 acres) was designated as wilderness by Public Law 94-567, including almost all of the dune field and sand sheet within the boundary. The significance of this designation to water resource management is that the installation of wells with machinery and operation of monitoring devices can only be done when they are demonstrated to be necessary under the provisions of the Wilderness Act.

The following four purpose statements are based on the Monument's enabling legislation and legislative history. They were developed as part of the Statement For Management (National Park Service, 1993), a document that identifies the Monument's purpose, significance, general management objectives, obstacles to achieving those objectives and actions that need to be taken to overcome those obstacles.

·To preserve and protect the Great Sand Dunes, its associated ecosystems, cultural and historical resources, and scenic and wilderness values.

·To provide opportunities to experience, understand and enjoy the Great Sand Dunes and surrounding area.

·To facilitate research to support management of the park and to promote scientific knowledge.

·To promote understanding and stewardship of resources and park values by providing educational opportunities.

The other document guiding overall park management, the General Management Plan, is dated and currently under revision. The management objectives developed here can be incorporated into the revised General Management Plan where appropriate.

NPS Organic Act and Management Policies

While the direction provided in the Presidential Proclamation establishing the Monument is rather general, it also directs that the unit will be managed by the National Park Service as provided for under the NPS Organic Act as amended (39 Stat. 535-536). Guidance for implementing the National Park Service Organic Act and its amendments is provided by the NPS Management Policies (1988), which addresses the entire spectrum of park operations. Excerpts of the Management Policies important to the management of water include:

The National Park Service will seek to perpetuate surface and ground waters as integral components of park aquatic and terrestrial ecosystems.

The National Park Service will seek to restore, maintain or enhance the quality of all surface and ground waters within the parks consistent with the Clean Water Act and other applicable federal, state, and local laws and regulations.

The National Park Service will seek state support in helping to protect and enhance the quality of park waters through special use classifications, such as outstanding resource waters.

Recognizing that parks are integral parts of larger regional environments, the National Park Service will work cooperatively with others to anticipate, avoid, and resolve potential conflicts, to protect park resources...

There are many other Acts, Executive Orders, regulations and policies important to the management of water, such as the Clean Water Act, Colorado Water Law and Water Quality Regulations. These are presented along with the discussion of various water topics in the next two chapters.

Water Resource Management Objectives

The following set of management objectives are developed for this plan, and support three major themes; (1) understand of the natural resources and processes in and around the Monument, (2) preserving the protecting those resources, and (3) sharing this knowledge with the public. They are intended to provide guidance for addressing the range of specific water issues facing the park.

Water Resources Management

- Preserve natural water quantity, quality, flow patterns and hydrologic processes, recognizing that these elements are essential for the existence of many of the physical and biological features of the Monument.

- Respond effectively to proposals for regional water development and export from the basin which could adversely affect park resources.

- Use cooperative relationships with the Colorado Water Quality Control Commission, Colorado State Engineer, U. S. Bureau of Reclamation, U. S. Geological Survey, U. S. Bureau of Land Management, San Luis Valley Water Conservancy, private land owners and others involved in water management to achieve the water resource management objectives presented here.

Monument Operations

- Ensure that the facilities and operations of the Monument do not adversely affect its water resources and water-dependent environments.

- Convey an understanding and appreciation of the relationships between water and other natural features in the San Luis Valley to the visiting public through the effective use of interpretation.

- Promote public awareness of the interrelationship of human occupation, water use and water resources in the San Luis Valley.

Water Quantity and Quality

- Maintain, or where needed, restore naturally high water quality.

- Seek the highest level of protection under state water quality standards appropriate for the Monument.

- To preserve the natural volume, timing and variability of stream flow, recognizing that these all can have an affect on many of the other resources of the Monument.
- Protect NPS water rights and water-related resources by protesting applications for water rights that may adversely affect the park, and by participating in general water-rights adjudications that involve park waters.

Native fish

- Support use of the Monument's isolated streams as refugia for populations of endangered native fish.

Monitoring

- Establish and maintain a long-term hydrologic monitoring program to document the condition, and provide an understanding of the surface and ground-water systems, and their interactions.

- Acquire appropriate information to adequately understand and manage water-related resources.

Geohydrology

- Enhance the understanding of the geohydrology and interactions between ground and surface-water systems.

Wetland Ecosystems

- Improve understanding of the hydrology, history and trends for the interdunal ponds, and document the physical, biological and chemical resources of the remaining ponds.

- Maintain natural flow regimes and geomorphic processes that support riparian vegetation communities.

Visitor Health and Recreation

- Provide for safe water-based recreation by ensuring that appropriate water quality standards are met.

DESCRIPTION OF WATER RESOURCES AND WATER RIGHTS

General Description

The Great Sand Dunes National Monument is in south-central Colorado along the eastern edge of the broad, flat San Luis Valley (Figure 1), which is 80 miles long (north to south) by as much as 50 miles wide (east to west) and has an elevation of between 7,500 feet and 8,000 feet above sea level on the Valley floor. The San Luis Valley, ringed by the Sangre de Cristo Mountains to the east and San Juan Mountains to the west, is drained by the Rio Grande. Conversely, Monument drainage flows to a Closed Basin (Figure 1) north of the Rio Grande, where water collects in a sump characterized by numerous small lakes.

The predominant feature in the Monument is the 39-mi^2 sand dune field with average elevations of between 7,800 feet and 8,000 feet and maximum relief above the valley floor of 750 feet. Dune field sands have been classed as part of the unconsolidated lake, river, and wind (eolian) deposited sediments known as the Alamosa Formation, which was first deposited 5 million years ago and is still being deposited.

The dune field is part of a much larger sand depositional area that extends as much as 20 miles westward from the Sangre de Cristo Mountain front. To better understand this San Luis Valley sand depositional area, it has been subdivided by other workers into three "provinces" (Andrews, 1981). The Active Dune Field Province, which includes the Monument's dune field, is the smallest of three eolian sand deposits found in the San Luis Valley, as it occupies only about one tenth of the total area covered by sand deposits. The Sand Sheet Province, a small part of which is encompassed by the Monument boundary, is composed of low-relief, vegetation-stabilized dunes, excepting small areas where blowout dunes have formed. Westernmost is the Dry Lake Province, in the Closed Basin's sump area where sand is stabilized by chemical compounds formed through long-term evaporation of the locally high water table, exposed there at the topographic surface. Few dunes form there (Andrews, 1981).

Visitor usage of the Monument is mostly confined to the southeast part of the dune field where access is provided via the main park road and the unimproved four-wheel-drive road that continues northwestward into Wet Mountain Valley.

Geologic Setting

Geologic History

Great Sand Dunes National Monument is part of a geologic system that includes the San Luis Valley and the surrounding mountains. The structures created during the formation of these features now determine the characteristics of the dune field and the regional hydrology. Most of the data used to identify the structures come from gas exploration well logs and geophysical surveys.

Prior to the formation of the San Luis Valley was the Laramide Orogeny (60 to 70 million years ago), which uplifted Paleozoic (245 to 570 Ma) sedimentary rocks. In some areas, erosion completely removed the sedimentary rocks, exposing the underlying Precambrian (older than 570 Ma) metamorphic rocks, while in other areas over 6,000 feet of sedimentary rocks remained. The most extensive sedimentary formations were the Pennsylvanian-age Minturn Formation (285 to 320 Ma) and the Pennsylvanian/Permian Sangre de Cristo Formation (250 to 300 Ma). Both are mostly shale, sandstone, and conglomerate. The erosional period was followed by deposition of the Vallejo/Blanco Basin Formation during the early Tertiary Period (35 to 66 Ma). It contains massive beds of mudstone interbedded with sand and gravel and is up to 2,000 feet thick (Greis and Brister, 1989).

The features of the modern San Luis Valley began to form when crustal extension initiated the Rio Grande rift, a system of down-dropped crustal blocks (grabens) that extends from Leadville, CO, to El Paso, TX. The San Juan Mountains were the first to develop. Initial rifting resulted in a volcanic field that was active from 17 to 35 million years ago (Lipman, 1975). It consists of lava and ash flows interbedded with volcaniclastic rocks. The majority are part of the Conejos Formation. Above the Conejos Formation are various ash-flow tuffs

and basalt flows. These flows extended all the way across what is now the valley floor, thinning with distance eastward.

As rifting continued, crustal blocks began to shift. The blocks that rose (horsts) now comprise the Sangre de Cristo Mountains while the blocks that dropped are now the San Luis Valley. This process began 18 million years ago and continues today (Chapin, 1971). The non-uniform decline of the valley graben was more extreme on the east side, least in the center, and intermediate on the west side, defining three distinct areas known as the Baca Graben, Alamosa Horst, and Monte Vista Graben, respectively. Cross sections constructed by the Colorado Water Resources and Power Development Authority show 16,000 feet of vertical displacement between the upper Precambrian contacts of the Sangre de Cristo Mountains and the Baca Graben.

The subsidence associated with the graben created a depositional basin within the San Luis Valley that is filled with unconsolidated sediments of the Santa Fe Group (Figure 3). The formations within the group are the Los Pinos, Santa Fe, and Alamosa. The Los Pinos Formation was deposited on the west side of the Valley from 4.4 to 26.8 million years ago (Lipman, 1975) and is composed of volcaniclastic sediments from the San Juan volcanic field. The Santa Fe Formation was deposited on the east side of the Valley from 1.8 to 12 million years ago (Lockman-Balk and Bruning, 1971). It is finer grained than the Los Pinos and is intertongued with it near the center of the Valley. Hanna and Harmon (1989) suggest that the upper Arkansas River Valley is the source of Santa Fe Formation sediments while B. S. Brister (personal commun., 1988) believes there were structural barriers that would have prevented sediment transport from the Arkansas to the San Luis Valley. The Alamosa Formation represents a change in deposition beginning about 5 million years ago when playa lakes developed in the northern half of the Valley (Hanna and Harmon, 1989). The change may have been caused by the Taos Plateau basalt flows which accumulated in the southern half of the Valley, 2.0 to 4.5 million years ago (Lipman and Mehnert, 1979) and blocked drainage from the north. The clay and silt lake sediments are interbedded with sand and gravel and can be up to 1,600 feet thick in the Baca Graben (Greis and Brister, 1989) but are generally less than 1,000 feet thick.

Dune Field Development

The active dune field is definitely a young geologic feature, but an absolute age has yet to be determined. U.S. Geological Survey geologists estimate that the dunes are between a couple of thousand years and 12,000 years old, and will use the optical thermoluminesence method on their dune field and sand sheet samples in an attempt to determine a more precise age. The eolian system could be much older than 12,000 years. Drill cores reveal at least 130 feet of eolian sand beneath the Valley floor.

The composition of the sand indicates that the majority of it originated in the San Juan Mountains. It was then transported to Valley floodplains by the Rio Grande and tributaries and carried by prevailing southwesterly winds to the Sangre de Cristo Mountain front. Details of sand movement into the present dune field are not completely understood, but recent studies indicate that sand sheet vegetation is a barrier to sand movement from sand sheet to dune field. The possibilities are that sand enters the dune field: 1) when the sand sheet isn't so heavily vegetated; 2) as clusters of dunes migrating across the sand sheet; 3) very gradually even when the sand sheet is vegetated; 4) a one-time "catastrophic" eolian event following formation of extensive glacial outwash; or 5) a combination of any of these possibilities.

Activity of the dunes is subject to numerous controlling factors, including aridity, sand supply, wind and its variability, topography of the Sangre de Cristo Mountains, and surface flow in streams on the dune field perimeter.

The shape of the Sangre de Cristo Mountains acts as a sand trap and creates a unique setting for the eolian deposits. Prevailing winds traveling across the San Luis Valley are directed to the deposition site because they exit the valley through Medano, Mosca, and Music Passes, and a change in the trend of the mountain front funnels wind into the three passes. The active dune field is the sand deposit located farthest downwind and is situated in a mountain front indentation adjacent to the passes.

Prevailing southwesterly winds are most common in the spring, but during the rest of the year, the wind can blow in any direction. The second most common wind direction comes from the northeast

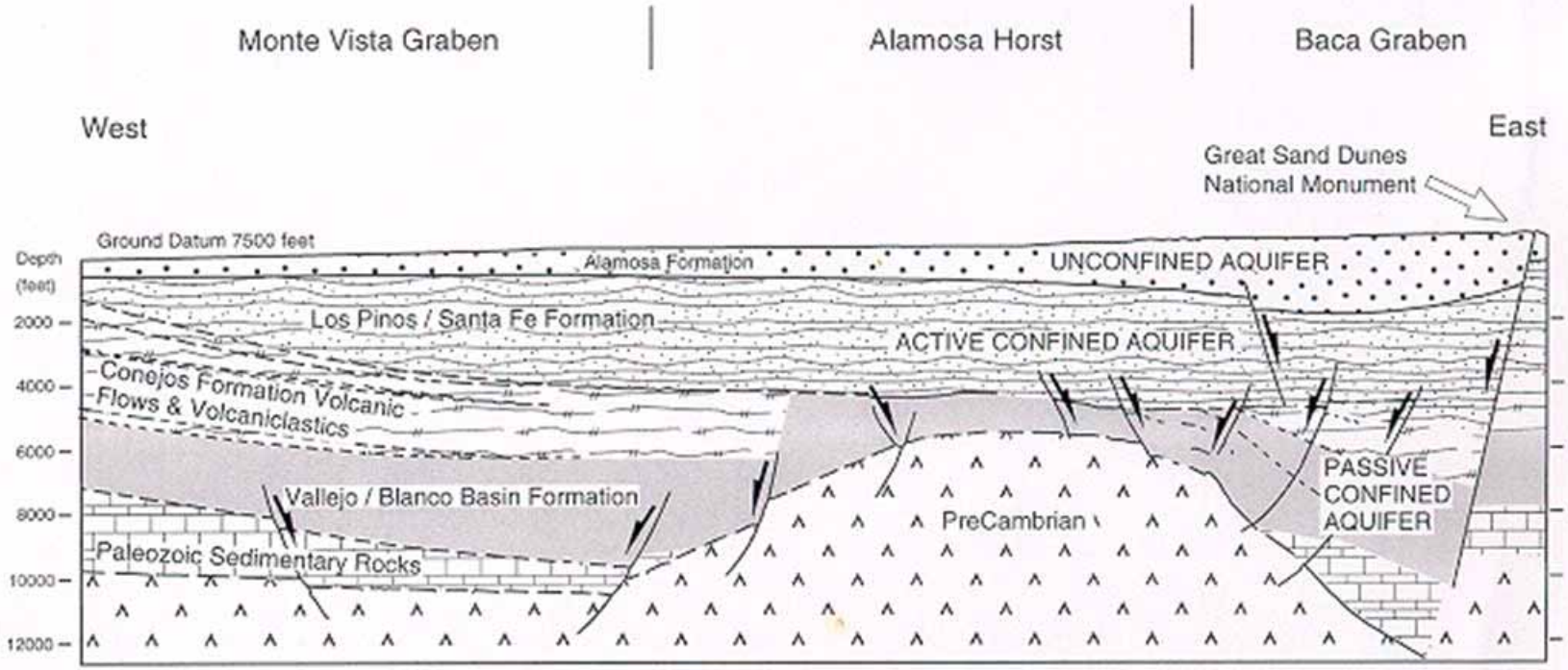

Figure 3. Geologic Cross Section of the San Luis Valley, Colorado, Showing Generalized Geology and Aquifiers.
(Modified from Hanna and Harmon, 1989)

whenever low air pressure systems are east of the Sangre de Cristo Mountains. These winds frequently diminish within a 10 mile zone west of the mountain front. Other wind directions are usually fluctuations in the two major directions caused by turbulent flow around the mountains.

Wind patterns change within the dune field and that results in differences in dune types. The majority of the dune field is exposed to winds from multiple directions. Dune types that develop here are reversing and star dunes. Both tend to grow vertically as opposed to migrating horizontally. The east-central edge of the dune field is sheltered from the northeastern wind by the adjacent mountains, forming migrating barchan and transverse dunes (Valdez, 1992).

Two Creeks flow along the perimeter of the dune field and influence the shape of it (Figure 2). Sand Creek flows along the northwest edge and Medano flows along the east and southeast edges. Their role is to erode sand from downwind parts of dune field and transport and deposit it further upwind. This may be responsible for the crescent shape of the dune field. Each stream builds a lobe of the crescent with the Medano lobe being much bigger since its contact with the downwind part of the dune field is greater.

The dune field is relatively complex because of interactions among the controlling factors and variance in those interactions in different parts of the dune field. In response to those interactions, three distinct regions have developed, the Sand Creek star dunes, Medano Creek ridge, and the central dune field (Valdez, 1992). The Sand Creek star dunes are in the northwest part of the dune field, at the base of Mount Herard. Winds that blow over this area are deflected northward or eastward toward either Music Pass or Medano Pass. Wind patterns become very complex and consequently dune ridges developed in many directions. The Medano Creek ridge is found on the southeast part of the dune field and is parallel to Medano Creek. The thickest sand deposits are found here (up to 750 feet) partially because Medano Creek supplies large amounts of sand to this area. It is unique because two sets of dune ridges are superimposed on each other. There are north-south trending dunes with northeast trending dunes in the interdunal troughs. Characteristics of the central dune field are large north-south trending dunes with well-developed troughs. It is the simplest area because winds are bimodal, for the most part, and it lacks an external source of sand.

Climate

The San Juan Mountains, on the western side of the San Luis Valley, play a significant role in the climate of the Monument, as the 14,000-foot San Juan range captures much of the airborne moisture traveling toward the Valley. As a result, the San Juan Mountains annually receive more than 50 inches of precipitation at the higher elevations (Ellis et al., 1993), while the San Luis Valley, is a desert, receiving on average about seven inches of precipitation at Alamosa, Colorado. The precipitation disparity is still apparent in the Sangre de Cristo Mountains which are nearly as tall as the San Jaun Mountains, yet precipitation averages less than 30 inches per year (Hearne and Dewey, 1988).

Daily meteorological measurements (precipitation, snowfall, temperature) have been recorded at Great Sand Dunes National Monument since 1946. Available data from 1951 through 1994 have been compiled to display monthly averages in Table 1a, annual averages in Table 1b, and annual totals in Table 2.

The Monument receives an average of 10.5 inches of precipitation each year as measured at park headquarters along Medano Creek. This is greater than the central and southern portions of the San Luis Valley due to the proximity of the Monument to the Sangre de Cristo Mountains. Precipitation increases sharply with elevation toward the crest of the mountains. Approximately one third of the precipitation falls as snow.

Two distinct seasons affect precipitation patterns in and around the Monument. The greatest amount of precipitation falls as rain during the monsoons of July, August and September, when moist subtropical air is carried north to produce scattered thunderstorms on most days. These storms generally originate with great regularity over the mountains, then drift or propagate out over the valleys where rainfall is less certain. They are capable of producing heavy rains and local flooding. Winter storms are quite different. They are produced by large frontal systems, which bring with them high winds, sharp temperature changes, and periods of heavy snow lasting from a few hours

Table 1a. Summary of Monthly Precipitation, Snowfall and Temperature for Great Sand Dunes National Monument, 1951-1994.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation												
Mean Monthly Precipitation (inches)	0.4	0.3	0.7	0.7	1.1	0.9	1.7	2.1	1.1	0.8	0.5	0.4
Mean Monthly Snowfall (inches)	6.4	4.8	7.1	4.1	1.0	0	0	0	0.1	2.9	4.2	5.4
Temperature (°F)												
Mean Minimum	8.8	13.1	20.4	27.7	36.5	45.0	50.2	48.3	41.3	31.3	19.6	10.9
Lowest	-25	-22	-7	-6	15	25	31	33	22	2	-12	-19
Mean Maximum	34.6	38.9	46.5	56.5	65.9	76.6	80.7	77.7	71.6	60.4	45.4	35.4
Highest	67	63	72	78	85	96	94	89	87	80	67	60

Table 1b. Summary of Annual Precipitation, Snowfall and Temperature for Great Sand Dunes National Monument, 1951-1994.

	Precip. (Inches)	Snowfall (Inches)	Mean High Temp. (°F)	Maximum Temp. (°F)	Mean Low Temp. (°F)	Minimum Temp. (°F)
Maximum (Year)	16.96 (1957)	64.3 (1992)	60.4 (1954)	96 (1982)	31.2 (1981)	-3 (1980)
Mean	10.51	36.6	57.3	88.5	29.3	-13.2
Minimum (Year)	5.85 (1951)	8.0 (1955)	50.7 (1979)	84 (1959)	23.9 (1974)	-25 (1963)
Standard Deviation	2.99	15.6	1.9	2.4	1.5	5.1

Table 2. Yearly Precipitation, Snowfall and Temperature at Great Sand Dunes National Monument, 1951 - 1994.

Year	Precip. (Inches)	5-Year Mean Precip. [1] (Inches)	Snowfall (Inches)	Mean High Temp. (°F)	Maximum Temp. (°F)	Mean Low Temp. (°F)	Minimum Temp. (°F)
1951	5.85	-	23.2	57.9	90	30.4	-18
1952	11.89	-	28	56.3	88	28.9	-10
1953	10.89	8.96	27.3	57.4	89	29.4	-9
1954	8.06	8.98	16	60.4	91	31.0	-10
1955	8.13	10.00	8	58.2	87	29.0	-14
1956	5.94	9.36	46	58.1	85	29.0	-6
1957	16.96	10.32	48.6	56.1	90	30.5	-12
1958	7.75	10.53	50.4	58.9	88	30.9	-8
1959	12.82	11.25	59.8	57.5	84	30.5	-7
1960	9.17	9.17	39.2	57.5	88	29.6	-15
1961	9.54	9.08	52.3	56.9	87	29.0	-19
1962	6.55	8.85	16	59.4	89	29.3	-17
1963	7.33	10.04	30.7	59.9	88	30.4	-25
1964	11.64	9.54	46	55.9	90	27.9	-14
1965	15.12	11.22	42.4	56.6	86	29.0	-14
1966	7.08	12.44	17.9	58.5	88	28.6	-12
1967	14.94	13.37	46.2	57.9	86	28.6	-11
1968	13.44	12.67	28	56.1	86	27.2	-12
1969	16.29	13.31	62.6	57.0	86	29.1	-8
1970	11.62	12.10	19	57.2	87	29.5	-9
1971	10.25	10.78	20.4	57.6	93	29.2	-24
1972	8.90	8.89	48.5	58.0	89	29.7	-15
1973	6.82	8.73	41	56.1	90	27.2	-8
1974	6.85	8.44	26	51.1	89	23.9	-15
1975	10.81	8.94	36	56.0	85	28.5	-20
1976	8.80	9.08	-[2]	58.3	89	28.3	-13
1977	11.41	9.34	-[2]	59.3	86	31.1	-12
1978	7.56	8.77	-[2]	57.6	92	30.9	-14
1979	8.13	9.36	37.3	50.7	88	25.6	-20
1980	7.96	9.39	25	59.6	90	31.0	-3
1981	11.76	10.13	42.5	59.7	90	31.2	-9
1982	11.56	10.46	20.4	56.6	96	29.6	-12
1983	11.28	11.40	46.9	55.9	85	29.5	-10
1984	9.76	11.43	30.5	55.5	86	28.2	-16
1985	12.64	10.66	31.8	57.2	89	29.9	-22
1986	11.94	10.30	37	58.2	88	30.7	-5
1987	7.68	10.13	43.8	54.7	89	26.5	-8
1988	9.52	10.40	43.5	60.1	88	30.8	-16
1989	8.89	10.05	43.5	59.9	92	30.2	-19
1990	14.00	11.41	59	58.3	93	30.6	-18
1991	10.19	12.51	56.2	56.4	88	28.9	-12
1992	14.47	13.82	64.3	54.9	89	28.2	-20
1993	15.01	-	59.7	55.6	87	29.3	-7
1994	15.43	-	43.4	58.1	91	30.6	-11

[1] The mean precipitation for each five year period. It is reported in the third year of the sequence, so values cannot be calculated for the first and last two years of the period.

[2] Incomplete record.

to a couple of days. Though month-by-month precipitation is less during the winter than summer, it is still sufficient to produce a substantial snowpack in the mountains during most winters.

Both rainfall and snow, are quite variable from year-to-year. Total precipitation has varied over the last 44 years from less than 6 inches to almost 17 inches. The 20 year period from 1951 through 1970 shows a greater degree of variability, with only 6 years falling within 2 inches more or less than the long-term mean. In contrast, the period from 1971 through 1990 shows relative stability with annual precipitation falling within 2 inches of the long-term mean in 12 years. Snowfall is even more variable, ranging from less than 10 inches to greater than 60 inches, though the variability is probably less higher on the watershed than at monument headquarters.

Topography and Vegetation

The Great Sand Dunes National Monument, in the easternmost San Luis Valley, adjoins the lower slopes of the Sangre de Cristo Mountains. The valley floor surrounding the dunes is generally flat with lots of small hills created by inactive dunes and blowouts. The topography slopes southward at an average of 53 feet/mile. The central and west sides of the valley are covered by floodplains which are extremely flat.

The Sangre de Cristo Mountains are typical fault block mountains, rising very abruptly from 8,000 feet up to over 14,000 feet. Within the Monument, alluvial fans at the mountain front are either only partially developed due to low local relief in the mountains, or are covered by dune field sands. The mountain front is heavily incised by stream valleys that have been glaciated above 10,000 feet.

The topography of the dune field is primarily sand dune ridges that slope from 20° to 34° on either side. Most ridges trend north-south except in the northwest and southeast parts of the dune field where dunes also trend in other directions. The ridges are closely spaced, and in some areas are developed on the slopes of adjacent dunes. Distances between ridges range from 200 feet to 1,000 feet, leaving interdunal troughs that are narrower than interdunal areas common in other dune fields.

Several vegetation surveys have been conducted, including an initial inventory by Dixon (1986). The initial phase of a multi-phase vegetation baseline mapping study was undertaken by McArthur and Sanderson (1992) in a grid of 118 circular plots, a job that resulted in the discovery of 59 plant species previously unrecognized in the Monument, and raised its total known plant species inventory to 347. Vegetation cover mapping, in which vegetation was classified with the aid of LANDSAT images, was done by Hoffer et al. (1992).

The three vegetation zones within the Monument are: 1) stabilized and active dunes; 2) wetlands; and 3) mountainside. The stabilized and active dune vegetation is found on the dune field and sand sheet, and contains shrubs, grasses, and forbs that grow well in unsaturated sand. Typical shrubs are rabbitbrush (*Chrysothamnus nauseosus*), horsebrush (*Tetradymia canescens*), and winterfat (*Ceratoides lanata*). Indian rice (*Oryzopsis hymenoides*), blowout grass (*Redfieldia flexuosa*), and sandhill muhly (*Muhlenbergia pungens*) are common grasses. Other vegetation includes scurf pea (*Psorlea lanceolata*), sunflowers (*Helianthus petiolaris*), and prickly pear cactus (*Opuntia polyacantha*). Vegetation cover varies from 0% over most of the dune field up to 75% on the sand sheet. Riparian zones are associated with wetlands created by ponds and streams. Several ponds are found near the west boundary where depressions intersect the water table. Dense willow (*Salix spp.)* patches, cattails (*Typha latifolia*), and rushes (*Scripus spp.*)commonly surround them. Stream bank riparian zones are marked by the growth of narrowleaf cottonwoods (*Populus angustifolia*). The mountainside zone begins with piñon-juniper-pine forests on the lower flanks that transcend into spruce-fir-aspen forests up the mountain slope. An alpine tundra environment begins at elevations above 11,500 feet (McArthur and Sanderson, 1992), which is entirely outside of the Monument boundary.

Surface Hydrology

Creeks

The active dune field blocks streams from flowing directly out of the Sangre de Cristo Mountains and into the San Luis Valley. As a result, only one main through-flowing drainage has developed on each side of the dune field. These are Sand Creek,

which flows from the Music Pass area and is joined by tributaries along the north dune field perimeter, and Medano Creek, originating above Medano Pass, and receiving several tributaries along the dune field's east perimeter. Both streams begin high in the Sangre de Cristo Mountains in glaciated valleys and have drainage basins above the Monument of roughly 15 and 10 mi^2 respectively. In the mountains and along the mountain front, these are typical mountain streams with steep gradients and rocky channels. Once their gradient lessens as they begin to flow towards the valley, braided channels form because of the large sand load they transport. Medano Creek's braided channel, mapped using the technology of global positioning satellites, is up to 5.5 miles long and 1,050 feet wide, covering a 0.76 mi^2 area, with an average gradient of 80 feet/mile. Sand Creek's braided section, as yet unmapped, appears to be slightly narrower and longer than Medano Creek, with a lower gradient.

On the braided sections of Sand and Medano Creeks, surge flow commonly develops. Surge flow, the flow of water in pulses or waves, is a rare occurrence in nature, requiring fast-flowing water with little turbulence, steep gradients, and smooth, sandy channels. Surge flow is initiated when large ripples called "anti-dunes" form, increasing the stream bed surface and increasing the volume of water over the anti-dunes by 20%. Breaking of the unstable anti-dune releases that extra volume of "stored" water in the form of a wave (Bean, 1977; Schumm et al., 1982). The wave period and size are dependent on water depth. In water less than ¼-inch deep, the pulses are tiny and their frequency may be several per second. The largest surges occur when spring runoff becomes channelized in a narrow channel about 20-feet wide; waves 8 to 12 inches high result with 40 to 60-second cycles. A more typical surge flow will be spread across the braided channel, surging on 15 to 20-second intervals to depths of only a few inches. Surging seems to be more prevalent on Medano Creek than on Sand Creek, possibly because of its steeper gradient.

All the water in Sand and Medano Creek, except what is lost to evapotranspiration, infiltrates into local aquifers. Sand Creek surface flow can reach the lakes of the sump area following high-volume spring runoff, but once there, all water will either evaporate or infiltrate. The alluvial fans and basin sediments along the Sangre de Cristo Mountains have been identified as recharge areas for aquifers below the Closed Basin (Hearne and Dewey, 1988). Infiltration characteristics of Medano Creek were studied by McCalpin (1992) to determine whether infiltration was significantly higher along inferred fault zones and if changes in water table elevations would affect surface flow. Conclusions are that infiltration rates depend on discharge, not faults, and that aquitard layers perch a near-surface aquifer below Medano Creek, possibly lessening the affect of changes in the regional aquifer on infiltration rates (McCalpin, 1992). Ground-electrical resistivity measurements were used to locate the aquifer below Sand Creek (Harmon and Hajicek, 1992). Findings are that Sand Creek usually recharges the surface aquifer within the confines of the Monument, but occasionally gains water from the aquifer. Further, a lowering of aquifer levels would result in a decrease in surface flow.

Gauges have been installed to measure the discharge of Sand and Medano Creeks at points where their surface flows enter the Monument since 1992. Hourly measurements are collected from a stilling well connected to a Parshall flume and transmitted to the Colorado Division of Water Resources, Denver, CO. Graphs for discharge from the 1995 water year, a relatively wet year, for Sand and Medano Creeks are depicted in Figures 4 and 5. Peak discharge occurs from April to July, and winter base flow conditions persist from October to March. Other peaks can be generated by summer rainstorms. Small diurnal fluctuations in discharge are observable during the spring and early summer, though their character changes somewhat and the major cause of the fluctuations shifts from snowmelt to changes in the rate of evapotranspiration in mid-to-late summer (McCalpin, 1992).

A graph of average monthly flow for Sand and Medano Creeks from April 1994 through November 1995 is depicted in Figure 6. Overlain on this is the quantified instream flow rights for these streams, which are discussed in more detail in the section on water rights (Page 57).

Sand Creek is the larger of the two creeks. The maximum flow in 1993 was greater than flume capacity, but estimated to be approximately 250 cubic feet per second (cfs). The 1994 maximum flow was 180 cfs. The measuring equipment is taken off line in the winter, so base flow

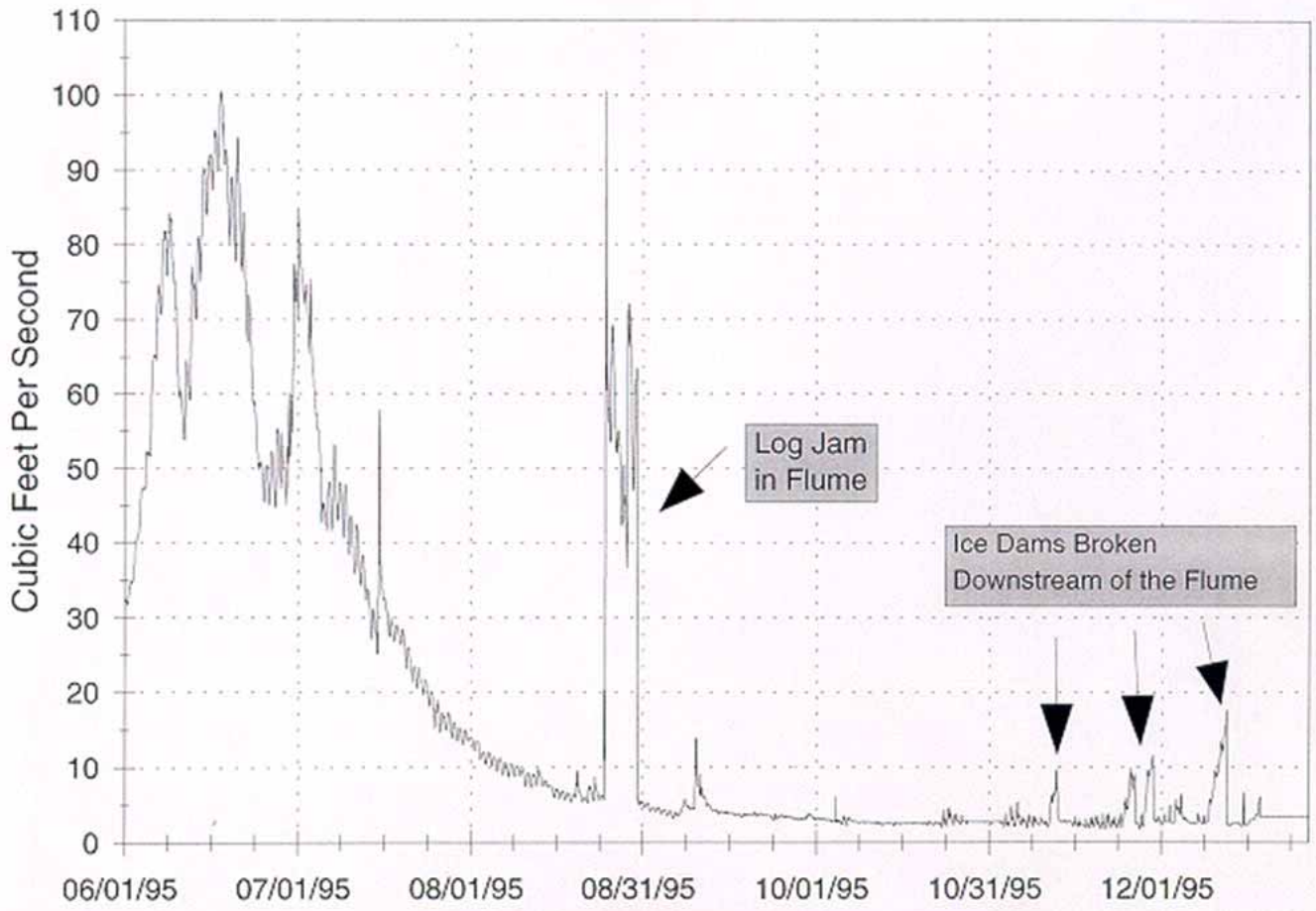

Figure 4. Graph of Medano Creek Discharge for 1995

Figure 5. Graph of Sand Creek Discharge for 1995

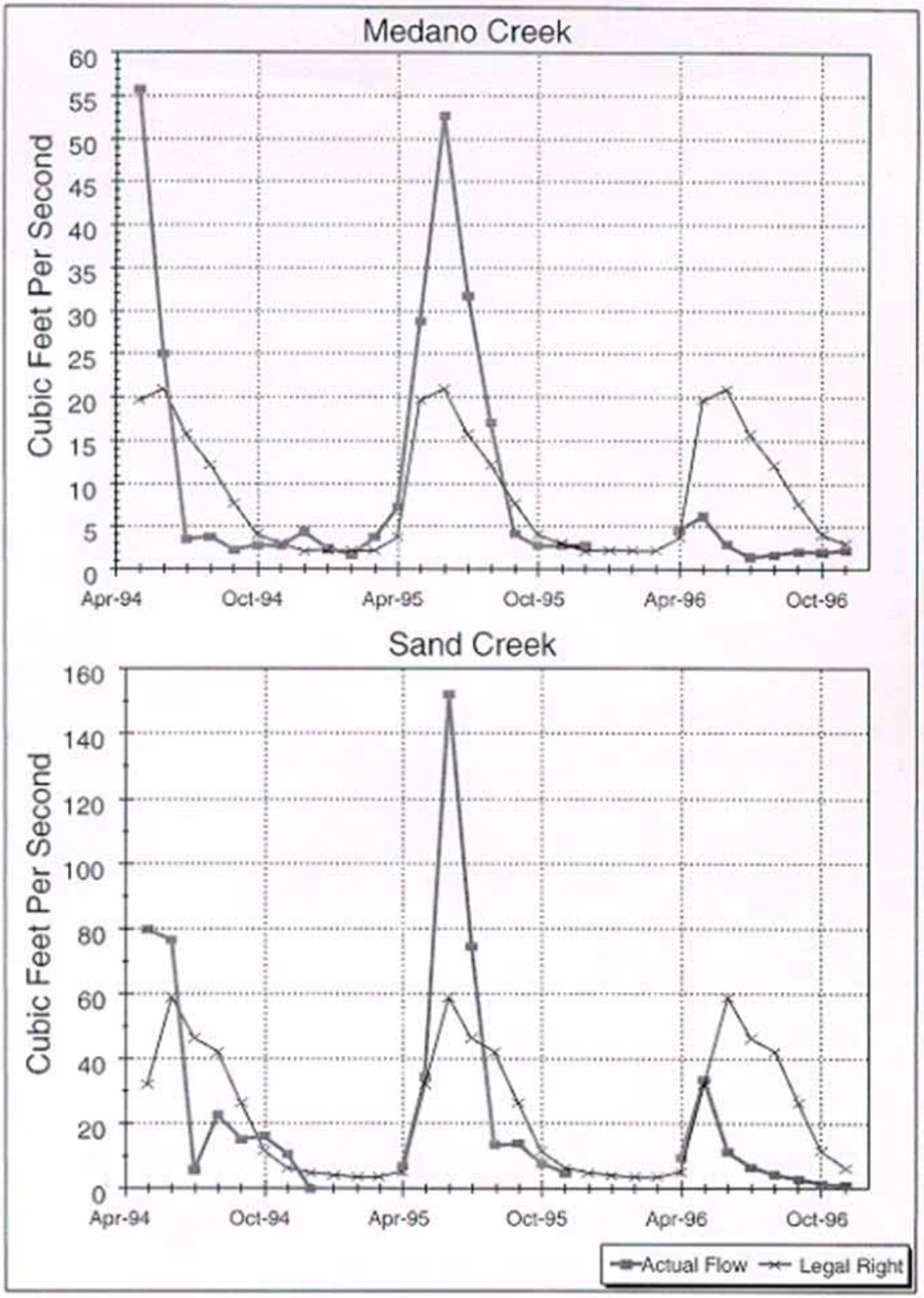

Figure 6. Average Monthly Flow and Instream Flow Rights for Medano and Sand Creeks, June 1994 to November 1996. Note that data for Sand Creek during June through August 1994 does not capture the entire flow due to equipment malfunction.

measurements aren't continuous, but it is estimated to be about 5 cfs. Retrieval of Colorado Water Quality Control Division database records of surface flow in Sand Creek will be completed as a Great Sand Dunes National Monument database of such information is built. Only one Sand Creek tributary junction is within the Monument boundary, that of Cold Creek, which is approximately 20% of the size of Sand Creek. No flow data are currently available for Cold Creek.

The stream discharge records of Medano Creek have been collected since July 1991, when a temporary Parshall flume was installed. Yearly maximum flows have been: 44 cfs in 1992; greater than flume capacity in 1993 (but estimated to be 100 cfs); and 73 cfs in 1994. Mean monthly flow for a recent time period is:

1994	May	55.8	cfs
	Jun.	25.0	cfs
	Jul.	3.5	cfs
	Aug.	3.8	cfs
	Sept.	2.2	cfs
	Oct.	2.8	cfs
	Nov.	2.7	cfs
	Dec.	4.4	cfs
1995	Jan.	2.4	cfs
	Feb.	1.7	cfs
	Mar.	3.7	cfs
	Apr.	7.2	cfs
	May	28.8	cfs
	Jun.	52.7	cfs
	Jul.	31.8	cfs
	Aug.	17.0	cfs
	Sep.	4.1	cfs
	Oct.	2.7	cfs
	Nov.	2.7	cfs
	Dec.	2.8	cfs
1996	Jan.	*	
	Feb.	*	
	Mar.	*	
	Apr.	4.7	cfs
	May	6.2	cfs
	Jun.	2.9	cfs
	Jul.	1.4	cfs
	Aug.	1.6	cfs
	Sept.	2.1	cfs
	Oct.	2.0	cfs
	Nov.	2.3	cfs

* Incomplete Data

The gauging site is used also by the U.S. Geological Survey's Rio Grande Valley National Water-Quality Assessment Program (NAWQA). This monitoring program began in 1991; its initial stage is scheduled to run through 1995. The goal of this program is to define Medano Creek's chemical and biological characteristics by making monthly measurements of discharge, dissolved oxygen, temperature, pH, alkalinity, and chemical composition, and annual aquatic surveys of its biological components. The tributaries that join Medano Creek within the Monument are Little Medano, Horse Canyon, Castle, Sawmill, Buck, Garden, and Mosca Creeks, with Little Medano and Mosca Creeks being the two largest.

Snow pack melt water is the source of some 60% to 70% of the total surface water that flows into the Monument (James McCalpin, consultant, written commun., May 1995).

Wetlands

Wetlands are lands transitional between terrestrial and aquatic environments where the water table is usually at or near the surface, or the land is covered by shallow water. Areas classified as wetlands must have one or more of the following attributes: 1) at least periodically, the land supports predominantly hydrophyte species; 2) the substrate is predominantly undrained hydric soil; and 3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year (Cowardin et al., 1979).

Wetlands in Great Sand Dunes National Monument were mapped and classified by the U.S. Fish and Wildlife Service in 1992 as part of the National Wetlands Inventory, and seven different types of *riverine* wetland systems were identified. The riverine wetlands, which occur in the channels of Medano and Sand Creeks and their tributaries, are characterized by few to no hydrophytes, and non-soil substrates covered by water during part of the growing season. Specific varieties of riverine wetlands identified within the Monument are listed below:

R4SBA. Riverine, Intermittent, Stream Bed, Temporarily Flooded. The most common type of Monument wetland, occurring in the lower reaches of the braided channels of Medano, Sand, and Cold Creeks where the streams flow

in the late spring and early summer when peak runoff is occurring.

R4SBC. Riverine, Intermittent, Stream Bed, Seasonally Flooded. Similar to R4SBA, but contain seasonal water more consistently because they occur in the upper reaches of the intermittent stream flow areas and in the centers of braided channels.

R2UBF. Riverine, Lower Perennial, Unconsolidated Bottom, Semipermanently Flooded. Channels immediately upstream of R4SBC wetlands, generally inundated except during late fall and winter.

R2USC. Riverine, Lower Perennial, Unconsolidated Shore, Seasonally Flooded. Occur on the perimeters of the R2UBF wetlands that are slightly higher in elevation and thus flooded less frequently.

R2USA. Riverine, Lower Perennial, Unconsolidated Shore, Temporarily Flooded. Equivalent to the R2USC but occur further downstream where water coverage is less frequent.

R3UBH. Riverine, Upper Perennial, Unconsolidated Bottom, Permanently Flooded. Found in the uppermost parts of Medano Creek within the Monument and characterized by generally rocky channels.

R3UBF. Riverine, Upper Perennial, Unconsolidated Bottom, Semipermanently Flooded. Within the Monument, wetland areas of the non-perennial parts of Medano Creek's tributaries.

Mapping of all seven of these riverine wetlands at 1:24,000-scale was completed by the U.S. Fish and Wildlife Service in 1992, utilizing color infrared aerial photography of 1983 to 1985. Copies of the unpublished maps have been obtained by the Monument.

The second main classification of wetlands are the *palustrine* variety, comprised of perennial and intermittent ponds and depressions that nearly intersect the water table and do support hydrophytes. They occur within the Monument along the banks of creeks, in abandoned stream channels, in the sand sheet, and the interdunal areas of the active sand dune field. Five specific varieties of palustrine wetlands identified in the Monument by the U.S. Fish and Wildlife Service's National Wetlands Inventory are listed below:

PAB6b. Palustrine, Aquatic Bed, Unknown Surface, Beaver. Wetlands created by beaver dams that are found on Medano Creek upstream from its confluences with Horse Canyon and Morris Gulch.

PUSC. Palustrine, Unconsolidated Shore, Seasonally Flooded. Intermittent ponds at the base of the dune field and within the sand sheet, occurring near the terminus of flow of Medano Creek. They contain water only when Medano Creek reaches them and during those times, often support amphibian life.

PEMB. Palustrine, Emergent, Saturated. Includes Denton Spring, Morris Gulch Spring, and several springs along the northern part of the Monument boundary at the base of Mount Herard.

PEMC. Palustrine, Emergent, Seasonally Flooded. Ponds, which can be intermittent or perennial, occurring either in the sand sheet (as interdunal ponds), or between the Medano and Mosca Creek channels (the island). Also occur in an abandoned drainage of the Cold Creek watershed.

PEMA. Palustrine, Emergent, Temporarily Flooded. Depressions in the sand sheet in which water may have been absent since ponds began evaporating in recent decades, but nevertheless are still near enough to the water table to support some wetland vegetation.

As in the case of the riverine wetlands, copies of the 1992 U.S. Fish and Wildlife Service maps of palustrine wetlands within the Monument have been obtained.

The wetlands of special concern to Great Sand Dunes National Monument management are the interdunal ponds within the active dune field (Figure 2) that have been created by the intersection of the water table with depressions in the sand sheet. Currently there are five of these interdunal ponds within the Monument, two of which have

been flooded only intermittently the last few years. All the ponds are smaller than one acre, but several acres of wetland-type vegetation surround the northernmost ponds. The northern ponds, which border state-leased lands, are protected by a peripheral electric fence, installed to prevent encroachment by grazing livestock.

West of the Monument are similar wetlands, some feeding streams. One example is a pond called Indian Spring, the origin of Big Spring Creek. Large-scale wetlands occur in the sump area of the Closed Basin, which is also known as the Dry Lake Province. The numerous shallow lakes and ponds in this area usually are dry in late summer and in winter. San Luis Lake, the largest in the sump area, covering nearly 1½ square miles, is artificially recharged by ground water pumped by the Bureau of Reclamation Closed Basin Project. The area is a State Park.

Aerial photographs and descriptions by early visitors indicate that there has been a great reduction in the number of interdunal ponds in the Monument vicinity. Aerial photographs taken in 1936 show as many as 60 ponds in the sand sheet, west of the dune field, while 1990 photographs of the same area show only three ponds. Interdunal ponds within the dune field were notable in quantity as late as the 1960's. Precise reasons for this diminishment are uncertain. The topic is addressed in subsequent sections of this report.

Surface Water Quality

Surface water quality baseline conditions within Great Sand Dunes National Monument can be determined best for Medano Creek, where water quality data have been collected in a systematic fashion from 1992 through 1995 as part of the U.S. Geological Survey's Rio Grande Valley National Water-Quality Assessment Program (NAWQA) (Ellis et al., 1993). A limited amount of additional water quality information is also available for Medano Creek, Sand Creek, Mosca Creek, Buck Creek, Castle Creek and several springs within the Monument from a small number of water quality determinations made from the 1960's to present as part of several different efforts undertaken by the U.S. Geological Survey, the Bureau of Reclamation, and National Park Service-sponsored cooperative research studies.

Surface Water Quality Standards

In accordance with the Clean Water Act, the State of Colorado (Colorado Department of Health-Water Quality Control Commission) has established surface water quality standards and designated use classifications for all surface waters within Great Sand Dunes National Monument. These standards are delineated in following sections.

Medano and Sand Creek and tributaries.--Under the State of Colorado classification system, nearly all Great Sand Dunes National Monument stream segments and wetlands fall under one specific set of designated use classifications and numeric standards. The numeric standards apply to physical and biological characteristics and content of metals and inorganic substances. This group of stream segments and wetlands includes Medano and Sand Creeks and all their tributaries and wetlands, and also Cold, Mosca, Little Medano, Buck, Garden, and Castle Creeks, drainages in Horse Canyon, Sawmill Canyon, Morris Gulch, and the unnamed drainage in the S.E. ¼, sec. 23, T. 26 S., R. 73 W. Further, the grouping includes 21 other small, unnamed streams in sec. 2, 3, 4, 11, 14, 23, 26, 35, T. 26 S., R. 73 W., and sec. 1, T. 27 S., R. 73 W.

The aforementioned waters bear the State Use Classifications of: a) Class 1 - Cold Water Aquatic Life; b) Recreation Class 2 - Secondary Contact; c) Domestic Water Supply; and d) Agriculture (State of Colorado, 1994a). The classification relative to aquatic life designates that the waters presently support a wide variety of cold water species, which may include sensitive species, and are reasonably expected to continue supporting such species in the future. Physical habitat, water flow and level, and water quality conditions are considered when assigning this use classification. Recreation Class 2 waters are suitable for limited contact, such as fishing and other streamside or lakeside recreation, through which ingestion of water *is NOT likely to occur*. Domestic water supply use is defined as suitable for potable water supplies that will meet Colorado drinking water standards upon standard treatment (coagulation, flocculation, sedimentation, filtration, and disinfection with chlorine or equivalent). Agriculture use is defined as suitable for irrigation of crops that would not be hazardous to either livestock or drinking water (State of Colorado, 1995a).

The waters have been assigned both specific and table value standards (TVS) for maximum allowable concentrations of a variety of metals and inorganic substances. TVS are those that vary according to other conditions of the water or the sampling situation. "Acute standards" are those that may not be exceeded by a single sample of a one-day time period, or by the calculated average of all samples collected in that one-day time period. The "chronic standards" are those that may not be exceeded by either the calculated average of samples collected over a *thirty-day* time period or by a single representative sample if only one sample can be collected, due to time, funding, or staffing constraints. There are also specified numbers for minimum concentration of dissolved oxygen, pH range, and maximum fecal coliform bacterial concentrations (State of Colorado, 1994a; 1995a). Most numerical standards and TVS are listed in Table 3 and Appendix B. Other standards (temperature, radioactive materials, miscellaneous) are listed in the "basic standards" text section, below.

Waters that flow in Rio Grande National Forest (*not* tributary to Sand/Medano Creeks).-- Somewhat different designated use classifications have been adopted by the State of Colorado for a second group of stream segments in Great Sand Dunes National Monument, defined as those tributary to the Closed Basin, present in the Rio Grande National Forest, and *not* tributary to either Sand Creek or Medano Creek (Table 3). This group of waters includes North Arrastre Creek and all unnamed stream segments in sec. 10, 15, and 16, T. 27 S., R. 73 W. The group may also include Evans Gulch and the unnamed stream segment that flows parallel to and immediately northeast of Evans Gulch (it has not been ascertained whether these two stream segments are tributary to Medano Creek). The main difference between this second group of streams and the Medano-Sand Creek group is that the former are designated as Recreation Class 1 - Primary Contact waters, meaning that the waters are suitable for recreation activities at which ingestion of small quantities of water are likely to occur, e.g., swimming. There are no variations in acceptable metals content (State of Colorado, 1994a; 1995a).

Denton Spring.--A third set of designated use classifications and water quality standards apply to the waters of Denton Spring (Table 3), because it is a wetland, the waters of which are tributary to neither Medano nor Sand Creeks and do not flow in the Rio Grande National Forest. The main difference is that the waters are classified as Class 2 - Cold and Warm Water Aquatic Life, which is defined as *not* capable of sustaining a wide variety of cold or warm water aquatic life, based on physical habitat, water flow or levels, or water quality conditions. The waters also bear a "use-protected" designation, which means that they do *not* warrant the special protection afforded by either the outstanding waters designation or the antidegradation review process. The assignment of use-protected designation to Denton Spring waters is due to the Aquatic Life Class 2 categorization (State of Colorado, 1994a, 1995a), and likely is based on the low flow from the spring (approximately 0.02 cfs).

Basic standards and Antidegradation Rule applicable to all surface waters.--All three of the Great Sand Dunes National Monument surface water grouping also are subject to *basic standards* for *temperature, uranium, and other radioactive materials, and organic chemicals*. Temperature standards, which generally pertain to some combination of water use/discharge, state that water is to be within normal diurnal temperature patterns, with no abrupt changes, and no changes deleterious to resident aquatic life. In general, 3° C is the maximum increase tolerable; such a temperature increase cannot be achieved in less than a 4-hour period, nor can it be maintained longer than 13 hours, unless regulated by permits. Exceptions may be possible in certain cases (State of Colorado, 1994a).

Other basic standards denote that levels of uranium and radioactive materials in waters must be maintained at the lowest practical levels, and any increases due to agricultural, municipal, or industrial practice are limited so that the resulting maximums (or natural levels, whichever is greater) do not exceed:

Uranium (U)	40 pCi/L
Cesium (^{134}Cs)	80 pCi/L
Plutonium ($^{238, 239, \text{and } 240}$Pt)	15 pCi/L
Radium ($^{226 \text{ and } 228}$Ra)	5 pCi/L

Table 3. Colorado Designated Use Classifications and Numeric Water Quality Standards for Surface Waters of Great Sand Dunes National Monument. From State of Colorado (1994a).

Affected Waters	Sand Creek, and Medano Creek, and associated tributaries and Wetlands[1]	North Arrastre Creek[2]	Denton Spring and Associated Wetlands
Water Quality-Based Designation[3]	None	None	Use Protected
Classified Uses	Aquatic Life 1 (cold) Recreation 2 Water Supply Agriculture	Aquatic Life 1 (cold) Recreation 1 Water Supply Agriculture	Aquatic Life 2 (cold & warm) Recreation 2 Agriculture
Physical/Biological			
Dissolved Oxygen	6.0 mg/L	6.0 mg/L	5.0 mg/L
Dissolved Oxygen (Spawning)	7.0 mg/L	7.0 mg/L	
pH	6.5 to 9.0	6.5 to 9.0	6.5 to 9.0
Fecal Coliform	200 col/100ml	200 col/100ml	200 col/100ml
Inorganic			
Ammonia (as N) (acute)	TVS[4]	TVS	TVS
Ammonia (as N) (chronic)	0.02 mg/L	0.02 mg/L	0.06 mg/L
Chlorine Residual (acute)	0.019 mg/L	0.019 mg/L	0.019 mg/L
Chlorine Residual (chronic)	0.011 mg/L	0.011 mg/L	0.011 mg/L
Cyanide, free	0.005 mg>l	0.005 mg>l	0.005 mg>l
Sulfide as H_2S	0.002 mg/L	0.002 mg/L	0.002 mg/L
Boron	0.75 mg/L	0.75 mg/L	0.75 mg/L
Nitrite (as N)	0.05 mg/L	0.05 mg/L	0.05 mg/L
Nitrate (as N)	10. mg/L	10. mg/L	
Chloride	250. mg/L	250. mg/L	
Sulfate	250. mg/L	250. mg/L	
Metals			
Arsenic (acute)	50. µg/L (Total Rec.)	50. µg/L (Total Rec.)	TVS
Cadmium	TVS	TVS	TVS
Chromium $^{+3}$ (acute)	50. µg/L	50. µg/L	TVS
Chromium $^{+6}$	TVS	TVS	TVS
Copper	TVS	TVS	TVS
Iron (chronic)	300. µg/L (Dissolved) 1,000. µg/L (Total Rec.)	300. µg/L (Dissolved) 1,000. µg/L (Total Rec.)	1,000. µg/L (Total Rec.)
Lead	TVS	TVS	TVS
Manganese (chronic)	50. µg/L (Dissolved)	50. µg/L (Dissolved)	1,000. µg/L (Dissolved)
Mercury (chronic)	0.01 µg/L (Total Rec.)	0.01 µg/L (Total Rec.)	0.01 µg/L (Total Rec.)
Nickel	TVS	TVS	TVS
Selenium (acute)	10. µg/L (Total Rec.)	10. µg/L (Total Rec.)	TVS
Silver	TVS	TVS	TVS
Zinc	TVS	TVS	TVS

[1] The Tributaries to Medano Creek include Cold Creek, Little Medano Creek, Mosca Creek, Buck Creek, Garden Creek, Horse Canyon, Castle Creek, Sawmill Canyon, Morris Gulch, unnamed creek in SE 1/4, sec. 23, T. 26 S., R. 73 W., and 21 other small, unnamed streams in sec. 2, 3, 4, 11, 14, 23, 26, 35, T. 26 S., R. 73 W., and sec. 1, T. 27 S., R. 73 W.

[2] Streams grouped with Arrastra Creek include all unnamed stream segments in sec. 10, 15, and 16, T. 27 S., R. 73 W. The group may also include Evans Gulch and the unnamed stream segment the flows parallel to and immediately northeast of Evans Gulch (it has not been ascertained whether these two stream segments are tributary to Medano Creek).

[3] Water Quality-Based Designations include; Outstanding Waters, Use Protected, or None. Where the designation is "none" the "Antidegradation Review Process" is applied for new or increased discharges.

[4] TVS = Table Value Standard. Numeric standards vary with hardness and are calculated through equations such as $e^{(1.64[\ln(\text{hardness})]-2.460)}$. Equations for each parameter are presented in Appendix 1, part a.

Strontium (^{90}Sr)	8 pCi/L
Thorium ($^{230 \text{ and } 232}Th$)	60 pCi/L
Tritium	20,000 pCi/L

(pCi/L = picocuries per liter).

However, it should be noted that mechanisms have been provided to pursue alternative site-specific standards for uranium and other radioactive materials (State of Colorado, 1994a; 1995a).

Basic standards have been established for numerous organic chemicals (Appendix B, part 1). Standards for specific organic chemicals are applicable depending on whether the waters are used for water supply or drinking water, supporting Class 1 or 2 aquatic life, or supporting all aquatic life, as noted in the table. Size and use of the fish in these waters may also affect the specific standards that are applicable (State of Colorado, 1995a).

Non-numeric basic standards address nonpoint source and point-source discharges that are human-caused. The concentrations, amounts, and combinations of these discharges are restricted so as to not cause bottom sedimentation or other build-up; not cause undesirable, harmful, or toxic color, odor, taste, pH, or other conditions that affect humans, aquatic life (including edible species), and other plants and animals; and not harm existing beneficial uses. Further, the discharges may not produce floating debris, film, or scum that is harmful to existing uses or produces shoreline deposition. Neither are discharges permitted that produce a predominance of undesirable aquatic life (State of Colorado, 1995a).

The *Antidegradation Rule*, applicable to all three groupings of surface waters in the Monument (described above), states that water quality shall be maintained at existing levels and within ranges suitable for existing designated uses; i.e. existing narrative and numeric standards (Table 3) will not be exceeded. However, there is an antidegradation review process that could approve certain degradation of waters to accommodate economic or social development (State of Colorado, 1995a).

Assessment of Surface Water Quality

Medano Creek.--Baseline water quality conditions within Great Sand Dunes National Monument are best understood in Medano Creek. In 1992, the U.S. Geological Survey, in conjunction with the National Park Service, established a National Water-Quality Assessment Program (NAWQA) monitoring site on Medano Creek on the eastern perimeter of the Monument (Figure 7). This station is known as "Medano Creek near Mosca, CO" (USGS ID 374752105300801). At this location, Medano Creek is characterized as a fairly high gradient mountain stream with a stream profile of approximately 2 feet deep by 8 feet across. Upstream land-use activities are limited, as the upstream watershed is predominated by steep, forested slopes of Rio Grande National Forest. Possible water-related impacts include seasonal (spring to early summer) water diversions by a senior water right holder (Wolf Springs Ranch), potential contamination from a number of abandoned hardrock mining claims, and possible impacts from summer and fall recreational use including four-wheel-drive stream crossings, horse trails, and stream-side camping.

While it is the long term goal of the NAWQA program to "describe the status and trends in the quality of a large, representative part of the Nation's surface- and ground-water resources and to provide a sound, scientific understanding of the primary natural and human factors affecting the quality of these resources" (U.S. Geological Survey, 1991), in doing so, the program produces a wealth of site-specific water quality information useful to the local land manager. The Medano Creek station, when it enters its "inactive" phase in 1996 will have provided park management with a multi-year assessment of basic physical and chemical water quality constituents, including monthly determinations of specific conductance, dissolved oxygen, pH, alkalinity, major cations and anions, seasonal assessments of benthic macroinvertebrate populations, a one-time determination of sediment trace element and organic contaminants, and a fisheries inventory.

A preliminary assessment of National Water-Quality Assessment Program (NAWQA) data collected through January, 1995 indicates that the existing water quality condition at the Medano Creek monitoring site is excellent.

Specific conductance (median = 80 µS/cm) and alkalinity (median = 40 mg/L) are low, which is typical snowmelt-fed, mountain streams of the Southern Rocky Mountains. In addition, specific

conductance appears to be related to discharge, with specific conductance typically ranging between 75 µS/cm and 100 µS/cm when discharge is less than 5 cfs, and ranging between 50 µS/cm and 60 µS/cm when snowmelt or large storm events cause stream flow to increase to greater than 50 cfs. Median dissolved oxygen concentrations exceed 9 mg/L (range = 7.2 mg/L to 11.4 mg/L), which approaches 100% oxygen saturation capacity (range = 95% to 101%), well above the limits necessary to protect cold water fish species. In addition, pH ranged from 7.2 to 8.1, again well within the range required to support a healthy cold water fish environment.

Chemically, the waters of Medano Creek may be characterized as a calcium bicarbonate dominant system, which again is typical for streams within the region. Suspended sediment concentration typically ranges from 5 mg/L to 20 mg/L. Trace metal concentrations in both the water (iron, manganese, strontium, boron) and bed sediments (silver, arsenic, cadmium, cobalt, chromium, copper, iron, mercury, manganese, nickel, lead, selenium, strontium, vanadium, zinc) appear typical of mountain tributary streams of the region, with only chromium in bed sediment (59 µg/L) being slightly elevated when compared to a similar site (Saguache Creek near Saguache, CO) (Appendix C).

Benthic macroinvertebrate populations sampled in Medano Creek as part of the National Water-Quality Assessment Program (NAWQA) indicate a highly diverse and healthy benthic macroinvertebrate assemblage. Preliminary analysis of the benthic macroinvertebrate data indicated the presence of over 40 individual species with large numbers of pollution intolerant mayflies (Order *Ephemeroptera*), stone flies (Order *Plecoptera*), and caddis flies (Order *Trichoptera*). The "EPT:Chironomid" ratio is also high, indicating a healthy and desirable macroinvertebrate community.

Fish species present in Medano Creek include only the Rio Grande cutthroat trout (*Oncorhynchus clarki virginalis*). In 1985, Medano Creek was reclaimed by the Colorado Division of Wildlife in order to provide habitat for the reintroduction of this extirpated species back within its native range. At this time, this species is naturally reproducing within Medano Creek and appears to be surviving well. The successes here and at other Division of Wildlife project sites in Colorado led to changing the status of the fish from and endangered species to a "species of special concern" (Fred Bunch, National Park Service-Great Sand Dunes National Monument, written commun., April 1991).

A limited additional amount of water quality data is available for Medano Creek from a one-time water quality sampling at the "Medano Creek near Mosca, CO" monitoring site by the U.S. Geological Survey in 1978, a one-time water quality reconnaissance survey at Medano Creek at Shockey's Crossing and South Boardwalk by the Bureau of Reclamation in 1991, and annual samplings of Medano Creek below the confluence with Castle Creek in both 1992 and 1993 (Table 4).

[Note: In evaluating water quality analytical data presented in this report, it should be remembered that there are two varieties of analyte determinations. Those described as "dissolved" are derived from splits of the water sample that has been filtered prior to any chemical analysis in order to remove any sediment or colloidal material that may be present. Thus only dissolved quantities of any analyte are detected and reported. The other concentrations are reported as "total recoverable", which is derived from a water sample that has not been filtered. The sample is subjected to a weak acid digestion that would capture not only dissolved analytes, but also would dissolve and capture quantities of the analyte that may be present suspended as colloids and/or attached by weak electrical bonds to the surfaces of sediment or clay particles in the sample. The digestion is not powerful enough to dissolve those sediment and clay particles. Some of the older data presented for certain analytes, particularly iron, in tables in this report are noted as "total", which is assumed to be equivalent to "total recoverable."]

Water quality data collected in August, 1978 by the U.S. Geological Survey at the "Medano Creek near Mosca, CO" sampling site is virtually identical to that collected during similar low flow (1 cfs) conditions during the 1992-1995 National Water-Quality Assessment Program (NAWQA) study. Data collected from 1991-1993 further downstream in Medano Creek (Shockey's Crossing, below Castle Creek, and South Boardwalk) is also similar in character to the National Water-Quality Assessment Program (NAWQA) site, though

Table 4. Surface Water Quality Analyses from Sand and Medano Creeks, Great Sand Dunes National Monument, Colorado. Most species analyses are expressed as DISSOLVED indicated by unshaded blocks, except for those expressed as TOTAL RECOVERABLE as indicated by a shaded blocks. Refer to Figure 7 for sample site locations.

Table 4	SAMPLE LOCATION, AGENCY CONDUCTING THE SAMPLING, AND SAMPLE DATE									
PARAMETER	Medano Cr. NAWQA[1] 1992-1995	Medano Cr. USGS 08-78	Medano Cr. @ Shockey's Crossing SLV LAB 12-90	Medano Cr. @ Shockey's Crossing USBOR 04-91	Medano Cr. @ S. Boardwalk USBOR 04-91	Medano Cr. @ Castle Cr. SLV LAB 12-90	Medano Cr. @ Castle Cr. SLV LAB 03-92	Medano Cr. @ Castle Cr. SLV LAB 12-90	Medano Cr. @ Castle Cr. SLV LAB 01-93	Sand Cr. USBOR 04-91
Number of samples	n = 24	n = 1	n = 1	n = 1	n = 1	n = 1	n = 1	n = 1	n = 1	n = 1
pH	7.0 - 8.7	8.1	--	7.5	7.7	--	6.7	--	7.9	8.0
Specific conductance (µS/cm)	52 - 101	100	--	76	109	--	100	--	109	86
Dissolved solids residue at 180°C, in mg/L	32 - 66	65	--	96	98	--	--	--	--	88
Alkalinity (total as $CaCO_3$) (mg/L)	22 - 49	44	--	--	--	--	--	--	55	--
Sodium, dissolved (mg/L)	1.5 - 3.2	2.5	3.0	2.7	2.7	3.0	2.3	2.9	4.0	3.4
Potassium, dissolved (mg/L)	0.5 - 0.9	1.0	0.7	1.6	1.6	0.8	0.8	0.8	1.5	2.0
Calcium, dissolved (mg/L)	5.1 - 12.0	12	4.3	12.0	25.6	4.0	4.8	5.0	5.6	12.0
Magnesium, dissolved (mg/L)	1.4 - 3.5	2.8	1.5	3.9	5.9	1.4	2.4	1.7	3.2	3.4
Hardness (total as $CaCO_3$) (mg/L)	19 - 44	43	--	--	--	--	--	--	--	--
Carbonate, dissolved (mg/L)	0	--	--	0	0	--	--	--	0.4	0
Bicarbonate, dissolved (mg/L)	27 - 60	--	--	37	47	--	--	--	55	32
Iron, dissolved (µg/L)	66 - 250	270	16	<50	<50	13	140	59	90	<50
Manganese, dissolved (µg/L)	7 - 16	10	0	<50	--	0	1.8	23	8.2	<50
Silica, dissolved (mg/L)	9.3 - 13.0	13.0	13.5	--	--	13.6	6.2	14.2	1.3	--
Fluoride, dissolved (mg/L)	0.1 - 0.2	0.2	0.17	--	--	0.20	0.19	0.23	0.11	--
Chloride, dissolved (mg/L)	0.3 - 0.8	0.8	0.5	2.1	5.7	1.5	2.5	1.5	3.7	2.1

Table 4 PARAMETER	SAMPLE LOCATION, AGENCY CONDUCTING THE SAMPLING, AND SAMPLE DATE									
	Medano Cr. NAWQA[1] 1992-1995	Medano Cr. USGS 08-78	Medano Cr. @ Shockey's Crossing SLV LAB 12-90	Medano Cr. @ Shockey's Crossing USBOR 04-91	Medano Cr. @ S. Boardwalk USBOR 04-91	Medano Cr. @ Castle Cr. SLV LAB 12-90	Medano Cr. @ Castle Cr. SLV LAB 03-92	Medano Cr. @ Castle Cr. SLV LAB 12-90	Medano Cr. @ Castle Cr. SLV LAB 01-93	Sand Cr. USBOR 04-91
Orthophosphate, dissolved (as P) (mg/L)	--	0.01	--	--	--	--	--	--	0.05	--
Nitrate, dissolved (as N) (mg/L)	--	0.04	--	--	--	--	--	--	--	--
Nitrate, diss. (as NO_3) (mg/L)	--	0.2	--	0	0	--	--	--	--	0
Sulfate, dissolved (mg/L)	--	6	--	10.6	10.6	--	--	--	0.6	26.9
Copper, dissolved (µg/L)	--	2	12	<5	95	2.5	<6	0.8	4.4	5.0
Lead, dissolved (µg/L)	--	13	0	0	0	0	<23	0	<4	5.0
Zinc, dissolved (µg/L)	--	0	44	17.0	32.0	5.0	<2	0	8.3	17
Arsenic, dissolved (µg/L)	--	1	1.3	0	0	0	4	1.6	--	<10
Cadmium, dissolved (µg/L)	--	2	0	0.4	0	0.4	<2.5	0	<0.3	0.3
Chromium, dissolved (µg/L)	--	0	--	0	0	--	--	--	--	0
Nickel, dissolved (µg/L)	--	0	--	0	<5	--	--	--	<0.9	0
Mercury, dissolved (µg/L)	--	0.1	--	0	0	--	--	--	--	<0.2
Selenium, dissolved (µg/L)	--	1	0	2.0	0	0	<4	4.0	--	4.0
Silver, dissolved (µg/L)	--	--	--	0	0	--	<4	0.1	<0.5	0

Abbreviations used: mg/L = milligrams per liter; µg/L = micrograms per liter; µS/cm = microsiemens/centimeter

Reporting Minimal Concentrations and Missing Data: -- = not tested or no data
< = less than the number shown where that number represents the limit of detectability.
0 = less than detectable where the limit of detectability is not known.

Sources of Analyses:
NAWQA, U.S. Geological Survey, Water Resources Division, Albuquerque, NM;
USGS, U.S. Geological Survey, Water Resources Division, Denver, CO;
USBOR, Bureau of Reclamation, San Luis Valley Projects Office Chemistry Lab., Alamosa, CO (sampled at request of the National Monument);
SLV LAB, samples analyzed by SLV Analytical Services, Alamosa, CO (sampled at request of the National Monument; funded by *Friends of the Dunes*).

[1] Note: A complete listing of NAWQA water quality data for Medano Creek is included in Appendix C.

dissolved solids, potassium, magnesium, and chloride are higher, no doubt influenced by chemical changes as the stream transitions from its "mountain stream" character exiting onto the sand sheet where it is influenced by a different geological environment.

Tributaries to Medano Creek.--Water quality data for streams tributary Medano Creek is relatively sparse. Water quality at the former U.S. Geological Survey Mosca Creek gauging station (USGS 08234200) was monitored on approximately six occasions from 1966 to 1968 (Table 5, parts a and b). The water quality at this site is more highly mineralized than that found at the National Water-Quality Assessment Program (NAWQA) site in Medano Creek with specific conductance, dissolved solids, alkalinity, hardness, sodium, calcium, magnesium, and chloride found at levels two to three times higher than those monitored at the Medano Creek National Water-Quality Assessment Program (NAWQA) site. These data are also consistent with more recent, though less extensive water quality determinations on Mosca Creek which occurred on an annual basis from 1991 to 1993. These higher concentrations of major cations and anions are presumably due to geological differences between the upper portions of the Medano Creek and Mosca Creek drainages. Unfortunately, only very limited trace metal data are available for Mosca Creek. Tests reveal that concentrations of manganese, arsenic, mercury, selenium, cadmium, silver, copper, and lead met State of Colorado water quality criteria, and neither zinc nor nickel could be evaluated due to lack of a water hardness determination.

Water quality data from other tributaries to Medano Creek including Buck Creek, Castle Creek, and Little Medano Creeks, as well as Mosca and Morris Gulch Springs is very limited and is provided in Table 5 (parts a and b). While these data are extremely limited (three samplings of Buck Creek, two of Mosca Spring and one of the other sites), they may be compared to State of Colorado water quality criteria applicable to these waters. The pH, nitrate, chloride, sulfate, iron concentrations at all of the above sites met State of Colorado water quality criteria on the days sampled.

Based upon limited sampling, the waters of Buck Creek appear to fall within State of Colorado water quality standards relative to manganese, arsenic, selenium, mercury, cadmium, copper, lead, nickel, and silver. Zinc concentrations could not be assessed against State of Colorado water quality standards due to an absence of a hardness determination needed to determine a Table Value Standard (see Appendix B, part 2).

Again, based upon a very limited number of available samples, Castle Creek appears to meet State of Colorado water quality standards for arsenic, manganese, selenium, lead, nickel, silver and mercury. Cadmium, copper, and zinc concentrations cannot be evaluated against State water quality standards due to absence of a water hardness determination, necessary for arriving at the appropriate Table Value Standard (see Appendix B, part 8).

Concentrations of arsenic, manganese, cadmium, lead, nickel, mercury, and selenium met applicable State of Colorado water quality standards in Little Medano Creek. Copper and zinc concentrations could not be assessed because hardness was not measured.

Sand Creek.--Only one water quality sample is available from Sand Creek (Table 4). Generally the water was slightly more mineralized than the water found at the National Water-Quality Assessment Program (NAWQA) monitoring site on Medano Creek, but very similar in chemical character to waters found lower in Medano Creek (Shockey's Crossing, below Castle Creek and South Boardwalk). This is presumably again due to the change in geologic environment once water enters the sand sheet.

While the data are limited to one sample, the pH and nitrate, chloride, sulfate, arsenic, iron, manganese, selenium, silver and nickel concentrations all met State water quality criteria. Cadmium, copper, lead, and zinc concentrations cannot be compared to State water quality criteria due to a lack of hardness data.

Denton Spring.--Water quality of Denton Spring, which is measured against slightly different standards than waters of the Medano and Sand Creek watersheds (Table 3), can be partially assessed with the analyses of two samples (Table 6) which indicate applicable State water quality standards were met for pH, iron, and manganese. No hardness concentration was determined so it is

Table 5, part a. Surface Water Quality Analyses from Springs and Creeks Tributary to Medano Creek, Great Sand Dunes National Monument, Colorado. Refer to Figure 7 for sample locations.

Table 5a	SAMPLE LOCATION, AGENCY CONDUCTING THE SAMPLING, AND SAMPLE DATE(S)											
PARAMETER	Buck Creek USBOR 04-91	Buck Creek SLV LAB 03-92	Buck Creek SLV LAB 12-90	Castle Creek USBOR 04-91	Little Medano Creek SLV LAB 12-90	Little Medano Creek USBOR 04-91	Morris Gulch Spring USGS 05-64	Mosca Creek USBOR 04-91	Mosca Creek SLV LAB 03-92	Mosca Creek USGS[1] 1967-1968	Mosca Spring USBOR 04-91	Mosca Spring USGS 05-64
Number of samples	n = 1	n = 1	n = 1	n = 1	n = 1	n = 1	n = 1	n = 1	n = 1	n = 6[2]	n = 1	n = 1
pH	7.7	6.7	--	7.6	--	7.5	7.6	7.7	6.9	7.3 - 7.9	7.5	7.0
Specific Conductance (µS/cm)	245	237	--	82	--	98	283	196	188	151 - 241	230	222
Dissolved Solids Residue at 180°C. (mg/L)	172	--	--	52	--	72	180	128	--	101 - 150	86	143
Alkalinity (total as $CaCO_3$) (mg/L)	--	--	--	--	--	--	--	--	--	66 - 112	--	--
Sodium, dissolved (mg/L)	3.4	3.2	7.9	3.4	2.3	2.8	6.1	2.8	3.5	5.8 - 9.6	9.9	9.5
Potassium, dissolved (mg/L)	3.9	0.6	0.7	3.1	0.8	3.1	1.0	2.0	0.7	--	1.6	0.8
Calcium, dissolved (mg/L)	13.6	13.2	20.7	10.4	6.5	14.4	43	29.6	14.0	18.0 - 33.0	36.0	27
Magnesium, dissolved (mg/L)	2.4	6.0	7.0	4.4	1.2	3.9	6.4	9.3	4.5	5.4 - 7.3	7.3	5.5
Hardness (total as $CaCO_3$) (mg/L)	--	--	--	--	--	--	134	--	--	70 - 108	--	90
Carbonate, dissolved (mg/L)	0	--	--	0	--	0	0	0	--	0	0	0
Bicarbonate, dissolved (mg/L)	126	--	--	37	--	52	130	92	--	80 - 136	105	113
Iron, diss. unless noted (µg/L)	<50	70	0	<50	7	<50	20[3]	0	90	--	<50	20[3]
Manganese, dissolved (µg/L)	<50	<2	0	<50	8	<50	--	--	1.8	--	<50	--
Silica, dissolved (mg/L)	--	8.4	18.6	--	12.4	--	14	--	7.8	15.0 - 17.0	--	17
Fluoride, dissolved (mg/L)	--	0.63	0.55	--	1.0	--	0.1	--	0.45	--	--	0.5

Table 5a PARAMETER	SAMPLE LOCATION, AGENCY CONDUCTING THE SAMPLING, AND SAMPLE DATE(S)											
	Buck Creek USBOR 04-91	Buck Creek SLV LAB 03-92	Buck Creek SLV LAB 12-90	Castle Creek USBOR 04-91	Little Medano Creek SLV LAB 12-90	Little Medano Creek USBOR 04-91	Morris Gulch Spring USGS 05-64	Mosca Creek USBOR 04-91	Mosca Creek SLV LAB 03-92	Mosca Creek USGS[1] 1967-1968	Mosca Spring USBOR 04-91	Mosca Spring USGS 05-64
Chloride, dissolved (mg/L)	2.1	3.0	1.0	5.7	0.17	2.1	1.4	5.7	3.0	2.0 - 4.0	5.7	2.6
Orthophosphate, diss. (as P) (mg/L)	--	--	--	--	--	--	--	--	--	0.02 - 0.05	--	--
Nitrate, diss. (as NO_3) (mg/L)	0	--	--	0	--	0	0.2	0	--	0.1 - 0.7	0	0.1
Sulfate, dissolved (mg/L)	10.1	--	--	16.8	--	13.4	37	22.1	--	10 - 14	24.5	15
Copper, dissolved (µg/L)	0	<6	2.5	<5	2.5	<5	--	0	<6	--	<5	--
Lead, dissolved (µg/L)	0	<23	0	0	0	0	--	0	<23	--	0	--
Zinc, dissolved (µg/L)	15.5	<2	18	10.0	5.8	17.0	--	--	<2	--	--	--
Arsenic, dissolved (µg/L)	0	4	1.3	0	0	0	--	0	2	--	0	--
Cadmium, dissolved (µg/L)	0	<2.5	0.8	0.3	0	0	--	0	<2.5	--	0	--
Nickel, dissolved (µg/L)	0	--	--	0	--	0	--	<5	--	--	0	--
Mercury, dissolved (µg/L)	0	--	--	0	--	0	--	0	--	--	0	--
Selenium, dissolved (µg/L)	8.5	<4	5.8	0	1.9	2.0	--	5.0	<4	--	3.5	--
Silver, dissolved (µg/L)	0	<4	--	0	--	0	--	0	<4	--	0	--

Abbreviations used: mg/L = milligrams per liter; µg/L = micrograms per liter; µS/cm = microsiemens/centimeter
Reporting Minimal Concentrations and Missing Data: -- = not tested or no data; < = less than the number shown where that number represents the limit of detectability; 0 = less than detectable where the limit of detectability is not known.

Sources of analyses:
USGS, U.S. Geological Survey, Water Resources Division, Denver, CO
USBOR, Bureau of Reclamation, San Luis Valley Projects Office Chemistry Lab., Alamosa, CO (requested by the NPS)
SLV LAB, samples analyzed by SLV Analytical Serv., Alamosa, CO (requested by the NPS; funding by *Friends of the Dunes*).

[1] USGS Station Identification number for the Mosca Creek is 08234200.
[2] Reported ranges of orthophosphate and $CaCO_3$ are from five samples; reported range of dissolved solids residue are from four samples; all other ranges from six samples.
[3] Samples from Morris Gulch Spring and Mosca Spring in May 1964 were analyzed for Total Recoverable Iron.

Table 5, part b. Surface Water Quality Analyses from Springs and Creeks Tributary to Medano Creek, Great Sand Dunes National Monument, Colorado. Refer to Figure 7 for sample locations.

Table 5b PARAMETER	SAMPLE LOCATION, AGENCY CONDUCTING THE SAMPLING, AND SAMPLE DATE(S)		
	Buck Creek SLV LAB 01-93	Mosca Creek SLV LAB 12-90	Mosca Creek SLV LAB 01-93
Number of samples	n = 1	n = 1	n = 1
pH	7.8	--	7.7
Specific conductance (µS/cm)	210	--	180
Dissolved solids residue at 180°C. (mg/L)	--	--	--
Alkalinity (total as $CaCO_3$) (mg/L)	100	--	82
Sodium, total recoverable (mg/L)	7.7	7.2	7.7
Potassium, total recoverable (mg/L)	0.9	0.6	0.8
Calcium, total recoverable (mg/L)	13.9	16.6	10.7
Magnesium, total recoverable (mg/L)	6.4	5.2	4.8
Carbonate, total recoverable (mg/L)	0.6	--	0.4
Bicarbonate, total recoverable (mg/L)	99	--	82
Iron, total recoverable (µg/L)	123	0	38
Manganese, total recoverable (µg/L)	18.1	0	3.3
Silica, total recoverable (mg/L)	1.6	17.5	1.4
Fluoride, total recoverable (mg/L)	0.24	0.49	0.20
Chloride, total recoverable (mg/L)	6.0	2.5	5.0
Orthophosphate, total recoverable (as P) (mg/L)	0.05	--	0.05
Nitrate, total recoverable (as N) (mg/L)	--	--	0.08

Table 5b PARAMETER	SAMPLE LOCATION, AGENCY CONDUCTING THE SAMPLING, AND SAMPLE DATE(S)		
	Buck Creek SLV LAB 01-93	Mosca Creek SLV LAB 12-90	Mosca Creek SLV LAB 01-93
Nitrate, total recoverable (as NO_3) (mg/L)	--	--	0.4
Sulfate, total recoverable (mg/L)	13.9	--	14.0
Copper, total recoverable (µg/L)	1.2	0.4	1.2
Lead, total recoverable (µg/L)	<4	0	<4
Zinc, total recoverable (µg/L)	5.1	2.0	1.4
Arsenic, total recoverable (µg/L)	--	0	--
Cadmium, total recoverable (µg/L)	<0.3	0	<0.3
Nickel, total recoverable (µg/L)	<0.9	--	0.9
Selenium, total recoverable (µg/L)	--	6.0	--
Silver, total recoverable (µg/L)	<0.5	0	<0.5

Abbreviations used: mg/L = milligrams per liter; µg/L = micrograms per liter; µS/cm = microsiemens/centimeter

Reporting Minimal Concentrations and Missing Data: -- = not tested or no data
< = less than the number shown where that number represents the limit of detectability.
0 = less than detectable where the limit of detectability is not known.

Sources of analyses: SLV LAB, samples analyzed by SLV Analytical Services, Alamosa, CO (requested by National Monument; funding by *Friends of the Dunes*).

Table 6. Surface Water Quality Analyses from Denton and Indian Springs, in and near Great Sand Dunes National Monument, Colorado. All USBOR species analyses expressed as DISSOLVED as indicated by unshaded blocks, and all SLV LAB species analyses expressed as TOTAL RECOVERABLE, as indicated by shaded blocks. Refer to Figure 7 for sample locations.

Table 6	SAMPLE LOCATION, AGENCY CONDUCTING THE SAMPLING, AND SAMPLE DATE(S)					
PARAMETER	Denton Spring USBOR 04-91	Denton Spring SLV LAB 01-93	Indian Spring USBOR 04-91	Indian Spring SLV LAB 12-90	Indian Spring SLV LAB 01-93	Drainage above Indian Spring SLV LAB 01-93
Number of samples	n = 1	n = 1	n = 1	n = 1	n = 1	n = 1
pH	7.8	7.4	9.1	--	7.0	7.6
Specific conductance (μS/cm)	331	298	303	--	219	1,480
Dissolved solids residue at 180°C. (mg/L)	140	--	234	--	--	--
Alkalinity (total as $CaCO_3$) (mg/L)	--	130	--	--	94	455
Sodium, dissolved (mg/L)	7.8	8.5	19.1	16.9	10.4	162
Potassium, dissolved (mg/L)	5.1	0.9	16.4	6.3	7.4	141
Calcium, dissolved (mg/L)	49.6	44.4	32.0	1.1	2.7	57.8
Magnesium, dissolved (mg/L)	7.3	6.4	8.8	0.8	2.6	65.1
Carbonate, dissolved (mg/L)	0	0.3	15.6	--	0.1	1.7
Bicarbonate, dissolved (mg/L)	163	129.7	84.2	--	93.3	453
Iron, dissolved (μg/L)	<50	53.1	<50	20.	202.0	204
Manganese, dissolved (μg/L)	<50	7.7	69.0	54.	38.4	1,237
Silica, dissolved (mg/L)	--	1.2	--	45.3	4.2	22.0
Fluoride, dissolved (mg/L)	--	0.38	--	0.59	8.30	2.60
Chloride, dissolved (mg/L)	69.6	7.2	2.1	1.5	3.2	40.0
Nitrate, dissolved (as N) (mg/L)	0	--	0	--	0.20	0.11

Table 6 PARAMETER	SAMPLE LOCATION, AGENCY CONDUCTING THE SAMPLING, AND SAMPLE DATE(S)					
	Denton Spring USBOR 04-91	Denton Spring SLV LAB 01-93	Indian Spring USBOR 04-91	Indian Spring SLV LAB 12-90	Indian Spring SLV LAB 01-93	Drainage above Indian Spring SLV LAB 01-93
Sulfate, dissolved (mg/L)	29.8	27.8	39.4	--	20.2	286.0
Copper, dissolved (µg/L)	50	1.4	<5	2.5	3.1	1.4
Lead, dissolved (µg/L)	0	<4.	0	0.	<4.	--
Zinc, dissolved (µg/L)	0	4.4	<10	4.1	9.2	9.2
Arsenic, dissolved (µg/L)	0	--	22	19.5	--	--
Cadmium, dissolved (µg/L)	0	<0.3	0.6	0.4	<0.3	<3
Nickel, dissolved (µg/L)	0	<0.9	0	--	<1.3	--
Mercury, dissolved (µg/L)	0	--	<0.2	--	--	--
Selenium, dissolved (µg/L)	20	--	5.0	3.0	--	--
Silver, dissolved (µg/L)	0	<0.5	0	0.	<0.5	--

Abbreviations used: mg/L = milligrams per liter; µg/L = micrograms per liter; µS/cm = microsiemens/centimeter

Reporting Minimal Concentrations and Missing Data: -- = not tested or no data
< = less than the number shown where that number represents the limit of detectability.
0 = less than detectable where the limit of detectability is not known.

Sources of analyses: **USBOR**, Bureau of Reclamation, San Luis Valley Projects Office Chemistry Lab., Alamosa, CO (sampling at request of the National Monument);
SLV LAB, samples analyzed by SLV Analytical Services, Alamosa, CO (sampling at request of the National Monument; funding by *Friends of the Dunes*).

not possible to assess if the Denton Spring water met State water quality criteria for arsenic, lead, zinc, cadmium, nickel, mercury, silver, copper and selenium. In addition, no data were available for dissolved oxygen, fecal coliform bacteria, ammonia, residual chlorine, boron, undissociated hydrogen sulfide, nitrite, cyanide, or chromium.

Water quality samples outside of but near Great Sand Dunes National Monument, including Indian Springs and the drainage upgradient from Indian Springs, are also provided in Table 6, and can be used for comparative purposes.

Ground-water Hydrology

Aquifers present beneath the Closed Basin part of the San Luis Valley are important for four reasons:

- As sources of ground water for agriculture in the Valley and potable water supplies in the Monument;

- Surface flow conditions in stream channels are influenced by ground water (some segments are gaining streams);

- Interdunal ponds occur where the dune surface intersects ground water;

- Other types of wetlands in the Monument and nearby are also influenced by ground water conditions.

Variations in the basin fill material with depth allow Hanna and Harmon (1989) to subdivide the aquifers within the San Luis Valley into three units (Figure 3). From the surface downward they are the unconfined, active confined, and passive confined aquifers. The unconfined is in the upper Alamosa Formation, above fine-grained lake deposits which are locally known as the blue clay. The water table in most locations is within ten feet of the surface in the unconfined aquifer, which is generally less than 100 feet thick except in areas where the underlying clays pinch out and the base of the unconfined aquifer joins with the active confined aquifer below,

The active confined aquifer, with a thickness range from 500 feet to over 5,000 feet, is below the blue clay layer in the lower Alamosa and upper Santa Fe and Los Pinos Formations. The aquifer base is defined by an unconformity on the east side of the valley and ash-flow tuffs on the west side. In areas that lack the blue clay layer, such as the Monument, the unconfined and active confined aquifers are in hydrologic connection.

The deepest aquifer is the passive confined, so named because of the lack of ground water movement within this aquifer. Its is based in the Precambrian basement rocks, the San Juan volcanic units and the underlying Blanco Basin/Vallejo Formations. Very little is known about this aquifer, but it is believed to have low hydraulic conductivity and poor water quality.

A comparison of the quantities of ground water available beneath the San Luis Valley with the amount of annual precipitation in the valley reveals a paradox. The surface receives less than ten inches of precipitation, yet below the surface is a very large aquifer system (Figure 3). Some early calculations estimated that over 2 billion acre-feet were stored in the aquifers above an elevation of 6,000 feet (Emery, 1971). Ground water is abundant in this arid environment because its source is the much wetter mountains that surround the valley. The San Juan Mountains provide much more recharge than the Sangre De Cristo Mountains due to greater precipitation and larger drainage basin. However, flow from the Sangre de Cristo's is locally important in the vicinity of the Monument. Major mechanisms of recharge include infiltration from streams, flow down-dip through the volcanic and volcaniclastic units (Harmon, 1989), and infiltration from irrigated land.

The western margin of the Sangre de Cristo Mountains is a major recharge zone for aquifers of the Closed Basin segment of the San Luis Valley, including, apparently, deeper aquifers of the Monument (Hearne, 1988). Once the water from the Sangre de Cristo Mountains infiltrates, it also recharges the active, confined aquifer (Hanna and Harmon, 1989). Infiltration of surface water from Sand and Medano Creeks also recharges ground water, perhaps as far westward as the area of ponds, springs and playas in the center of the Closed Basin, between Alamosa, CO, and the Monument (Figure 1) (Harmon, 1989). The actual infiltration rate of this surface water is controlled mainly by condition and behavior of the unconfined aquifer, which, in turn, can be influenced strongly by such factors as

variance in available water due to short-term climatic fluctuations, long-term climatic changes, and anthropogenic alteration of the ground-water level. By inference, there is probable hydraulic connection between surface flow in the Monument, ground water in the unconfined or "regional" aquifer in the Monument, and ground water in some parts of the active confined aquifer of the Closed Basin.

Data derived from monitoring wells suggest that hydrostratigraphy within the confines of Great Sand Dunes National Monument varies from that of the San Luis Valley in significant ways. Most Monument ground-water monitoring wells reveal no artesian water pressure, suggesting that the Valley's confined aquifer (or perhaps just the confining clay layers) are mostly absent beneath the Monument. These clay layers are thought to pinch out to the west of the Monument (Hanna and Harmon, 1989). The unconfined or "regional" aquifer is suspected of being a depths of 125 feet to 150 feet beneath the Monument.

Ground-water Monitoring

In order to gain greater understanding of the Monument's hydrostratigraphy, a ground-water monitoring program (Figure 7) was begun in late 1990, with the installation of a grid of eight wells, mostly less than 25-feet deep, in Medano Creek. Subsequently, other ground-water monitoring wells were drilled in other parts of the Monument. A summary of the wells, their depths, locations, and the aquifers that they intersect is in Table 7. Water-level monitoring data from some of the wells is shown on Figures 8, 9 and 10.

An impetus for the timing of this ground-water monitoring effort was the proposed entrepreneurial exercise of American Water Development, Inc. (AWDI) to pump deep-aquifer San Luis Valley ground water from the Baca Grant for exportation out of the Valley. Based on the hydraulic interconnections described above, it was determined that the proposed ground water withdrawal would cause drawdown of the water table beneath the Monument in varying amounts, depending on location: 75 feet to 150 feet beneath Sand Creek and 25 feet beneath Medano Creek (AWDI model); 32 feet beneath Sand Creek (Colorado State Engineer's model); 150 feet beneath Medano Creek (Hadlock, 1995). These water table drawdowns would affect the point of the terminus of flow for both Sand and Medano Creeks to some degree, thus compromising their ability to prevent escape of blown sand from the dune field. The highly preliminary hydrologic modeling by Hadlock (1995), relying on limited data, predicts that the terminus of flow of Medano Creek would retreat upstream 21,000 feet in response to water table drawdown of 150 feet. The creek would never reach the dune field area under such conditions.

Only a small area of the well grid in Medano Creek (Figure 7) has been examined for detailed information about the hydrostratigraphy. Localized perching of ground water on an aquitard at depths as shallow as 20 feet has been recognized there for the past few years (McCalpin, 1992). This aquitard, comprised of silty, fine- to medium-grained sand with some clay and gravel, was found in Well J''' (J4), but not in Wells D1 or D2, which are 300 feet to the northwest. Beneath this aquitard is another perched aquifer extending to depths of 90 feet to 94 feet and bottomed by a second aquitard, which is believed to be similar to the 20-foot deep aquitard identified by Hadlock (1995), and confirmed to be present by remote-sensing radar tests by the U.S. Geological Survey (no published report).

Testing of the hydraulic conductivity of this aquifer system between 100-foot and 200-foot depths determined a horizontal hydraulic conductivity of 1×10^4 feet/year; vertical hydraulic conductivity was then estimated to be 1×10^3 feet/year (Hadlock, 1995).

Ground water Use

A large-scale ground water extraction activity in place in the eastern part of the San Luis Valley is the Closed Basin Project of the Bureau of Reclamation. This project, which accounts for the majority of ground-water withdrawal from the aquifer system of the Alamosa Basin (Hearne and Dewey, 1988), salvages shallow ground water that would otherwise be lost to non-beneficial evapotranspiration. Ground water is removed until the water table is lowered by about 2 feet and that extracted water is conveyed by canals to the Rio Grande. This project is designed to have no effect on the Monument's water table; the cone of depression from the ground-water removal comes no closer than 3 miles to the Monument boundary (National Park Service, 1990).

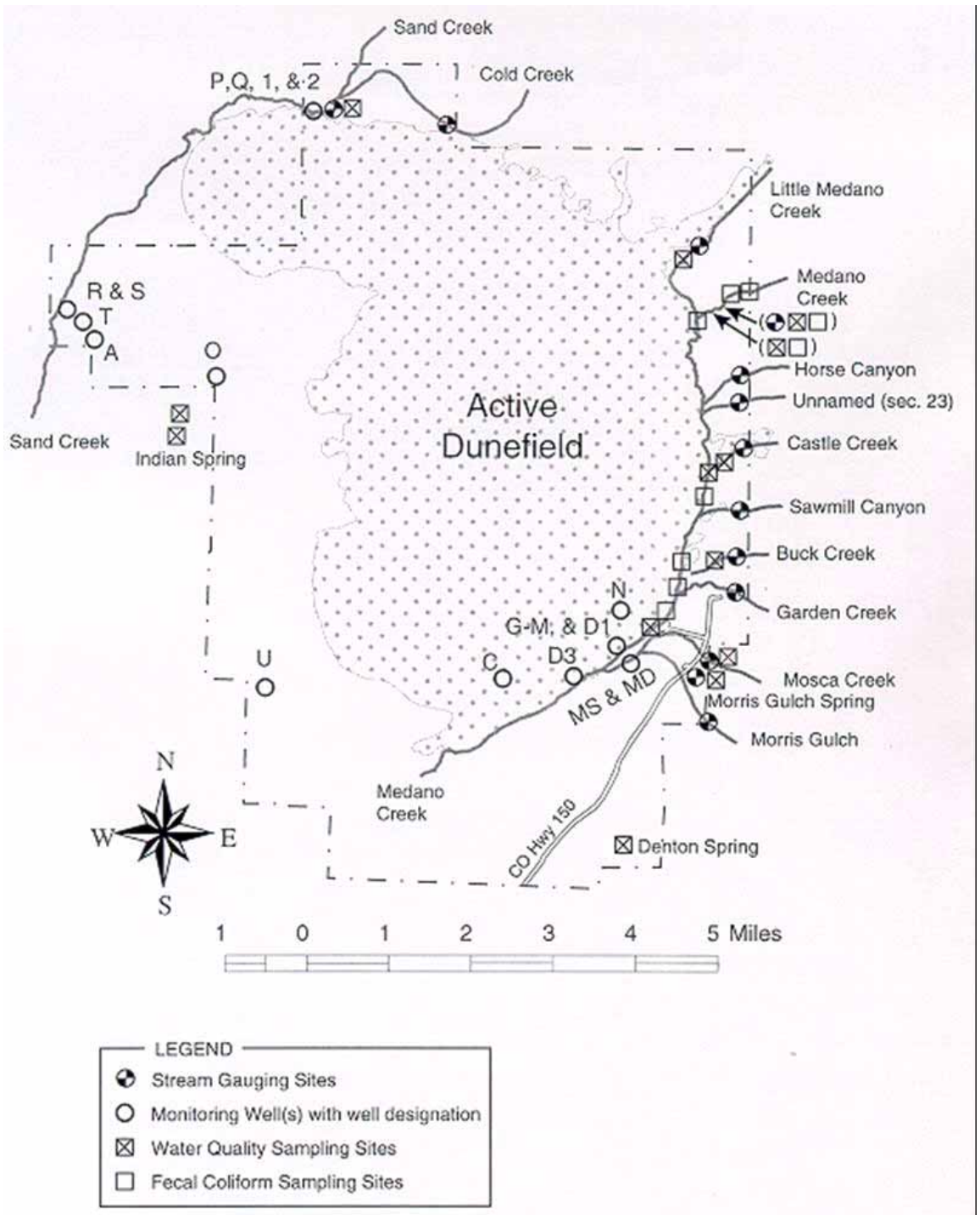

Figure 7. Surface and Ground Water Monitoring Sites

Table 7.--Groundwater Monitoring Wells in Great Sand Dunes National Monument, Colorado.

Refer to Figure 7 for well locations.

Well Name	Location	Date Drilled	Total Depth feet	Water Level (at the time of drilling)		Water Level Stability	Monitoring Method	Aquifers Intersected
				Depth feet	Elevation feet			
A	Sand sheet	1990	<25	≈ 8.5	≈ 7,7673.	Minor Seasonal Fluctuation[2]	Automated[1]	Shallow, perched
C	Dune field base, Medano Cr.	12-2-90	135	132.5	7,747.5	Undetermined	Manual; intermittent	Unconfined "regional"
D1	Medano Cr. well grid	8-17-93	100	71.01	7,945.0	Stable[2]	Manual; bi-weekly or monthly	Unconfined "regional" and shallow, perched
D3	Medano Cr.	8-24-93	100.0	79.18	7,869.9	Stable[2]	Manual; bi-weekly or monthly	Unconfined "regional"
G	Medano Cr. well grid	12-7-90	22	4.5	8,008.8	Fluctuates Seasonally	Manual; bi-weekly or monthly	Shallow, perched
H	Medano Cr. well grid	12-90	≈ 15	3.4	8,009.2	Fluctuated Seasonally	Abandoned 1996	Shallow, perched
I	Medano Cr. well grid	12-7-90	13	3.0	8,006.8	Fluctuates Seasonally	Manual; bi-weekly or monthly	Shallow, perched
J4	Medano Cr. well grid	8-18-93	25	22.76	7,993.5	Fluctuates Seasonally	Currently Buried	Shallow, perched
K	Medano Cr. well grid	12-7-90	13	3.9	8,013.4	Fluctuates Seasonally[2]	Manual; bi-weekly or monthly	Shallow, perched
L	Medano Cr. well grid	12-7-90	23	8.2	8,009.5	Fluctuates Seasonally	Manual; bi-weekly or monthly[4]	Shallow, perched
M	Medano Cr. well grid	8-20-91	14	12.83	8,010.9	Fluctuates Seasonally[2]	Manual; bi-weekly or monthly	Shallow, perched
N	Dune field base, Medano Cr.	7-7-92	18.5	17.08	8,022	Minor Fluctuation	Manual; bi-weekly or monthly	Shallow, perched

Table 7 (continued). Groundwater Monitoring Wells in Great Sand Dunes National Monument, Colorado.

Well Name	Location	Date Drilled	Total Depth feet	Water Level (at the time of drilling)		Water Level Stability	Monitoring Method	Aquifers Intersected
				Depth feet	Elevation feet			
Mosca Deep	Mosca Cr.	8-24-93	50	>50 Dry	<7,968.9	Dry	None	
Mosca Shallow	Mosca Cr.	8-24-93	12	3.95	8,016.1	Varies with Mosca Creek	Manual; bi-weekly or monthly	Shallow, perched
O	Sand Sheet	8-27-93	25	19	7,699.	Stable[2]	Manual; intermittent	Shallow, perched
P	Sand Cr. well grid	8-28-93	40	14.3	7,813.4	No Data	Manual; intermittent	Shallow, Perched
Q	Sand Cr. well grid	8-28-93	30	10.5	7,813.	No Data	Manual; intermittent	Shallow, perched
R	Sand Cr. well grid	8-29-93	105	8.7	7,680.4	Fluctuates Seasonally[2]	Manual; intermittent	Shallow, perched
S	Sand Cr. well grid	8-29-93	31.3	8.0	7,683.2	Fluctuates Seasonally	Manual; intermittent	Shallow, perched
T	Sand Cr. well grid	8-29-93	99	12.6	7,677.6	Minor Fluctuation[2]	Manual; intermittent	Shallow, perched
U	Sand Sheet	4-18-96	8	4.8	7,689.0	Stable[2]	Automated	Shallow, Perched
Well 1	Sand Cr. Well Grid	10-8-92	11	5.8	7,839.2 (Est.)	Fluctuates Seasonally[2]	Automated; hourly	Shallow, Perched
Well 2	Sand Cr. Well Grid	10-8-92	12	8.8	7,836.2 (Est.)	Fluctuates Seasonally[2]	Automated; hourly	Shallow, Perched

[1] Data recorded on punch tapes that are downloaded into U.S. Geological Survey database, Pueblo, CO.

[2] Figures 8, 9, and 10 show a graphical record of water level fluctuations in these wells.

[3] Automated monitoring with druck pressure transducer and datapod from September 1991 to April 1992 (McCalpin, 1993).

[4] Automated monitoring with druck pressure transducer and datapod from September 1991 to January 1992 (McCalpin, 1993).

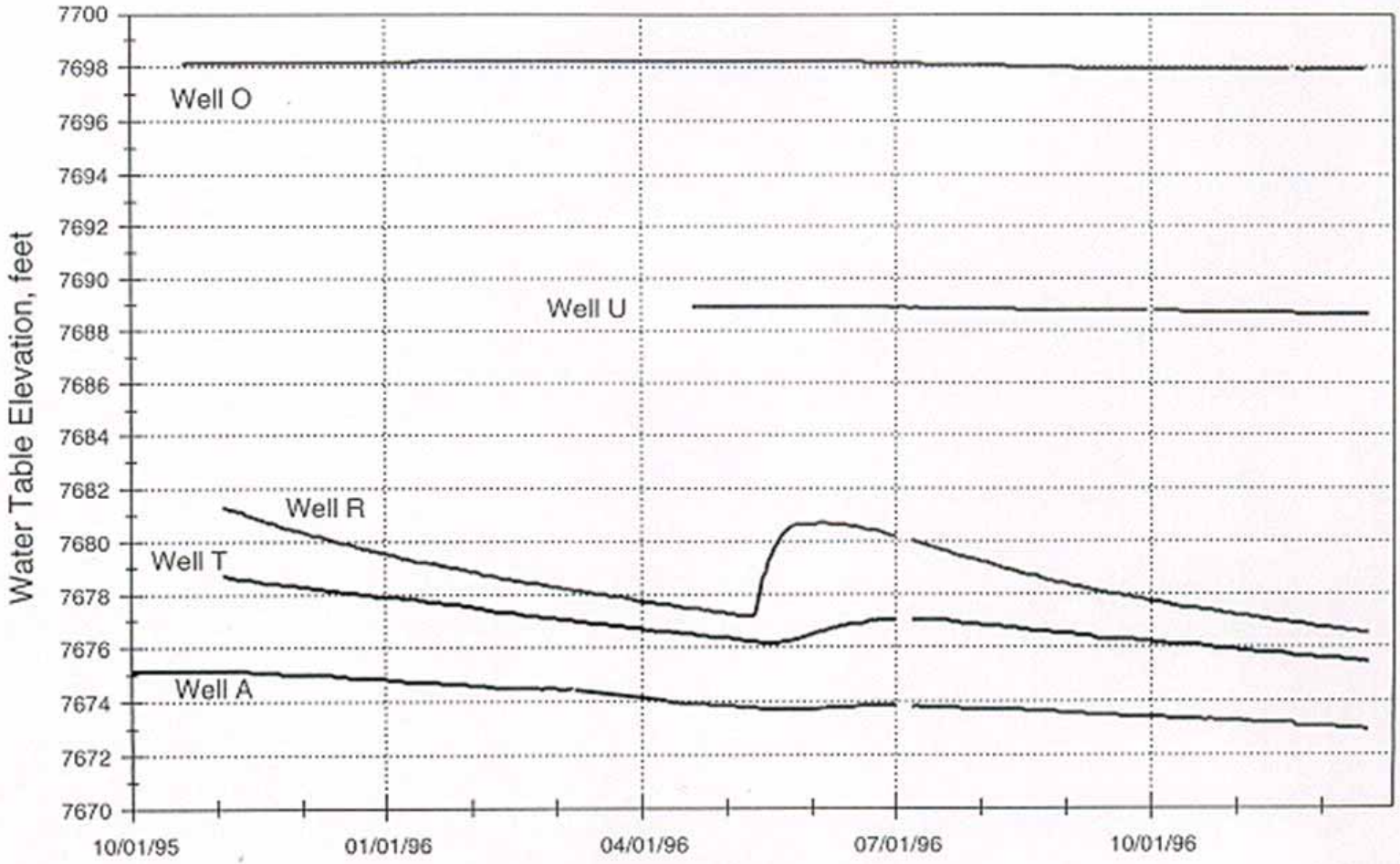

Figure 8. Water Levels in West Side Wells, Wells O, U, T, R, and A, for October 1995 to November 1996

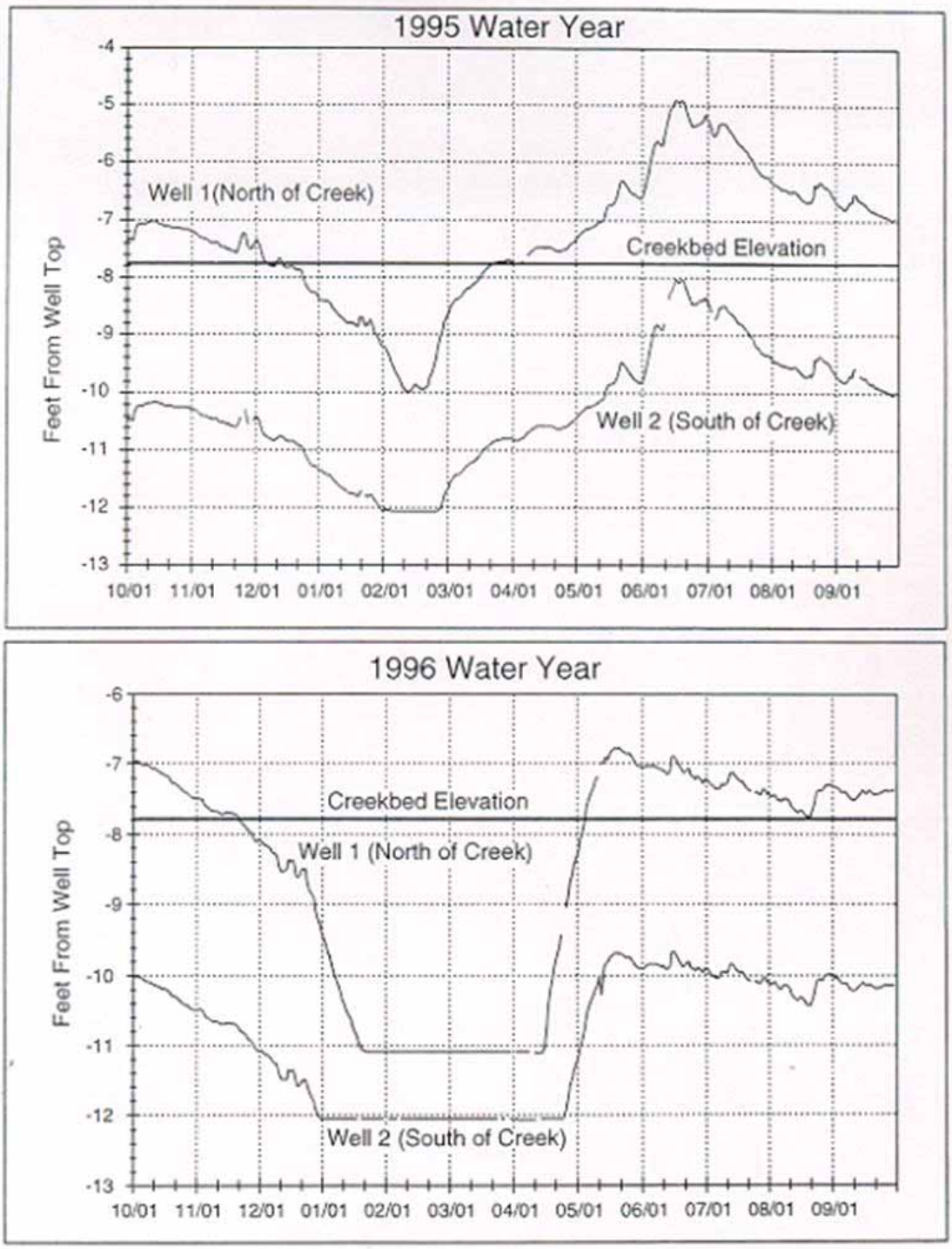

Figure 9. Water Levels in Sand Creek Flume Wells, Wells 1 and 2, for Water Years 1995 and 1996

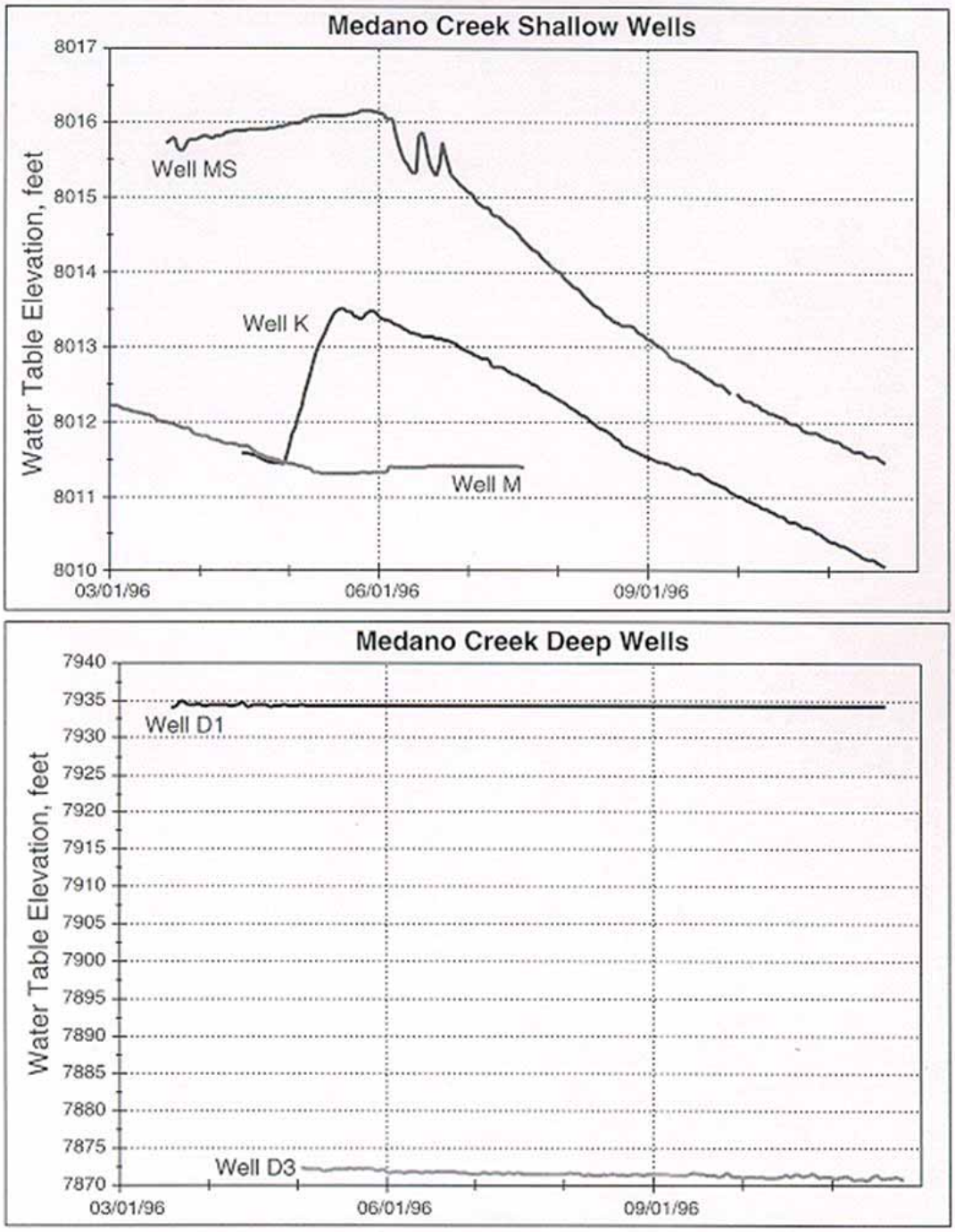

Figure 10. Water Levels in Medano Creek Wells, Wells K, M, MS, D1, AND D3, for March to November, 1996.

Ground Water quality

Limited amounts of ground-water quality analytical data are available. Samples have been collected from three of the four Great Sand Dunes National Monument water supply wells and from several ground-water monitoring wells, including six in Medano Creek, one in the sand sheet, and two from the edge of the dune field (Table 8, parts a and b, and Table 9).

Ground-Water Quality Standards

Great Sand Dunes National Monument ground water is regulated under the State of Colorado-Water Quality Control Commission's interim narrative standard, applicable to all ground waters with less than 10,000 mg/L of total dissolved solids. Certain statewide numeric standards apply also. No classified uses have been established for Great Sand Dunes National Monument ground water, and thus it is not within any existing State "Specified Area", to which site-specific numeric standards would apply (State of Colorado, 1994c; 1995b). Numeric standards applicable to the Monument's ground water are statewide interim numeric standards (see Appendix B, parts 2 and 3), or existing ambient water quality as of January 31, 1994, whichever is less stringent, although this does not preclude cleanup of already polluted areas of ground water. Further, there are additional statewide interim numeric standards for radioactive material (State of Colorado, 1995b):

	picocuries/liter
Cesium (^{134}Cs)	80
Plutonium ($^{238, 239, \text{and } 240}Pt$)	15
Radium ($^{226 \text{ and } 228}Ra$)	5
Strontium (^{90}Sr)	8
Thorium ($^{230 \text{ and } 232}Th$)	60
Tritium	20,000

Assessment of ground-water quality

Only a partial assessment of ground-water quality can be made due to the absence of data for many of the chemicals and characteristics addressed by standards. Further, it should be noted that assessment of analytical data relative to many of the inorganic chemicals for which content is known (arsenic, boron, cadmium, chloride, chromium, copper, fluoride, iron, lead, manganese, mercury, nickel, nitrate, selenium, silver, sulfate, zinc) is only tentative, because it cannot be ascertained whether current sampling protocols relative to filtering and preserving (acidifying) the samples were followed. In some of the older samples, particularly, it is likely that current protocols were *not* followed.

No ground-water samples were analyzed for aluminum, antimony, asbestos, barium, beryllium, cobalt, cyanide, lithium, nitrite, total nitrite plus nitrate, thallium, vanadium, organic chemicals, foaming agents, or radioactivity of alpha, beta, and photon emitters, or the characteristics of color, corrosivity, and odor due to lack of laboratory testing for those contents and characteristics.

Ground water in near-surface aquifers.-- Monitoring wells A, G, H, I, J4, K, L, and N all intersect only shallow, near-surface aquifers wherein infiltration is impeded, likely by thin and discontinuous clay layers deposited during the recent geologic history of local creek bed migrations. These waters therefore are indicative of only the water quality in the shallowest ground water in the Monument. Samples from these monitoring wells contain less than the statewide interim numeric levels of dissolved solids, arsenic, cadmium, chloride, chromium, fluoride, mercury, nickel, nitrate, silver, sulfate, zinc (within sampling protocol uncertainties discussed above), and also are within the suitable range for pH (Table 8, parts a and b; Table 9; Appendix B, part 2).

Samples that exceed statewide interim levels are: one sample from Well C exceeding both human health and agricultural use interim levels for lead; one sample from Wells I, K, and N, and two samples from Well C exceeding both secondary drinking water and agricultural use interim numeric levels for iron; several samples (Wells A, C, H, I, K) exceeding secondary drinking water interim levels for manganese and a few of those also exceeding agricultural use interim levels for manganese; one sample from both Wells G and H exceeding human health interim levels for selenium. The higher concentrations of several parameters in Well C, as compared to the other shallow wells, can be attributed to its location away from the active recharge zone, thus indicating a longer residence time for water and/or the influence of the regional aquifer.

Table 8, part a. Groundwater Quality Analyses from Monitoring Wells in Medano Creek, Great Sand Dunes National Monument, Colorado. Refer to Figures 7 for well locations.

Table 8a PARAMETER	WELL, SAMPLING AGENCY, DATE OF SAMPLE									
	Well G USBOR 04-91	Well G SLV LAB 03-92	Well H USBOR 04-91	Well H SLV LAB 03-92	Well I USBOR 04-91	Well I SLV LAB 03-92	Well J USBOR 04-91	Well K USBOR 04-91	Well K SLV LAB 04-92	Well L USBOR 04-91
Number of samples	n = 1	n = 1	n = 1	n = 1	n = 1	n = 1	n = 1	n = 1	n = 1	n = 1
pH	7.3	7.00	7.0	6.9	7.1	6.9	7.5	7.6	6.5	7.5
Specific conductance (µS/cm)	83	84	74	92	96	97	89	91	87	96
Dissolved solids residue at 180°C. (mg/L)	98	--	88	--	84	--	52	76	--	96
Alkalinity (total as $CaCO_3$) (mg/L)	--	--	--	--	--	--	--	--	--	--
Sodium, dissolved (mg/L)	2.8	2.2	3.4	2.2	3.4	2.4	2.8	3.4	2.3	3.4
Potassium, dissolved (mg/L)	3.9	1.8	3.9	1.9	3.9	2.3	5.9	3.9	1.9	4.3
Calcium, dissolved (mg/L)	11.2	1.8	10.4	2.4	12.8	2.3	12.8	12.0	1.7	13.6
Magnesium, dissolved (mg/L)	2.0	1.4	2.4	1.6	2.9	1.5	3.9	2.4	1.4	2.9
Hardness (total as $CaCO_3$) (mg/L)	--	--	--	--	--	--	--	--	--	--
Carbonate, dissolved (mg/L)	0	--	0	--	0	--	0	0	--	0
Bicarbonate, dissolved (mg/L)	34.2	--	5.5	--	39	--	39	42.1	--	44.5
Iron, dissolved (µg/L)	55	70	250	50	7,600	70	4,670	455	90	<50
Manganese, dissolved (µg/L)	<50	1.8	53	<2	1,200	<2	2,690	388	<2	<50
Silica, dissolved (mg/L)	--	9.8	--	10.1	--	11.4	--	--	10.7	--
Fluoride, dissolved (mg/L)	--	0.2	--	0.15	--	0.14	--	--	0.18	--
Chloride, dissolved (mg/L)	2.1	1.5	2.1	1.5	3.9	2.5	2.1	2.1	2.5	2.1
Orthophosphate, dissolved (as P) (mg/L)	--	--	--	--	--	--	--	--	--	--
Nitrate, dissolved (as N) (mg/L)	--	--	--	--	--	--	--	--	--	--
Nitrate, dissolved (as NO_3) (mg/L)	0	--	0	--	0	--	0	0	--	0

Table 8a PARAMETER	WELL, SAMPLING AGENCY, DATE OF SAMPLE									
	Well G USBOR 04-91	Well G SLV LAB 03-92	Well H USBOR 04-91	Well H SLV LAB 03-92	Well I USBOR 04-91	Well I SLV LAB 03-92	Well J USBOR 04-91	Well K USBOR 04-91	Well K SLV LAB 04-92	Well L USBOR 04-91
Sulfate, dissolved (mg/L)	10.6	--	13.9	--	12.0	--	13.9	8.2	--	10.1
Copper, dissolved (µg/L)	<5	<6	0	<6	10	<6	14	5	<6	0
Lead, dissolved (µg/L)	0	<23	0	<23	13	<23	20	11	<23	<5
Zinc, dissolved (µg/L)	0	8	<10	6	95	42	1,250	22	7	--
Arsenic, dissolved (µg/L)	<5	5	0	4	5	3	5.5	0	4	0
Cadmium, dissolved (µg/L)	0	<2.5	0	<2.5	0	<2.5	1.3	0	<2.5	0
Chromium, dissolved (µg/L)	0	--	0	--	0	--	0	0	--	0
Nickel, dissolved (µg/L)	0	--	0	--	<5	--	<5	0	--	0
Mercury, dissolved (µg/L)	0	--	0	--	0.2	--	<0.2	<0.2	--	0
Selenium, dissolved (µg/L)	0	15	0	14	0	<4	0	<2	<4	<2
Silver, dissolved (µg/L)	0	<4	0	<4	0	<4	0	0	<4	0

Abbreviations used: mg/L = milligrams per liter; µg/L = micrograms per liter; µS/cm = microsiemens/centimeter

Reporting Minimal Concentrations and Missing Data:
-- = not tested or no data
< = less than the number shown where that number represents the limit of detectability.
0 = less than detectable where the limit of detectability is not known.

Sources of analyses: **USBOR**, Bureau of Reclamation, San Luis Valley Projects Office Chemistry Lab., Alamosa, CO (sampling at request of the National Monument); **SLV LAB**, samples collected and analyzed by SLV Analytical Services, Alamosa, CO (sampling at request of the National Monument; funding from *Friends of the Dunes*).

Table 8, part b. Groundwater Quality Analyses from Monitoring Wells in Medano Creek, Great Sand Dunes National Monument, Colorado. Refer to Figures 7 for well locations.

Table 8b PARAMETER	WELL, SAMPLING AGENCY, DATE OF SAMPLE										
	Well G SLV LAB 12-90	Well G SLV LAB 01-93	Well H SLV LAB 12-90	Well H SLV LAB 01-93	Well I SLV LAB 12-90	Well I SLV LAB 01-93	Well J SLV LAB 12-90	Well J SLV LAB 01-93	Well K SLV LAB 12-90	Well K SLV LAB 01-93	Well L SLV LAB 12-90
Number of samples	n = 1	n = 1	n = 1	n = 1	n = 1	n = 1	n = 1	n = 1	n = 1	n = 1	n = 1
pH	--	7.4	--	6.6	--	6.5	--	6.4	--	6.3	--
Specific conductance (µS/cm)	--	82	--	93	--	98	--	--	--	82	--
Dissolved solids residue at 180°C. (mg/L)	--	--	--	--	--	--	--	--	--	--	--
Alkalinity (total as $CaCO_3$) (mg/L)	--	38	--	42	--	48	--	42	--	42	--
Sodium, total recoverable (mg/L)	3.0	3.4	3.2	3.6	5.0	3.6	3.3	3.7	3.3	3.5	3.0
Potassium, total recoverable (mg/L)	2.5	1.9	3.0	2.0	7.1	2.0	6.4	3.2	3.4	2.0	2.5
Calcium, total recoverable (mg/L)	0.8	1.7	0.3	2.5	2.1	2.9	5.1	1.8	0.1	1.7	0.6
Magnesium, total recoverable (mg/L)	0.5	1.3	0.4	1.5	3.3	1.5	5.6	1.3	0.4	1.2	0.4
Hardness (total as $CaCO_3$) (mg/L)	--	--	--	--	--	--	--	--	--	--	--
Carbonate, total recoverable (mg/L)	--	0.1	--	0.0	--	0.0	--	0.0	--	0.0	--
Bicarbonate, total recoverable (mg/L)	--	37.9	--	42.0	--	48.0	--	42.0	--	42.0	--
Iron, total recoverable (µg/L)	79	134	278	33.1	8,350	85.4	4,970	270	500	103	52
Manganese, total recoverable (µg/L)	15	4.6	69	1.9	1,150	2.6	2,800	43.5	461	7.4	23
Silica, total recoverable (mg/L)	22.8	1.9	25.4	1.9	26.6	2.1	26.8	2.6	27.1	2.1	24.5
Fluoride, total recoverable (mg/L)	0.2	<0.1	0.19	<0.1	0.22	<0.1	0.16	<0.1	0.20	<0.1	0.19

Table 8b PARAMETER	WELL, SAMPLING AGENCY, DATE OF SAMPLE										
	Well G SLV LAB 12-90	Well G SLV LAB 01-93	Well H SLV LAB 12-90	Well H SLV LAB 01-93	Well I SLV LAB 12-90	Well I SLV LAB 01-93	Well J SLV LAB 12-90	Well J SLV LAB 01-93	Well K SLV LAB 12-90	Well K SLV LAB 01-93	Well L SLV LAB 12-90
Chloride, total recoverable (mg/L)	1.5	2.6	1.0	4.5	1.0	3.8	1.0	3.2	1.5	3.2	1.5
Orthophosphate, total recov. (as P) (mg/L)	--	0.3	--	0.9	--	0.1	--	0.9	--	0.1	--
Nitrate, total recoverable (as N) (mg/L)	--	0.30	--	0.20	--	0.30	--	0.20	--	0.15	--
Nitrate, total recoverable (as NO_3) (mg/L)	--	1.30	--	0.90	--	1.30	--	0.90	--	0.70	--
Sulfate, total recoverable (mg/L)	--	0.9	--	0.4	--	0.5	--	--	--	--	--
Copper, total recoverable (µg/L)	1.3	1.6	1	0.9	14	1.6	19	5.3	6.3	0.9	1
Lead, total recoverable (µg/L)	18	<4	0	<4	18	<4	18	<4	14	<4	5
Zinc, total recoverable (µg/L)	2	2.2	8.8	1.0	106	3.9	136	19.1	29	2.7	0
Arsenic, total recoverable (µg/L)	2.5	--	1.6	--	8	--	7.5	--	0	--	0.4
Cadmium, total recoverable (µg/L)	0	<0.3	0	<0.3	0	<0.3	1.7	<0.3	0	<0.3	--
Chromium, total recoverable (µg/L)	--	--	--	--	--	--	--	--	--	--	--
Nickel, total recoverable (µg/L)	--	<0.9	--	0.9	--	0.9	--	4.0	--	<1.3	--
Mercury, total recoverable (µg/L)	--	--	--	--	--	--	--	--	--	--	2
Selenium, total recoverable (µg/L)	0	--	0	--	0	--	0	--	2	--	0
Silver, total recoverable (µg/L)	0	<0.5	0	<0.5	0.2	<0.5	0	<0.5	0	<0.5	0

Abbreviations used: mg/L = milligrams per liter; µg/L = micrograms per liter; µS/cm = microsiemens/centimeter

Reporting Minimal Concentrations and Missing Data:
-- = not tested or no data
< = less than the number shown where that number represents the limit of detectability.
0 = less than detectable where the limit of detectability is not known.

Sources of analyses:
USBOR, Bureau of Reclamation, San Luis Valley Projects Office Chemistry Lab., Alamosa, CO (sampling at request of the Monument);
SLV LAB, samples collected and analyzed by SLV Analytical Services, Alamosa, CO (sampling at request of the Monument; funding from *Friends of the Dunes*).

Table 9. Groundwater Quality Analyses from Water Supply Wells and Monitoring Wells in the Sand Sheet & Base of the Dune Field, Great Sand Dunes National Monument, Colorado. Most analyses are for DISSOLVED as indicated by unshaded blocks, except for SLV LAB samples, which are expressed as TOTAL RECOVERABLE and indicated by shaded columns. Refer to Figures 7 for well locations. NOTE: Well C sample of 1990 contains high sediment content which was not removed with filtering.

Table 9	WELL, SAMPLING AGENCY, DATE OF SAMPLE								
PARAMETER	Well No. 1 USGS 04-64	Well No. 3 USGS 08-78	Well No. 4 USGS 07-78	Well A USBOR 04-91	Well C USBOR 04-91	Well A SLV LAB 12-90	Well C SLV LAB 12-90	Well C SLV LAB 01-93	Well N SLV LAB 01-93
Number of samples	n = 1	n = 1	n = 1	n = 1	n = 1	n = 1	n = 1	n = 1	n = 1
pH	8.0	7.9[1]	7.9[1]	8.0	7.1	--	--	7.7	6.7
Specific conductance (µS/cm)	373	455	436	179	195	--	--	142	73
Dissolved solids residue at 180°C. (mg/L)	230	275	267	132	180	--	--	--	--
Alkalinity (total as $CaCO_3$) (mg/L)	--	210	200	--	--	--	--	38	20
Sodium, dissolved (mg/L); [SLV LAB TOTAL RECVR.]	18	13	18	9.9	6.0	8.1	5.8	5.8	4.2
Potassium, dissolved (mg/L); [SLV LAB TOTAL RECVR.]	1.7	1.5	1.0	9.4	7.0	5.9	8.4	8.7	2.1
Calcium, dissolved (mg/L); [SLV LAB TOTAL RECVR.]	50	72	64	15.2	22.4	1.0	4.7	11.3	0.7
Magnesium, dissolved (mg/L); [SLV LAB TOTAL RECVR.]	8.0	9.8	8.8	9.8	3.9	0.9	5.6	8.6	0.5
Hardness (total as $CaCO_3$) (mg/L)	158	220	200	--	--	--	--	--	--
Hardness (non-carbonate) (mg/L)	6	15	0	--	--	--	--	--	--
Carbonate, dissolved (mg/L); [SLV LAB TOTAL RECVR.]	0	--	--	0	0	--	--	0.2	0.0
Bicarbonate, dissolved (mg/L); [SLV LAB TOTAL RECVR.]	186	250	240	57.9	5.5	--	--	37.8	20.0
Iron, dissolved unless noted (µg/L); [SLV LAB TOTAL RECVR.]	40[2]	50	70	135	9,550	102	10,230	15,200	19.1
Manganese, dissolved (µg/L); [SLV LAB TOTAL RECVR.]	--	70	560	54	1,470	31	1,530	3,300	2.0
Silica, dissolved (mg/L); [SLV LAB TOTAL RECVR.]	21	16	20	--	--	41.8	30.0	3.0	2.9
Fluoride, dissolved (mg/L); [SLV LAB TOTAL RECVR.]	0.4	0.8	1.6	--	--	0.75	0.22	<0.1	0.10

Table 9 PARAMETER	WELL, SAMPLING AGENCY, DATE OF SAMPLE								
	Well No. 1 USGS 04-64	Well No. 3 USGS 08-78	Well No. 4 USGS 07-78	Well A USBOR 04-91	Well C USBOR 04-91	Well A SLV LAB 12-90	Well C SLV LAB 12-90	Well C SLV LAB 01-93	Well N SLV LAB 01-93
Chloride, dissolved (mg/L); [SLV LAB TOTAL RECVR.]	9.8	5.3	6.7	5.7	2.1	2.5	1.5	5.6	4.3
Orthophosphate, diss.(as P)(mg/L); [SLV LAB TOTAL RECVR.]	--	--	--	--	--	--	--	1.1	0.2
Nitrate, dissolved (as N) (mg/L); [SLV LAB TOTAL RECVR.]	--	--	--	--	--	--	--	8.1	3.8
Nitrate, dissolved (as NO_3) (mg/L); [SLV LAB TOTAL RECVR.]	2.2	--	--	0	0	--	--	35.9	16.8
Sulfate, dissolved (mg/L); [SLV LAB TOTAL RECVR.]	28	31	26	24	15.8	--	--	18.0	6.6
Copper, dissolved (µg/L); [SLV LAB TOTAL RECVR.]	--	--	--	5.0	15	2.9	19	--	1.4
Lead, dissolved (µg/L); [SLV LAB TOTAL RECVR.]	--	--	--	0	15	0	18	270	<4
Zinc, dissolved (µg/L); [SLV LAB TOTAL RECVR.]	--	--	--	46	215	36	241	251	27.8
Arsenic, dissolved (µg/L); [SLV LAB TOTAL RECVR.]	--	--	--	0	<5	0	5.8	--	--
Cadmium, dissolved (µg/L); [SLV LAB TOTAL RECVR.]	--	--	--	0	0.8	0.4	1.3	--	<0.3
Chromium, dissolved (µg/L); [SLV LAB TOTAL RECVR.]	--	--	--	0	0	--	--	--	--
Nickel, dissolved (µg/L); [SLV LAB TOTAL RECVR.]	--	--	--	0	0	--	--	92.0	4.0
Mercury, dissolved (µg/L); [SLV LAB TOTAL RECVR.]	--	--	--	<0.2	0.2	--	--	--	--
Selenium, dissolved (µg/L); [SLV LAB TOTAL RECVR.]	--	--	--	0	2.0	0	3	--	--
Silver, dissolved (µg/L); [SLV LAB TOTAL RECVR.]	--	--	--	0	0	0	0	<0.5	<0.5

Abbreviations used: mg/L = milligrams per liter; µg/L = micrograms per liter; µS/cm = microsiemens/centimeter

Reporting Minimal Concentrations and Missing Data:
-- = not tested or no data
< = less than the number shown where that number represents the limit of detectability.
0 = less than detectable where the limit of detectability is not known.

Sources of analyses:
USGS, U.S. Geological Survey, Water Resources Division, Denver, CO
USBOR, Bureau of Reclamation, San Luis Valley Projects Office Chemistry Lab., Alamosa, CO (sampling at request of the National Monument)
SLV LAB, samples analyzed by SLV Analytical Services, Alamosa, CO (sampling at request of the National Monument; funding from *Friends of the Dunes*).

[1] pH determined in laboratory for these samples only.
[2] Total.

Ground water in the upper part of the unconfined aquifer.--All three of the water supply wells for which analyses are available apparently penetrate the upper part of the unconfined or "regional" aquifer, and thus are indicative of water quality in this deeper ground water to at least some degree. The conclusion is based on both the variant water chemistry in these deeper samples as compared to the water in the uppermost, perched aquifers, and also the depth of the wells and the estimated depth of the unconfined aquifer at the sampled locations. The 250-foot deep, uncased, Well No. 4 is indicative of quality of a mixture of water from both the shallow, perched aquifers and the uppermost part of the unconfined aquifer. The 375-foot deep Well No. 3, which is cased to a depth of 115 feet, is indicative solely of the water quality in the upper part of the unconfined aquifer. Similarly, the 350-foot deep well No. 1 is indicative of water quality in solely the upper part of the unconfined aquifer, because it is cased to the hole diameter to a depth of 146 feet.

Few tests that are addressed by statewide interim numeric levels of chemicals were performed on samples from these wells, including most metals (only manganese was determined). Water from Wells No. 3 and 4 exceeds interim levels of manganese for secondary drinking water use; water from Well No. 4 also exceeds agricultural use interim levels for manganese. Samples are within the interim levels for pH, dissolved solids, fluoride, chloride, sulfate, and nitrate. Water in Well No. 1 is within interim levels for boron content (not listed in Table 9); boron content was not tested in the other two water supply wells. No further assessment can be made with existing data.

Water Supply and Water Treatment Systems

The initial potable water supply system (since abandoned) was emplaced at the Great Sand Dunes National Monument in 1939 to serve the only two facilities in existence at that time: the headquarters building (then a residence) and a campground (now a picnic area). Water supplies came from Morris Gulch Spring and Mosca Spring respectively (Glen Bean, National Park Service-retired, personal commun., April 1995). The water was gathered through collection boxes at the springs, and moved through pipelines by gravity flow to cement reservoirs near the use sites. No pumps were used and there was no water treatment. No quantification of that era of water usage is known.

The 1950's-era drought caused Morris Gulch and Mosca Springs to "nearly dry up" in 1956 (National Park Service-Water Resources Division file data, Fort Collins, CO, 1957), forcing development of new water supplies. Since that time, water wells were drilled and well water became the source for the Monument's domestic, administrative, and operational needs. Well locations are shown on Figure 11.

Changes made in response to the drought resulted in the development, over several years, of the two separate water supply systems that currently serve the Monument. All water now is derived from ground water, through four wells. Wells No. 2 and 4 supply one system, officially registered as Public Water Supply System identification number (PWSID) 202350, which serves the Piñon Flats Campground area and the following specific facilities: five comfort stations, six water fountains, one seasonal residence, and an RV dump station. Well No. 2 supplies the vast majority of the campground system's water. A pipeline connects that well to a 50,000 gallon steel reservoir located on the upper slopes of an alluvial fan 300 feet northeast of the group campground loop (Figure 11). From this pipeline are branching, 2-inch, cast iron pipes that transport water to the various facilities. It is only at the beginning of the visitor season that Well No. 4 is utilized, to slowly fill the 50,000 gallon reservoir as Well No. 2 supplies the immediate water needs of the campground. Both wells connect to the same distribution pipeline, but are separated on that pipeline by a valve. All water facilities on the campground system except one comfort station, and the seasonal housing on the residential system are taken off line and drained during the off season. Water use varies considerably in the course of a year (Figure 12).

A second water supply system (PWSID 202300) serves the visitor's center, residential housing, administrative area, maintenance shop, horse barn, picnic area, and dunes parking lot. Water from Well No. 1 supplies nearly all the water, although Well No. 3 can be operated manually to supplement the supply during times of peak use. Well No. 3 is utilized for an annual total of about only 40 hours. The system utilizes a 50,000 gallon steel reservoir, east of and uphill from the horse barn. Distribution is through

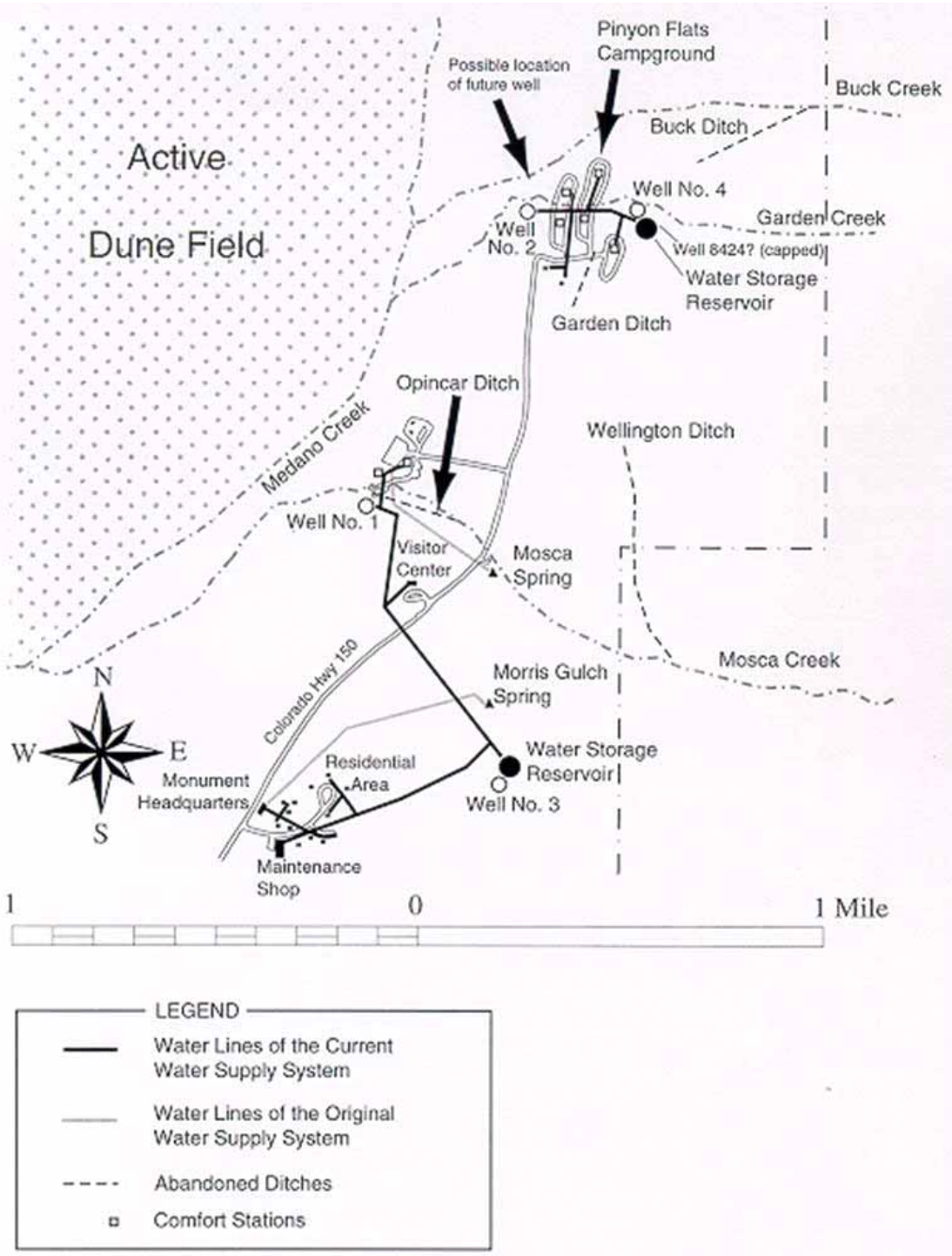

Figure 11. Water Supply Systems of Great Sand Dunes National Monument.

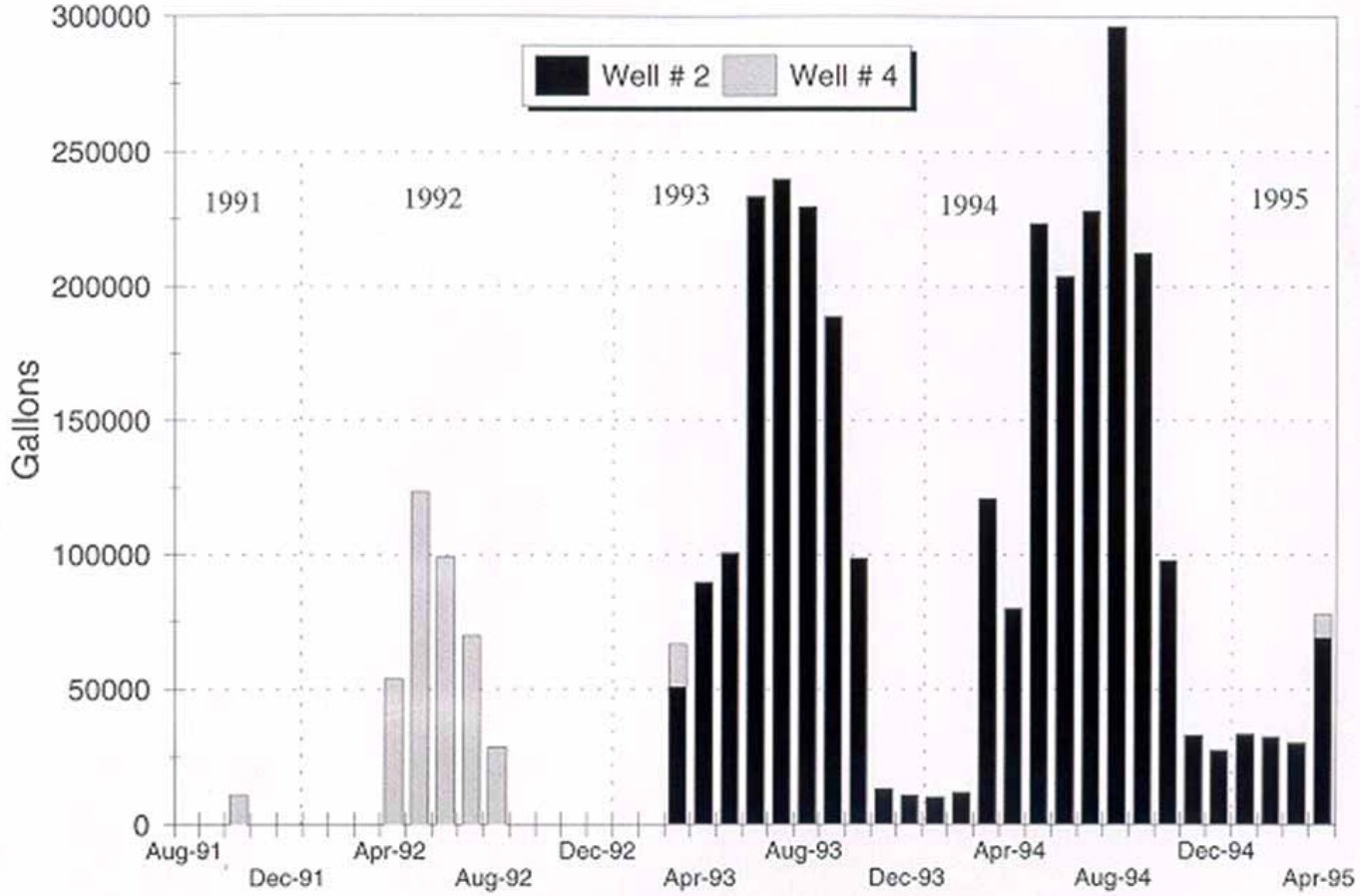

Figure 12. Quantified Water Use from the Campground Water Supply System (PWSID 202350)

4-inch cement, asbestos pipes that branch off the pipeline leading from Well No. 1 to the storage reservoir (Great Sand Dunes National Monument file data). Water use from this system is graphed on Figure 13.

Both systems are classified as Public, Transient, Non-community Water Systems (PNC) because few people (less than 25) constitute the permanent, year-round resident population and/or there are less than 15 total service connections. All use of the campground system is by a transient population (estimated at 75 persons at any one time during the summer season). The residential system serves 22 year-round residents, and none of the other users of that system, seasonal employees hired during the visitor season, use the system for as much as six months (National Park Service, 1993, p. 2; Bruce Hart, National Park Service-Great Sand Dunes National Monument, personal commun., February 1995; Sheryl Kendall, Colorado Water Quality Control Division, Drinking Water Section, personal commun., March 17, 1995). Because of the limited number of people with long-term exposure to the water of a PNC system, stringency of monitoring is reduced.

Descriptions of Wells

Well No. 1

"Well No. 1" (official identification GRSA W342673AF01; permit no. 36273-F) was initially drilled under permit 16400, and is thus referred to in old National Park Service files as both "well 16400" and "the Mosca Creek Well." It is located on the valley floor, southeast of the South Ramada picnic site, and about 0.9 miles northwest of and 275 feet lower than its storage reservoir. The historical use for Well No. 1 was domestic and irrigation. Well No. 1 was drilled in "fractured basement rock" from April through May 1957 to a depth of 350 feet. It is constructed as follows: cased with 12 3/4-in. steel casing between 0 feet and 146 feet; also cased between 0-feet and 290-feet with 8 5/8-in. steel casing; perforated casing was reported in different sources as between 250-feet and 280-feet and between 290-feet and 320-feet (the latter reported by the State Engineer). The static water tests in 1957 showed a flow rate of 18 gpm; flow of 80 gpm was sustained for 6 hours (G.W. Miller, National Park Service-Region 3 Assistant Regional Director, Santa Fe, NM, written commun., February 2, 1962; National Park Service-Water Resources Division file data, Fort Collins, CO, no date).

Wells No. 2 and No. 8424

"Well No. 2" (official identification GRSAW352673AF02; permit no. 04331F), located in Piñon Flats Campground on the lower slopes of an alluvial fan, 0.3 miles west of and about 150 feet below the storage reservoir, was drilled between July 17 and August 1, 1963. No well log or descriptive information, data on total depth or casing, etc., was found in the course of this plan development. A contamination problem with this well, possibly related to the sewage system of the campground or other domestic water use, was noted and in May 1983 a replacement well was drilled (well permit 08424). Well 08424 did not yield water in the quantities anticipated, having a flow of only 2 to 3 gpm (National Park Service-Water Resources Division file data, Fort Collins, CO). A precise location of well 08424 is not known.

Well No. 3

"Well No. 3" (official identification GRSA W022773AF03; permit no. 036263-F), a new well to replace an existing well ("Well No. 1"), is located above the work center and staff residential area, about 25 feet south of the storage reservoir. The well, having an 8-in.-diameter, was drilled to a depth of 375 feet between June 23 and August 4, 1978, and is constructed as follows: open hole between 115-feet and 375-feet; 8-in. casing between 10-feet and 115-feet; concrete grouting between 0-feet and 10-feet. The static water level was at 117 feet at the time of completion. Pumping tests, conducted in August 1978, indicate that the maximum pumping rate should not exceed 35 gpm. The well, drilled entirely in hard rock, produced an average of 25 to 30 gpm over 8 hours at the time of the initial pumping tests. In approximately the late 1970's, the flow rate became unpredictable, and the well is no longer capable of producing 25 gpm, and in dry times, flow has fallen as low as 8 gpm (Bill Wellman, National Park Service-Great Sand Dunes National Monument, written commun., 1993; National Park Service-Water Resources Division file data, Fort Collins, CO, no date.)

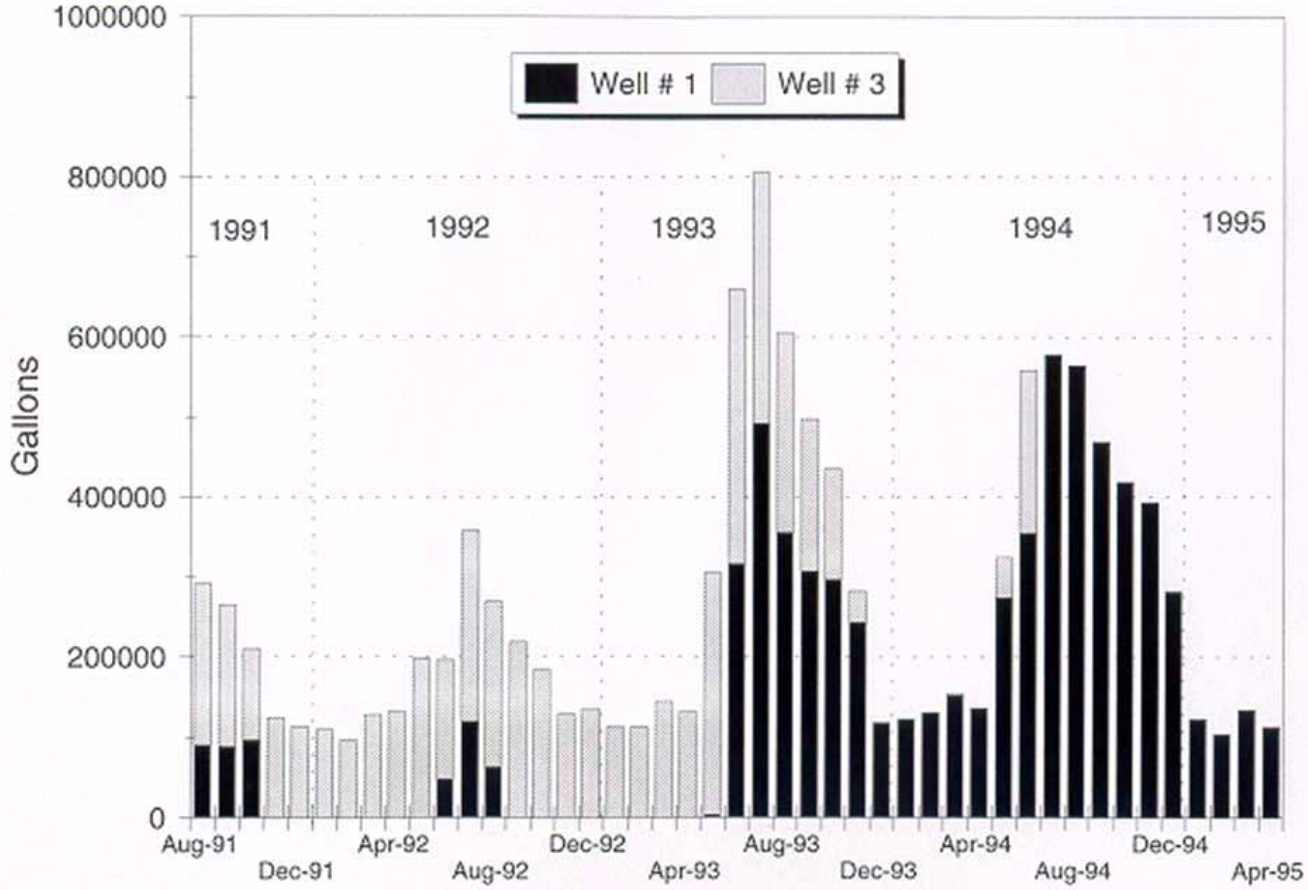

Figure 13. Quantified Water Use from the Residential Water Supply System (PWSID 202300)

Well No. 4

"Well No. 4" (official identification GRSAW352673B04; permit no. not known) is an 8-in.-diameter well drilled between June 2 and 22, 1978, to replace an unspecified existing well (probably Well No. 2). Located immediately south of the campground system storage reservoir, its construction is as follows: an open hole between 31 feet and 250 feet; 8-in. steel casing between 10 feet and 31 feet; concrete grouting between 0 feet and 31 feet. Upon completion, the static water level was 91 feet; total depth 250-feet. Interpretation of July 1978 pumping tests is that a maximum pumping rate should be 10 gpm (National Park Service-Water Resources Division file data, Fort Collins, CO, no date).

Water Treatment

Chlorination is used to maintain 0.2 mg/L concentration of free residual chlorine in the water supply systems. Chlorine is distributed automatically at each well pumphouse.

Potable Water Quality Standards and Testing

All potable water supplies within the Monument must meet State of Colorado Drinking Water Regulations, as applicable and as prescribed in State of Colorado (1994b). The current state classification of both the campground (PWSID 202350) and the residential (PWSID 202300) water supply systems as PNC results in identical testing requirements for both, which entails monitoring in three areas: 1) total coliform and fecal coliform bacteria; 2) nitrate and nitrite; and 3) residual water supply disinfectant. Maintenance Division staff of the Monument regularly perform the water quality testing. Sampling and testing procedures in place as of April 1995 and the water quality results of these tests reveal that Great Sand Dunes National Monument is *in full compliance with all applicable State of Colorado drinking water quality standards*.

Bacteriological Monitoring

The State of Colorado requires that both Monument water supply systems be sampled at one location each calendar quarter and tested for the presence of total coliform bacteria (State of Colorado, 1994b). The Great Sand Dunes National Monument has adopted a more stringent sampling regimen. The sampling and record keeping procedures currently in place are within compliance of all State standards. Bacteriological monitoring of both water supply systems is conducted twice monthly. In each system, one sample is collected from a lone sample locality; the sampling site is selected on a revolving basis, so that, in the course of one year, all segments of both water supply systems are evaluated. Currently, samples are processed and examined for total coliform bacteria at SLV Analytical Services, Alamosa, CO, using the MPN/multiple test tube method (MPN is "most probable number"), at a cost of $7.50 per sample. Records are available back to January 1991.

A total coliform-positive samples invokes various requirements for repeat sampling and testing of those samples for either fecal coliform or, alternatively, *E. coli*. (*Escherichia*). There are various tiers of remedial actions, public notifications, and non-compliance levels that are invoked if positive samples are recurrent. Procedures are documented in State of Colorado (1994b). Fecal coliform is not harmful, but its presence is an indicator that fecal material may have reached the water supply and also that associative but less readily identified pathogens may also be in that water supply (Lynn Cudlip, National Park Service-Curecanti National Recreation Area, personal commun., February 1995).

Since August 1992, when the MPN/multiple test-tube technique was instituted at the Monument, no samples have registered a positive total coliform bacteria content. In the time previous to August 1992 for which records are available (a period of 19 months), another testing technique was used (membrane filter method) and two samples from the residential water supply system registered positive total coliform bacteria. The specific samples are the August 12, 1991 sample from building B5, and the September 10, 1991 sample from building B28 (both residence trailers). Re-sampling of both sites detected no coliform bacteria. It is reasoned that the initial membrane filter method samples may have been collected prior to adequate flushing of the water taps that are the sample sites (Bruce Hart, National Park Service-Great Sand Dunes National Monument, personal commun., April 12, 1995).

Nitrate and Nitrite Monitoring

The water supply systems must be tested annually for combined nitrate and nitrite (State of Colorado, 1994b), which can be indicative of agricultural or human waste contamination of water supplies. Certified laboratories must be used to test these samples; CDS Laboratories [Casa del Sol, Inc.], Durango, CO, is utilized. To meet State of Colorado requirements, all four wells (Nos. 1, 2, 3, and 4) are tested annually (in the third quarter) for combined nitrate and nitrite content. Every third year, the annual analysis is for separate nitrate and nitrite content. If the annual combined nitrate-plus-nitrite sample exceeds 0.5 mg/L, then the next scheduled sample is required to be separate nitrate and nitrite. If the next analysis is below 0.5 mg/L nitrate plus nitrite, then the separate test requirement is reduced once again to every third year. Colorado's MCLs for nitrate and nitrite are the same as those in Appendix B, Part 4.

As of April 1995, the Monument was required to collect and submit samples to the certified laboratory for separate nitrate and nitrite analysis in the third quarter of 1995 because recent samples from both systems have exceeded the intermediate State standards of 0.5 mg/L combined nitrate and nitrite (both expressed as nitrogen (N)). In August 1993, 0.72 mg/L combined nitrate and nitrite were registered in a sample from the residential system, and in both August 1993 and July 1994 the combined nitrate-nitrite in Well No. 2 exceeded 0.5 mg/L (with 1.11 mg/L and 0.78 mg/L, respectively). These samples have *not* exceeded of the State MCL (which is 10 mg/L), but do invoke a requirement for *separate* nitrate and nitrite analysis during the next scheduled testing.

Great Sand Dunes National Monument conducts additional, non-required testing for nitrate at Well No. 2 (campground water supply system) with a portable test kit. Samples are collected twice monthly during high-use times of the visitor season and once a month during low-use times. This additional testing is done because, in the past, there have been two instances in which water from Well No. 2 was found to contain detectable levels of contaminants, and in one of those instances, the contaminant was definitely nitrate. In 1989, following an abnormal, prolonged period of pumping of Well No. 2 (when it was supplying the for nearly the entire Monument), a well water sample analysis (Bruce Hart, National Park Service-Great Sand Dunes National Monument, personal commun., February 1995) indicated 18 mg/L nitrate (National Park Service, 1994b), reported as nitrogen (N). Follow-up testing of Well No. 2 has revealed no other instance of nitrate levels exceeding the MCL in the past 7½ years.

There are two possible explanations for the lone high-nitrate sample. One is that the abnormal pumping regimen increased the cone of depression around the well and drew nitrate from some source into the well field. It follows that elimination of heavy pumping rates on Well No. 2 could solve the problem. Another possible reason is that the 1989 analysis was spurious. This is supported by all the following analyses being within the MCLs but cannot be proven because the high-nitrate sample was discarded without re-testing.

Following the 1989 high nitrate reading, measures have been adopted to assure no nitrate contamination of the campground water supply. The pumping regime applied to Well No. 2 was modified in the summer of 1994 and since that time the pump of Well No. 2 has been operated regularly for short time intervals, utilizing an automated, electronic timer on the pump switch. The water test results collected since 1989 suggest that, if there ever was a problem with nitrate contamination in Well No. 2, this action is suitable mitigation.

If there truly is contamination of the well water, the most likely source is the absorption field of Piñon Flats Campground, which is upgradient from the well and 520 feet distant (National Park Service, 1994b). Based on the unproven possibility that sewage effluent from the nearby campground absorption field could be infiltrating the well field, a new well site was selected by Water Resources Division (Figure 11) and plans made to relocate Well No. 2. No drilling was undertaken due to the unavailability of local drillers (Bill Wellman, Great Sand Dunes National Monument, personal commun., January 1995) and none is planned in the near future because the modified pumping regime appears to be successful mitigation.

About 1983, contaminants (unspecified) that may have been related to an identical pollutant problem were encountered in a water sample from the same

well. The well at that time was relocated and redrilled, but the replacement well (no. 8424) yielded only 2 to 3 gpm (L. E. Surles, National Park Service-Associate Regional Director for Park Operations, written commun., 1983). The capped well north of the campground water supply tank (Figure 11) is thought to be Well 8424 (Great Sand Dunes National Monument Staff, personal commun., April 1995).

Water Supply Disinfectant Monitoring

The State of Colorado requires that a residual disinfectant capable of killing or removing pathogenic organisms be used in public water supply systems which utilize ground water exclusively, and that a detectable residual of that disinfectant be maintained in at least 95% of the samples collected from the extremities of the water supply system. Sampling sites must be identical to those used for total coliform bacteria and sampling frequency must be the sample as that use for total coliform bacteria. Therefore, sampling is required *once per calendar quarter* from one site in each water supply system. There is some leeway for instances in which more than 5% of the samples have no detectable residual disinfectant: the residual must be restored in at least two months over the time period in which that water supply system is serving the public (State of Colorado 1994b).

The Monument utilizes chlorine as the disinfectant in its water supply systems and monitors its residual presence as free residual chlorine to assure that the water disinfection systems are functioning properly. Maintenance Division staff checks each of the two water supply systems *daily* for free residual chlorine, using a portable test kit for on-the-spot analysis, and choosing to target a concentration of 0.2 mg/L *free residual chlorine* as the standard residual concentration. It should be noted that, according to State of Colorado standards, chlorine residual may be measured as total chlorine, combined chlorine, or as chlorine dioxide to meet the 0.2 mg/L concentration minimum (State of Colorado, 1994b). Maintenance Division staff should consider these different chlorine measurement options because their adoption could result in meeting minimum residual disinfectant concentration levels with greater ease, particularly in the light of the situations described below and the general difficulty in maintaining free residual chlorine in a water supply system.

There are some technical difficulties in maintaining a level of 0.2 mg/l of free residual chlorine in the water supply systems. Chlorine does not remain in the chemically free state for long, even inside the water supply pipes, so 0.2 mg/L free residual chlorine can be attained only through two actions. One is using water from the system frequently so that the chlorine content is frequently refreshed with the newly chlorinated water entering the supply pipes. Frequent use of the system keeps fresh water moving through the water pipes and keeps the water from which chlorine has not yet dissipated widely distributed in the system. For infrequently used systems, such as the campground area water supply system, the free residual chlorine level frequently will fall below 0.2 mg/L in any segment of the system for which water has not been replenished for several hours.

In August 1992, several steps were instituted to counteract this situation and improve the record of free chlorine residual in the water supply systems. The actions have been successful, with a notable decrease in the number of times that collected samples contain less than 0.2 mg/L free residual chlorine. The systems are flushed frequently through the taps, particularly in times of low water usage, and samples are collected only after running the water taps for 15 or 20 minutes. Often, this action alone will return the free residual chlorine levels to compliance levels. Higher concentrations are added at the initial chlorination point (well pump housings), also particularly during times of low levels of water use. At such times, enough chlorine is added so that concentrations at the chlorination point are 1.0 to 1.5 mg/L. However, by the next morning, chlorine levels in the pipes of that water supply systems commonly will contain only 0.3 to 0.5 mg/L free residual chlorine due to the natural dissipation and chemical combination of the chemical. In addition, better chlorination pumps were installed. Monument records for testing of free residual chlorine content date back to August 1991 (Bruce Hart, National Park Service-Great Sand Dunes National Monument, personal communs., March 1995, April 1995; Great Sand Dunes National Monument file data).

National Park Service Public Health Guidelines

Several areas of drinking water quality monitoring also are addressed in National Park Service Public Health Management Guideline (NPS-83), Release

No. 2 (National Park Service, 1993), an internal National Park Service guidance document which is advisory in nature, and does not constitute a set of legal requirements relative to water quality maintenance and testing. The document is, nevertheless, constructed within U.S. Environmental Protection Agency (USEPA) regulations (John Collins, National Park Service, Denver, CO, personal commun., February 1995).

Standards in National Park Service Public Health Management Guideline (NPS-83), mostly summarized in Appendix B, Parts 4, 5 and 6, are more stringent than State of Colorado standards with regard to seven test categories, including:

** Primary inorganic analysis (Appendix B, Part 4);*
** Secondary inorganic analysis (App. B, Part 4);*
** General mineral analysis (Appendix B, Part 4);*
** Unregulated VOCs (Appendix B, Part 6);*
** Other unregulated chemicals (App. B, Part 5);*
** Separate lead and copper monitoring (see NPS-83, National Park Service, 1993);*
** Radionuclides monitoring (see NPS-83, National Park Service, 1993).*

As of June 1995, the completed water quality testing of the Monument water supply systems is completely in accordance with the advisory testing regimen outlined in NPS-83 (National Park Service, 1993) for one of these categories (*Other unregulated chemicals*) and partially in accordance with seven of the other eight categories. No testing for radionuclides has ever been performed (Great Sand Dunes National Monument file data). Specifics of the differences between this advisory testing regimen and actual water quality testing performed have been conveyed to the Monument management in a separate report (Chatman, 1995a). In no case where a test has been performed has a NPS-83 standard been exceeded, but in several instances, no tests for specific analytes have been performed.

Future Population Growth

The current classification of the residential water supply system as PNC is dependent on the total resident population and the total number of service connections of that water supply system. Additional housing units are planned for the Monument, which may cause the system to be reclassified as community or non-transient, and may invoke a more stringent monitoring program relative to:

* Inorganic substances;
* Pesticides, herbicides, PCBs, SOCs, VOCs, and other chemicals;
* Separate lead and copper tests;
* Gross alpha particles and radionuclides (see Chatman (1995a)).

Other changes would occur relative to the advisory criteria from NPS-83 (National Park Service, 1993) that would be applicable to Great Sand Dunes National Monument drinking water quality monitoring. In some cases, more stringent criteria would apply (see Chatman (1995a)).

No changes are anticipated that would affect the classification of the campground water supply system (PWSID 202350).

Wastewater Disposal System

Wastewater is treated at various locations through septic tank-leach field combinations. The only exceptions to this treatment regime are the various water fountains and the foot wash at the Dunes parking area, which drain directly into the local subsurface.

Campground comfort stations are connected to a 2,000 gallon, two-compartment septic tank. Leach fields of the dunes parking and picnic area comfort stations are not utilized due to their proximity to Medano Creek and the near-surface aquifer there. Instead, effluent from the two septic tanks is collected at a lift station and pumped uphill along the dunes parking lot road to another leach field. The visitor's center utilizes a 5,000 gallon septic tank. Several septic tanks, mostly of 900-gallon capacity and two-compartment design, serve the permanent residence housing. All other facilities are on systems with septic tanks of less than 500 gallons. Most wastewater treatment facilities are shown on Figure 11. Some older wastewater treatment systems, including pit toilets and cesspools at the picnic area and at the Monument headquarters, have been abandoned.

Historical Water Supply Ditches

Several water diversion ditches are on lands that were acquired and added to Great Sand Dunes

National Monument over time. They no longer are used to carry water. Their foreseen use is exclusively for historical interpretation of the area (K. R. Asheley, National Park Service-Associate Regional Director, Rocky Mountain Region, written commun., July 3, 1980). The ditches are described below.

Opincar Ditch

The 1,500-foot long Opincar Ditch (Figure 11), built by George Opincar, of Blanca, CO, to divert Mosca Creek waters to power a gold placering operation along Medano Creek, had historically been used exclusively for power purposes. It was this mining operation, ironically a financial failure, that focused citizen concern and culminated in creation of the Monument (Bill Wellman, National Park Service-Great Sand Dunes National Monument, written commun., October 21, 1991) so as to protect the dunes and adjoining lands from development activities, such as mining. The tract on which this ditch is located was purchased from the Linger Brothers about 1941 and added to the Monument. The Opincar gold claims had been examined by the General Land Office (predecessor to the Bureau of Land Management) in 1939, and found to be without discoveries of mineral; consequently, in 1941 the claims were declared null and void.

Other Diversion Structures

A few other diversion structures once existed in the Monument, but they have been long abandoned and little visable trace remains. Two water diversion structures existed on lands acquired from the Linger Brothers. Mosca Creek Pipe Line (Figure 11) historically derived water from Mosca Spring for domestic, stock, and irrigation uses. Mosca Creek Ditch, an approximately 2,200-foot long structure, was built to divert Mosca Creek waters at the Monument boundary (National Park Service-Water Resources Division file data, Fort Collins, CO).

Buck Creek Ditch (Figure 11), a 1,350-foot long irrigation ditch designed to divert water from Buck Creek, and the 400-foot long Garden Ditch (Figure 11), for domestic and irrigation use water from Garden Creek (formerly known as Placer Creek), both are on acquired land known as the Wellington tract (National Park Service, 1948). Construction on both was completed by the late 1920's, at the latest (National Park Service-Water Resources Division file data, Fort Collins, CO).

Another water diversion ditch, trending north-south and perhaps an attempt to interconnect the Buck and Garden Ditches has been found by Monument personnel; it has not been mapped. Yet another water diversion ditch was found by Monument personnel south of the Garden Ditch; it is not mapped. No historical information is known concerning either of these latter two ditches. It is likely that both were made by owners of the Wellington tract after 1948, when the ditches existing at that time were surveyed by the National Park Service, and prior to purchase of the Wellington tract by the United States in 1964.

Water Rights

The United States has water rights for flow in specific Great Sand Dunes National Monument streams, ground water from specific wells, and undeveloped ground water to meet future needs. These water rights will be better understood after a reading of the background section describing the various types of water rights and how they are determined.

General Background on Water Rights in Colorado

Appropriative Water Rights

Most water rights systems in the West are based upon the Doctrine of Prior Appropriation. That is, the person who applies water to a state-defined beneficial use (e. g., appropriates the water) has a right that is superior to those who commence their use later: "first in time, first in right." The right is a property right that can be bought, sold, and its point of diversion, place, and manner of use can generally be changed without loss of priority. The right is only to the use of the water; the water belongs to the public. Generally, if the water is not used for a period of consecutive years, it may be lost through action by the state (forfeiture) or an intent by the right holder (abandonment).

In Colorado, both surface and ground waters are subject to appropriation. Technically, the application of water to a beneficial use is all that is required to establish a right. However, in order to establish a priority and to change the point of

diversion, place, and manner of use of a right, it must be adjudicated (decreed). Generally, a diversion or some means of controlling the water is required. However, this requirement does not apply to an appropriation by the State for fish and wildlife purposes. For wells, a permit must also be obtained from the State Engineer to construct the well, install a pump, and place the water to a beneficial use.

Water rights in Colorado are administered through the Office of the State Engineer, and its seven water divisions, each headed by a division engineer. Great Sand Dunes National Monument is located in Water Division 3, which generally corresponds to the Rio Grande River Basin in Colorado.

Federal Reserved Water Rights

When the Federal Government reserves land for a purpose it also reserves water, unappropriated at the time of the reservation, necessary to accomplish the purposes for which Congress or the President authorized the land to be reserved. The right vests as of the date of the reservation, whether or not the water is actually put to use, and is superior to the rights of those who commence the use of water after the reservation date. Depending upon the purposes of the reservation, Federal reserved rights may include water for consumptive uses, such as domestic and irrigation, as well as nonconsumptive uses, such as instream flow.

General adjudications are the means by which the Federal Government claims its reserved water rights as provided by the Act of June 10, 1952 (66 Stat. 560, 43 U.S.C. 666) (McCarran Amendment). Commonly, in a general adjudication, all water users on a stream and its tributaries must claim their water rights, and, after considering evidence and testimony, the court issues the decree(s) setting forth the rights within the adjudicated area, including the Federal reserved water rights. Adjudications are generally in State courts, but Federal courts also have jurisdiction.

Decreed Water Rights of the Monument

The United States was joined, in 1979, in a general adjudication of water rights in Colorado Water Division 3 pursuant to the McCarran Amendment, and in 1979 submitted claims, which were amended in 1981. In 1989 the District Court for Water Division 3 decreed Federal reserved and appropriative water rights for Great Sand Dunes National Monument. The decrees are referred to by Case Numbers 81CW161, 81CW163, and 81CW164, assigned to the 1981 amendments to the original 1979 filing. Case Number 81CW161 concerns reserved rights to specific wells; 81CW163, appropriative rights to wells; and 81CW164, reserved rights to stream flows, future consumptive uses (wells), and an appropriative right to a spring flow.

For each case listed above, the decree is one of consent between the United States and various protestors and approval by the district court. It is not precedent setting except as it applies to the water rights in question. The water rights are subject to administration by the State Engineer, and the State Engineer can require that essential measuring devices be installed.

Stream and Spring Flows

Reserved water rights to continuous minimum stream flows were decreed to the United States for the water in several streams, quantified at their entry points into the Monument. The water rights are solely for instream purposes; no diversions or consumptive use is to be made of these waters, except for naturally occurring stream losses. Specific streams include Medano, Sand, Mosca, Little Medano, Cold, Buck, Garden and Castle Creeks, the drainages of Horse, and Sawmill Canyons, the drainage in Morris Gulch, and the unnamed drainage in SE. ¼, sec. 23, T. 26 S., R. 73 W. (Figure 2). Priority dates for these water rights are either March 17, 1932 or June 17, 1956, depending on when the lands were set aside for the Monument. Flow rates vary by month; a compilation of the specific flow rates, in cfs, is in Table 10 and depicted in graphical form for Sand and Medano Creeks in Figure 6. The rates represent flows existing at the time the decree was issued, and are based on the necessity of these waters to fulfill the purposes of the Monument.

An appropriative water right was decreed to the United States for 0.02 cfs of the waters of Denton Spring (Figure 2) for wildlife purposes ("ecosystem management") with a priority date of December 31, 1946; that quantity is essentially the entire yield of Denton Spring. The spring has created a wildlife habitat and provided drinking water for wildlife since at least 1946, and has been managed as such

Table 10.--Instream Flow Rights, Great Sand Dunes National Monument, Colorado

Stream Name	Quantified Instream Flow Right[1] by Month in cubic feet per second (cfs)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Medano Creek	2.25	2.17	2.17	3.69	19.66	20.94	15.73	12.20	7.70	4.09	3.05	2.09
Sand Creek	4.11	3.49	3.49	5.34	32.24	58.93	46.40	42.09	26.49	11.70	6.36	4.72
Mosca Creek	0.26	0.26	0.25	0.47	2.32	1.63	1.16	0.69	0.43	0.32	0.31	0.21
Little Medano Creek	0.49	0.47	0.47	0.80	4.26	4.54	3.41	2.64	1.67	0.89	0.66	0.45
Cold Creek	0.62	0.60	0.60	1.02	5.45	5.81	4.36	3.38	2.14	1.14	0.85	0.58
Buck Creek	0.08	0.08	0.08	0.14	0.70	0.49	0.35	0.21	0.13	0.10	0.09	0.06
Garden Creek	0.06	0.06	0.06	0.11	0.56	0.40	0.28	0.17	0.10	0.08	0.08	0.05
Horse Canyon	0.06	0.06	0.06	0.12	0.57	0.40	0.29	0.17	0.11	0.08	0.08	0.05
Castle Creek	0.12	0.12	0.11	0.21	1.04	0.73	0.52	0.31	0.19	0.14	0.14	0.09
Sawmill Canyon	0.09	0.09	0.09	0.16	0.81	0.57	0.41	0.24	0.15	0.11	0.11	0.07
Unnamed (sec. 23)	0.07	0.07	0.07	0.12	0.61	0.43	0.31	0.18	0.11	0.08	0.08	0.06
Morris Gulch	0.12	0.12	0.12	0.22	1.08	0.76	0.54	0.32	0.20	0.15	0.15	0.10
Denton Spring	Appropriation is a continuous flow of approximately 0.02 cfs.											

[1] Or natural flow, whichever is less.

since that time (Case 81CW164, Findings of Fact, Conclusions of Law and Decree, 1989).

Ground Water

Ground water for domestic use of the Monument staff and visitors, and for uses related to administration and operation is diverted by virtue of reserved water rights (Case 81CW164, Findings of Fact, Conclusions of Law and Decree, 1989) and appropriative rights (Case 81CW163, Findings of Fact, Conclusions of Law and Decree, 1989). Well locations are shown on Figures 7 and 11.

Well No. 4.--"Well No. 4" was decreed a federal reserved water right of 10 gpm for domestic use, with a priority date of March 17, 1932 (Case 81CW161, Findings of Fact, Conclusions of Law and Decree, 1989).

Future needs.--For future domestic, administrative, and operational water needs of staff and visitors, an additional 8.0 acre-feet/year has been decreed as a federal reserved water right to the United States, with a priority date of June 17, 1956. The water is to be diverted through one or more wells in the Monument and used in the Monument. No water wells have yet been drilled. If a well is drilled, the United States must provide the State Engineer all the material required for the filing of a well permit, and the State Engineer must grant the permit if it meets the requirements set forth in the decree (Case 81CW164, Findings of Fact, Conclusions of Law and Decree, 1989).

Wells No. 2 and No. 3.--Appropriative water rights have been decreed to the United States for two wells (See Case 81CW163, Findings of Fact, Conclusions of Law and Decree, 1989), including "Well No. 2", in Piñon Flats Campground, for 30 gpm (priority date of August 1, 1963), and "Well No. 3" , for 25 gpm for domestic and municipal uses (priority date of June 23, 1978). Well No. 3 was drilled as a new well to replace an existing well ("Well No. 1") (Denise Newberry, National Park Service-Water Resources Division, written commun., National Park Service-Water Resources Division file data, Fort Collins, CO; L. E. Surles, National Park Service, Associate Regional Director, Park Operations, written commun., 1983).

Well No. 1.--The National Park Service, through the Department of Justice, is seeking a decreed right for "Well No. 1" to supplement Well No. 3. In 1989, when the decree was issued for Well No. 3, the National Park Service did not believe that Well No. 1 would be needed, and so no water right was sought at that time. A new permit (no. 036273-F) was obtained for Well No. 1 on February 28, 1990, after flow from Well No. 3 began to diminish, that allows Well No. 1 to be used as a supplemental well for Well No. 3. Until a decree for a change in water right is obtained, Well No. 1 is considered by the State Engineer as having a priority junior to all vested water rights. Interim permissible water use from Wells No. 1 and No. 3 is as follows: combined maximum pumping rate is not to exceed 25 gpm; combined annual amount of water to be appropriated is not to exceed 8.9 acre-feet. Use of the water is restricted to domestic and municipal use in the picnic area, visitor center, employee housing, and work center (National Park Service-Water Resources Division file data, Fort Collins, CO, no date).

Unperfected Water Rights for which Decrees were Not Pursued by the United States

Water right decrees for several water diversion ditches in the Monument (described above in the "water supply" section) were not pursued. The ditches are as follows.

The Department of Justice declined to file applications for Garden, Opincar and Buck Creek ditches in the general adjudication because there was, in their opinion, no chance of getting water rights for the ditches. With regard to the Opincar Ditch, the Department of Justice further concluded "...to the extent a water right ever existed, the appropriator abandoned it long ago. Research by the National Park Service, indicates that the Gold Mining venture for which the water right was originally granted never panned out." "The Park Service has no interest in developing the Opincar Ditch water right and because of the Monument's decreed instream flows, will vigorously oppose any effort to revive this long dead right." (See January 6, 1992 letter to Clerk of the Water Court, from James J. Dubois, Department of Justice). Case Number 81CW162, a claim submitted to the district court for surface water from Mosca Pipeline at Mosca Spring, was withdrawn by the Department of Justice.

Objection to Application of AWDI

The United States and other agencies were among numerous objectors to a 1986 application by American Water Development, Inc. (AWDI) for as much as 200,000 acre-feet/year of ground water from an area near Villa Grove and from the unconfined aquifer beneath the Baca Grant (Figure 1), which adjoins Great Sand Dunes National Monument along the northern part of the Monument boundary; 1,832.65 acres of the Baca Grant constitute a private inholding within the Monument. The AWDI intent was to drill wells, from 200-feet to 2,000-feet depths, and sell the water to urban areas outside of the San Luis Valley (Laughlin, 1992; The Denver Post, 1994).

AWDI sought rights based upon ownership of the water by virtue of land grants, appropriation of tributary ground water, and appropriation of nontributary ground water (December 1986 Resume of Water Right Applications, Water Division 3). The United States objected based on injury to its water rights, noncompliance with Colorado Statutes and filing requirements, that the waters at issue were tributary, the applications speculative, and the applicant did not own the water claimed pursuant to land grants (February 24, 1987, Statement of Opposition).

The land grant claims were dismissed by the court, AWDI withdrew its claim to tributary ground water, and the District Court (later affirmed by the Colorado Supreme Court) denied claims to nontributary ground water because they found the water to be tributary to natural streams, including Medano and Sand Creeks (National Park Service-Water Resources Division file data, Fort Collins, CO; Case No. 92SA141, Colorado Supreme Court). A 1994 appeal to the U.S. Supreme Court resulted in that Court's refusal to hear the case (Water Court Reporter, 15, Fall 1994).

Upstream Water Rights Including Senior Water Rights

Some water rights for Sand Creek and Medano Creek waters upstream from the Monument may be of concern at some future date. Most of these water rights, described below, are senior to those held by the United States.

Medano Creek

Two surface diversion ditches are utilized by the Wolf Springs Ranch. They are Medano Ditch and Hudson Ditch (Figure 1), which, combined, have an appropriative water right for 15 cfs between May 15 and July 15, with a priority date of July 21, 1914. After July 15, the diversions must be shut off, and the discharge flows into Medano Creek and thus into Great Sand Dunes National Monument. These water rights are senior to those of the United States.

Other water operations on Medano Creek should be noted, as their use could affect the Monument's instream flow. Via a civil agreement of May 10, 1956, the Wolf Springs Ranch and Medano Ranch owners allow 3 cfs of Medano Creek water to flow into Hudson Ditch between October 1 and May 15 of each year. Investigation was not successful in locating a decree relative to this water diversion. If a decree does exist, it would be junior to that of the United States, which holds a 1932 priority date on its decree relative to Medano Creek (Bill Wellman, National Park Service, written commun., May 1995).

Farther upstream, the United States (Rio Grande National Forest) has an appropriative water right for a minimum of 42 acre-feet of water for Medano Lake, year-round, with a priority date of March 9, 1977. This water right is junior to water rights decreed within the Monument.

Sand Creek

In the Sand Creek watershed, there are three senior water rights upstream from Great Sand Dunes National Monument:

Ditch	Priority date	Quantity
Trujillo	May 20, 1878	13.33 cfs
Lastre	April 1, 1898	5 cfs
Medano Creek-Sand Creek	July 1, 1908	40 cfs

The United States water right for minimum instream flow in Sand Creek is junior to the three senior water rights mentioned above, with a priority date of Mar. 17, 1932. The appropriative water rights for the Sand Creek Lakes (Little, Lower, and Upper), owned by the United States (USDA-Forest

Service), are all junior to Monument water rights on Sand Creek, each with priority dates of January 19, 1977 (Wayne Williams, Colorado Division of Water Resources, Water Division III, Water District 35, Fort Garland, CO, personal communs., February and April 1995). Nevertheless, these water rights are notable because they involve Sand Creek water upstream from the Monument.

Land-disturbance Impacts on Water Resources

There are three different types of land disturbances in and near the Monument that have the potential to affect water resources; former landfills, firing-range use, and mineral development, all of which are discussed below.

Landfills and Firing Range

Within the Monument boundary are three sites formerly used by the National Park Service as landfills. Landfill disposal of most refuse on National Park Service land was once widely practiced. Currently, such practices are no longer followed. All three landfills are inactive. In addition, there is one inactive firing range in the Monument.

The landfill located about 2,000 feet northwest of Denton Spring (Figure 2) occupies one-half acre. Another landfill, much smaller, is located about 1,800 feet farther to the southeast up the drainage that emanates from Denton Spring. No further actions are planned at the sites following the Rocky Mountain Region's Hazardous Materials Coordinator's examination that found no immediate hazardous materials dangers. The larger and northwesternmost of the two sites contains household debris, cans, bottles, and tires. The contents of the smaller site are not known to be tabulated, but are likely the same.

A third landfill, about 3,000 feet south of the Monument shop building, occupies about 2+ acres (Figure 2) and is currently operated as a surface storage site for non-hazardous National Park Service materials. The landfill part of the area has recently undergone some remediation. A contractor was hired to locate and excavate ten 55-gallon steel drums that had been buried on the site. Each contains an unknown liquid substance. All drums have been removed from the ground and placed in individual, sealed and leak-proof containers, currently stored on the surface at the retrieval site. And old report suggests that the substance may be linseed oil (Great Sand Dunes National Monument file data, 1991); alternatively, the liquid could be creosote or "penta", the chemical used to substitute for creosote after creosote's carcinogenic characteristics were recognized. Linseed oil's presence is not usually monitored in environmental surveys and it is not considered a hazardous material (Ralph White, U.S. Geological Survey Water Quality Laboratory, Denver, CO, personal commun., March 17, 1995). The removal of the unknown liquid from the Monument is being coordinated with the Regional Hazardous Materials Coordinator's office. At one time, the accumulated materials of several National Park Service units will be collected and transported to one site, likely Denver, CO, for positive identification and appropriate disposal. In the time period during which the National Park Service was still implementing a policy of ceasing landfill use on National Park Service units, large amounts of buried household and campground garbage and trash, including old water heaters and stoves, were buried at the site. These remain buried and the Monument will eventually formulate a plan of appropriate clean up (Bill Wellman, National Park Service-Great Sand Dunes National Monument, personal commun., April 1995).

About 300 feet northwest of Denton Spring (Figure 2), is an inactive, two-acre small weapons firing range that was used for a short time in years past by private citizens, the National Park Service, and the Forest Service (U.S. Department of Agriculture). The soil here contains some unquantified amount of lead from spent bullets. Whether this presents a hazard to water resources has not been determined, though a greater hazard probably exists to plants and foraging animals that utilize the site, rather than to water resources.

Mineral Development

Mineral-development activities that potentially could affect water quality of the Monument are in three categories:

* current petroleum exploration on the Baca Grant and recent gold exploration there;

* past mining within the Monument in the Cold Creek watershed;

* past mining activity outside the Monument boundary but within watersheds that drain into the Monument.

There are other mines and prospects within and near the Monument that are thought not to represent any potential for water quality degradation. These and other mines and prospects in the Monument and vicinity are detailed further in a separate report supplied to Monument management (Chatman, 1995c).

Mineral Development on the Baca Grant

The Baca Grant (Figure 1) is a 100,000-acre contiguous tract of private land that is immediately adjacent to Great Sand Dunes National Monument. The 1,832.65 acres of the Baca Grant that are in the southeasternmost corner of the tract have been incorporated into the Monument as an inholding. Surface and mineral ownership of the Baca Grant (*and the inholding*) is fee simple absolute. This land and minerals status was verified both through literature (Luis Maria Baca Mining and Development Company, 1935), and through a May 3, 1995 search of U.S. Bureau of Land Management records. The Baca Grant ownership leased the grant's minerals to one mineral exploration company and some surprising and potentially developable mineral discoveries, detailed below, have resulted.

Petroleum.--Lexam Explorations USA, Inc., Wheat Ridge, CO, has been conducting gold exploration of a geophysical target (low-angle, west-dipping detachment fault zone) on the Baca Grant since 1990. In the process of core drilling the gold targets in this cataclastic zone, the company accidentally discovered that the zone also has acted as a trap of live oil in Precambrian-age gneiss immediately underlying the detachment zone. Oil was found in 27 of the 42 gold exploration drill holes. The oil, a biodegraded crude, was examined and found to have originated from Cretaceous sediments, heretofore unrecognized in the eastern San Luis Valley. The potential of this discovery has expanded with follow-up exploration and the firm now (May 1995) has suspended its gold exploration on the Baca Grant in favor of concentration solely on development of the petroleum potential.

There are four petroleum exploration targets that have been defined by Lexam Explorations, Inc. (Figure 1). *It is notable that the southernmost target includes most of the 1,833-acre inholding in the northwesternmost part of the Monument.* Two exploratory wells are planned for the Deadman Creek target, which is 4 miles further to the northwest. Both wells will penetrate the Precambrian-age rocks below the confining high-clay cataclastic part of the detachment zone; one well is to be 4,500-feet deep and the other 6,500-feet deep. Both are to be spudded in during the summer of 1995 (James Donaldson, Lexam Explorations, Inc, written commun. to Colorado Oil and Gas Conservation Commission, May 18, 1995).

The four targets are defined by not only the presence of live oil, but also the presence of several Mesozoic sedimentary rock formations that are petroleum reservoirs and/or petroleum source rocks in other localities in the West. These rocks were thought to have been removed from the San Luis Valley through erosion many ages ago. They include several well-known rock formations, including Upper Mancos Shale, possibly the Niobara Formation; Lower Mancos Shale; sandstone of the Dakota Formation; and the Morrison Formation. All unconformably overlie Precambrian-age crystalline rocks that are very common in the Sangre de Cristo Mountain range. These rocks are within a heretofore not widely known structural unit (Figure 14) that lies between the Sangre de Cristo Mountains fault block on the east and the San Luis Valley graben (which is deeply buried by Tertiary and recent sediments of the Santa Fe Formation) on the west. The structural unit's upper margin is defined by the detachment zone. Once the effort to explain the oil shows began, public domain gravity data were utilized to partially define this intermediate structural unit. It's size and location were further refined through a privately contracted aero-magnetic survey. The structural unit has roughly a 16-mile by 4-mile area and is about 3 miles west of the main basin bounding fault of the Sangre de Cristo Mountain front.

The Mesozoic sedimentary rocks, at this point in the exploration program, are used to define target areas for potential petroleum reservoirs, even though they are actually above the detachment zone. They are in connection with the cataclastic layer of the detachment zone through a system of normal faults

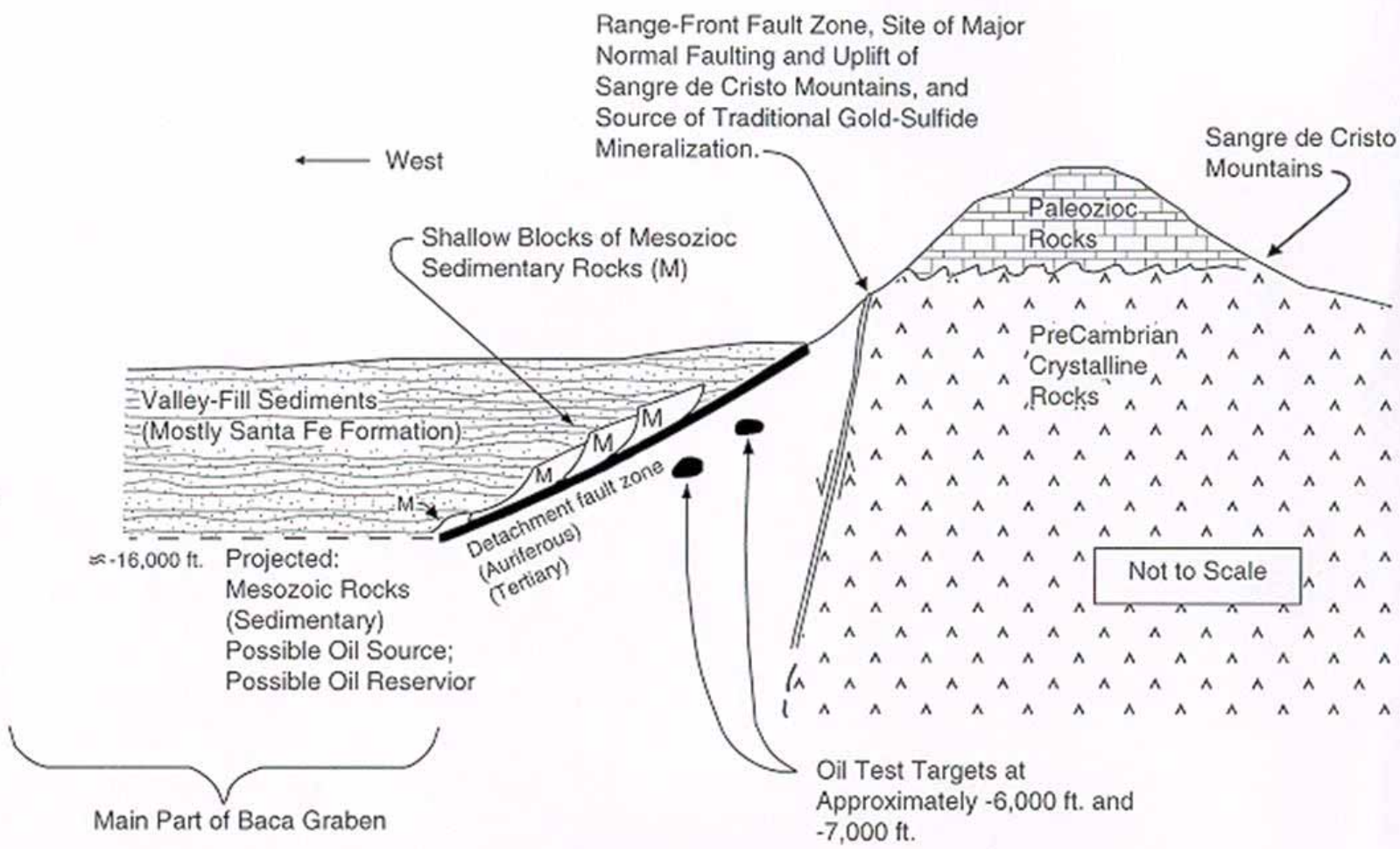

Figure 14. Generalized Cross Section of the Structures and Lithologies in the Baca Grant.
(Modified from data presented by Tom Watkins at Colo. Scientific Society meeting, May 9, 1995)

that also may be important traps. It is thought that many of these Mesozoic formations are deeply buried (about 16,000-feet deep; see Figure 14) petroleum source rocks or reservoir rocks on a western extent of the cataclastic layer. But according to the currently available data the only known reservoir rocks are the Precambrian crystalline rocks immediately below the cataclastic zone (Figure 14).

The petroleum exploration is modeled on geophysical, structural, and lithologic analogs in Nevada. In the Railroad Valley area of Nye County, NV, are the Grant Canyon and the Bacon Flats petroleum fields, from which 19,000,000 barrels of oil have been produced from a very small area (a 300-acre field). In the Pine Valley area of Nevada, in Eureka County, the Blackburn field has produced about 3,000,000 barrels of oil; it also is a field of a very small area. These analogs favor the existence of both petroleum source and reservoir rocks on the hanging wall of the detachment fault zone along the Sangre de Cristo Mountains. Exploration is not advanced enough to speculate on economic viability (unless noted otherwise, data from a presentation by Tom Watkins, Lexam Explorations, Inc., to the Colorado Scientific Society, Denver, CO, May 1995).

Gold prospecting.--A gold prospecting program was undertaken on the Baca Grant by Lexam Explorations, Inc. in 1990, using Battle Mountain Gold Company's San Luis Mine, located near the town of San Luis, CO, as a model. The San Luis Mine hosts both oxidized and sulfidic, refractory, disseminated gold of hydrothermal origin in a 24 to 27 million-year-old low-angle, detachment-style fault zone associated with the Rio Grande rift. The same type of clay layer that acts as the petroleum trap on the Baca Grant oil shows also acted as barrier to upward-migrating auriferous hydrothermal fluids at the San Luis Mine. Those hydrothermal fluids therefore tended to pool below the clay zone. Refractoriness of the ore is due to both incorporation of the gold into pyrite mineral grains and silica flooding. Other sulfide minerals, present in minor quantities, include sphalerite and galena. These were prospected for lead and zinc decades ago. Some copper is present, which is suggestive of an original content of chalcopyrite in the deposit. The complete milling and recovery processes, which utilize grinding, sulfide ore roasting, and cyanide leaching, are on-site (Alan Wallace, U.S. Geological Survey, Central Mineral Resources, Denver, CO, personal commun., May 17, 1995). The San Luis Mine was operating as of May, 1995. In order to have a sense of the scale of this operation, it should be noted that the operation in 1994 was profitable, during which time 73,000 oz gold were produced at an average total operating cost of $317/oz. In 1995, production is targeted at 68,000 oz gold; 17,000 oz have been produced during the first quarter of the year (Rocky Mountain Pay Dirt, Feb. 1995). The San Luis Mine deposit contains 12 million short tons at a grade of 0.04 oz Au/st (data from presentation by Tom Watkins of Lexam Explorations, Inc., to Colorado Scientific Society, Denver, CO, May 9, 1995).

The same anomalous geophysical zone on the Baca Grant in which Lexam Explorations, Inc. discovered oil was also the company's initial disseminated gold deposit exploration target. Forty-two exploratory drill holes were completed around Deadman Creek in and near the foothills (data from presentation by Tom Watkins of Lexam Explorations, Inc., to Colorado Scientific Society, Denver, CO, May 9, 1995). Gold exploration completed to date has not been of enough success that a reserve estimate could be substantiated. Gold mineralization encountered has been was weak and spotty (Jim Cappa, Colorado Geological Survey, personal commun., May 1995). No mine plan for gold production from the site was ever filed with the State of Colorado (Jim Stevens, Colorado Division of Minerals and Geology, Denver, CO, personal commun., May 1995). The only data available to characterize the actual grade of gold metallization in the area come from a U.S. Bureau of Mines field investigation in Deadman Creek on the Baca Grant, work done in the process of evaluating mineral resource potential peripheral to the proposed Sangre de Cristo Wilderness. About ½ mile south of the Deadman Creek drainage channel are two, interconnected, near-surface adits with at least four portals and over 400 total feet of underground excavations. It appears that these adits intersect the clay zone of the Lexam Explorations, Inc. detachment fault gold target. Of the eight U.S. Bureau of Mines samples from that zone, five contain gold in the range of 0.01 oz gold per short ton to 0.06 oz gold per short ton. All concentrations were determined through fire assay. Most samples also contain about ½ oz silver per short ton and some have elevated arsenic content (300 to 600 parts per million) (Ellis et al., 1983;

U.S. Bureau of Mines field notes, Denver, CO, June 19, 1979).

These are gold concentrations that are sufficiently high to attract exploration interest, but that are also low enough to make profitable mining difficult unless delineated reserve tonnages are high and/or the deposit is highly amenable to beneficiation.

It is important to note that, while the gold exploration has currently been suspended, the price of gold has been somewhat volatile in past years and an a substantial increase in the price of gold will almost certainly bring about a return of the exploration program. The main gold exploration target is the same area as the Deadman Creek oil exploration target (Figure 1), but the structural zone that is thought to be the gold host probably extends from Crestone, CO, all the way to the 1,832-acre AWDI inholding in the Monument. The structural and mineralogic similarities with the gold deposit of the San Luis Mine suggest the possibility, unproven as yet due to lack of exploration, that the structural zone is continuous between San Luis Mine and the Baca Grant. If such is the case, the zone would extend beneath the Great Sand Dunes National Monument.

Lode Mining

In past years and as recently as 1937, there was lode mining for various metals along much of a 70-mi distance of the Sangre de Cristo Mountains' western slope. Archeological remains of Spanish-exploration era mining south of Crestone, CO (Figure 1) have been found. The more recent era of mining was started about 1870, as vuggy, gold-bearing quartz veins were noted in the Baca Grant (Figure 1). Few of the mines were very large or had very high quantities of ore mined from them, although some $7 million to $8 million worth of precious metals were produced during the American-era of mining, which peaked between 1880 and 1904. The Independent (or Independence) Mine was one of the largest operations (Parker, 1952; Gabelman, 1953; Benedict and Coggin, 1973; Ellis et al., 1983). As is the usual case with mining districts, there is a periphery around the main mining areas in which even smaller and less productive mine and prospect excavations are made. Such is the case within and around the Monument.

In addition to small mines and prospects within the boundary of Great Sand Dunes National Monument, there are numerous mine and prospect excavations upstream of and in watershed that drain into the Monument. The potential for water quality in the Monument experiencing any detrimental effects from these areas are assessed below.

Pulps (pulverized, powdered rock of less than 100-mesh size particles, that are ready for laboratory assays) of nearly all the U.S. Bureau of Mines rock-chip samples collected from these mineralized zones and prospects have been obtained for the National Park Service. Also obtained are field notes describing these sites and samples, laboratory assay reports, and an index, tying the ordered sample numbers used in a related U.S. Bureau of Mines mineral resource report (Ellis et al., 1983) to the more random numbering scheme found in the field notes. Most of these data are compiled in Chatman (1995c).

Lode mining within the Monument.--Most of the lode mining within the Monument occurred in the Cold Creek watershed on a small, unnamed tributary of Cold Creek. The main (southernmost) working does contain a 2,300 cubic yard dump that is adjacent to the unnamed Cold Creek tributary drainage channel, but reports (U.S. Bureau of Mines field notes, Denver, CO, July 10, 1982) suggest little metallized or sulfidized rock is present in that dump and two rock-chip samples are lacking anomalous levels of hazardous substances (U.S. Bureau of Mines file data, Denver, CO). The mine is not, therefore, likely to be contributing to water quality degradation via such mechanisms as acid mine drainage or heavy metal loading.

Three other groups of prospect excavations in this watershed (Figures 2), all north of the main Cold Creek drainage channel, are thought to be the source of at least some of the iron-oxide cementation of sediment that occurs occasionally in Sand Creek. Iron-oxides alone are not detrimental, but in this geologic environment the mineral group potentially could carry heavy-metal ion concentrations or be indicative of sulfide minerals, which, in turn, can generate acids when exposed to water. The sites should be investigated further. Mitigating the potential for water quality degradation problems are the facts that there is little surface flow in Cold Creek, and rock-chip samples from the sites are generally devoid of concentrations of toxic materials.

Other lode-type mineral excavations in the Monument are thought not to be potentially detrimental to water quality, based on some combination of the following factors:

* small size of workings;
* absence of concentrated metallization or sulfidization;
* distance from stream drainage channels;
* known high water quality.

That group of excavations includes those in Sawmill Canyon; on the Wellington tract; and at Denton Spring. The sites are detailed further in Chatman (1995c).

Lode mining upstream from the Monument.--The patented Myrtle K Mine and mill site, upstream from the Monument on Sand Creek (Figure 2), is on a narrow fault zone that contains sulfide forms of iron and copper minerals and a 2,100 cubic yards dump, a boiler, and a five-stamp mill, all immediately adjacent to the creek. Samples of the fault and a shear zone at the site contain slightly elevated levels of arsenic, boron, copper, manganese, and zinc, based on semi-quantitative analyses (U.S. Bureau of Mines field notes, Denver, CO, June 14, 1979; U.S. Bureau of Mines file data, Denver, CO). The site should be investigated further.

Mine and prospect sites upstream from the Monument in other watersheds are mostly without consequence relative to Monument water quality due to some combination of small workings size, lack of metallization or sulfidization, neutralizing bedrock, or distance from drainage channels. This includes workings in Medano Creek, Buck Creek, Morris Gulch, Evans Gulch, South Arrastre Creek, and a working in the Sand Creek watershed, about ½ mile downstream from the Myrtle K Mine. Some historical information is suggestive of copper loading in Mosca Creek, possibly related to releases of mineral processing reagents, but recent, limited water quality testing provides no indication of degraded water quality in Mosca Creek (sites detailed further in Chatman (1995c)). Should poor water quality be detected in the future, the metallized part of the Mosca Creek watershed, including the old prospect workings, should be investigated more closely.

An upstream site from the Monument that should be examined now is the easternmost working (an adit) in North Arrastre Creek (Figure 2). An abandoned, small mill was reported to the south of the adit. Information is lacking about the milling method employed or the presence of tailings and reagents. Contents of the steel drum reported at the adit opening are unknown (U.S. Bureau of Mines field notes, Denver, CO, May 14, 1982). Condition of the site should be verified with a field examination, and a decision made at that time about the need for water quality testing upstream and downstream from the mine.

Placer Mining Inside the Monument

The 1928 report that gold associated with magnetite grains was detected in dune field sand sparked a financially unsuccessful gold rush. Claims were staked on lands now within the Monument, not only on Medano Creek, but also in the dune field. One claimant had claims occupying 11 mi^2 of the dunes. Mining ended by 1938, but some prospecting (collection and assay of dune sand samples for gold content) continued to 1941. The major detriment was the low gold concentration. Another, more recent attempt to retrieve placer gold in the region occurred in 1980 at some unknown site on Medano Creek, most likely inside the Rio Grande National Forest. That work ended due to the lack of access routes (U.S. Bureau of Mines file data, Denver, CO, including interview with Paul Maddrell (undated but post-1963 material); U.S. Bureau of Mines field notes, Denver CO, May 15, 1982, including interview with Bob Schultz, Ranger, U.S. Department of Agriculture, Forest Service; Alamosa Daily Courier, 1938; Voynick, 1992).

The abandoned placer claim sites appear to represent no water quality issue for the Monument. All equipment and materials have been removed. Water quality testing done since 1990 reveals no anomaly of mercury, the most likely contaminant that a placer gold operation might release into the creek (used to amalgamate small placer gold particles).

Mineral Ownership

It has been projected that the high-angle, low-tonnage precious metals vein zone that follows the range-bounding fault of the western front of the Sangre de Cristo Mountains also may be present beneath the sand dune field of the Monument (Johnson et al., 1984; Johnson and Ellis, 1984). Similarly, it has been suggested that the low-angle detachment fault zone that in 1995 was undergoing both mining for low-grade, disseminated gold at the San Luis Mine, San Luis, CO, and prospecting for gold on the Baca Grant, also is beneath the dune field (Alan Wallace, U.S. Geological Survey, Central Mineral Resources, Denver, CO, personal commun., May 1995).

The issue, as it may affect the Monument, is primarily one of mineral ownership. The Monument is protected from internal and peripheral mineral development at sites where the Federal government has reserved the mineral rights. Mineral rights for the entire Federal surface and most inholdings within the Monument are reserved by the United States. The exception is the AWDI inholding (Figure 2), where both surface and minerals are owned privately (Jim Sharum, National Park Service, Denver, CO, personal commun., May 23, 1995, and June 1995). Due to the current status of this inholding as a petroleum prospect, it is considered unlikely that the United States will be offered an opportunity to purchase the tract or its mineral rights.

Mineral rights in the three-section area of private land in and around Liberty, CO (an approximately 2.5 square mile tract in T. 25 S., R. 73 W., secs. 19, 29, 30) (Figure 2), all are reserved by the Federal government, with the exception of a block of mineral patents in sec. 19, immediately south of Liberty, and a part of a mineral patent in NE. ¼, NE. ¼, sec. 29, about 1.5 mile to the southeast (Jim Sharum, National Park Service, Denver, CO, personal commun., May 23, 1995). This land, or at least an access corridor through it along Sand Creek northward to the Rio Grande National Forest boundary, would be beneficial to National Park Service trail use. Although the land is in delinquent tax status, and a tax deed for it has been issued, the United States is not involved in any negotiations to obtain it.

Because of the large percentage of Federal reserved mineral rights in these areas, mineral resource potential related to both gold and petroleum will not affect most values in future land acquisition by the Monument. This is because any lands acquired would be most likely managed as Wilderness, idling the Federal mineral estate. Conversely, private mineral ownership may have resulted in increased land values due to mineral resource potential.

WATER RESOURCES ISSUES AND RECOMMENDATIONS

Building on the description of the water resources and legal requirements provided in the previous chapter, this chapter examines specific issues identified in the scoping process, and proposes actions to address them. Where these actions will require additional funding or staff, project statements are presented, which will be incorporated into the Monument's Resource Management Plan. The project statement is the standard format used in the National Park Service to express a resource-related need, and to compete for funding. A summary of all of the proposed project statements can be found at the end of this chapter, while the full text of the project statements are located in Appendix A.

Water resources issues of Great Sand Dunes National Monument are be divided into four main categories:

1) **preservation of the dunes and other features** of "scenic, scientific, and educational interest", as authorized in Great Sand Dunes National Monument's enabling legislation;

2) maintaining **water quality**;

3) long-term **funding and staff** needs for the Monument, and

4) **other issues**

Preservation issues are both diverse and interrelated. The very existence and natural maintenance of the dune field, and the phenomenon of surge flow in Medano and Sand Creeks, are all dependent on an array of related natural processes. Prevailing winds blow the dune field sands towards Medano and Sand Creeks which capture and transport sand to locations ideal for being blown back onto the dune mass. A decrease in the flow of either creek would hamper creek capabilities to maintain the sand budget, and could also decrease or destroy the surge flow. Protection of ground-water levels is integral to maintaining the flow of the creeks and is therefore an equally critical issue for maintaining the dunes and the surge flow phenomenon. Water rights can be an effective tool for preventing damaging ground- and surface-water withdrawals. Ground-water level maintenance is also important in protection of interdunal ponds and similar palustrine wetlands.

Water quality issues relate largely to public use of the Monument, where the concern lies in the high-use wading areas of Medano Creek and primitive camping zones in both Medano and Sand Creek watersheds. Achieving a state designation of "Outstanding Waters" would provide Monument streams with the highest level of regulatory protection available. The quality of potable water supplies must also be assured.

A complex water resource management program is being presented here, the implementation of which will require a commitment of additional funds and staff to the Monument. These needs are evaluated in the funding and staff section.

Many of the other issues addressed in the final part of this chapter have been either largely resolved in the planning processes, or are currently being addressed, such as fisheries management and 404 permitting for maintenance of the Medano Pass road. Topics where further work is prescribed include the eventual incorporation of the lands where an important spring is located on the sand sheet into the Monument, and enhancing the interpretation of water resources.

Preservation of the Dunes and Other Features

The topic of preservation combines issues related to water quantity, water rights and geomorphic issues. Collectively these issues associated with the amount, location and timing of water have been the subject of a great deal of interest on the part of the National Park Service and many others, and will continue to be so for the foreseeable future. The body of scientific investigation has shown that while water resources in the area are important in their own right, they are also intimately tied to the existence and preservation of the dunes and related resources, and the public's enjoyment of them.

Water Budget Delineation

Delineation of the Monument water budget was identified during the Water Resources Management Plan scoping process as the most critical water

resources issue facing the Monument. A water budget is an accounting of the annual sums all sources of water that enter and leave the area, including snow pack melt from the Sangre de Cristo Mountains, stream discharge, rainfall, and ground water. Water budget calculation will involve data collection, database building, and data assessment, all undertaken by Monument staff.

In order for Water rights to be used as an effective tool to protect Monument resources, high-quality water budget data needs to be collected consistently over time. Not only will the hydrologic processes be better understood, but the NPS will be able to use extensive documentation to demonstrate injury should it occur. The AWDI plan, and subsequent Stockman's Water Inc. plan, to pump and export as much as 200,000 acre-feet of ground water per year from lands adjoining the Monument, is an example of the type of activity from which Monument water resources needed to be protected. As long as there is flat ground in the valley, and a substantial amount of subsurface water, new projects will continue to be proposed.

The water budget database of the Monument is far from complete, though it is considered superior to that of most NPS units. The database is currently comprised of:

•Surface flow data from automated gauges on Medano Creek (1991 to present) and Sand Creek (1992 to present, excluding winters), Sporadic Mosca Creek surface water flow data are available for parts of 1967 and 1968.

•Rainfall and other weather data from 1950 to date.

•Ground-water data from McCalpin (1992), Hadlock (1995), have been compiled. This is far from a complete picture of the water budget.

•Snow pack data from one SNOTEL installed in 1995.

Effective data management and quality assurance programs are also part of the water budget database.

Three proposed projects will directly enhance data collection related to the water budget, two for monitoring surface water, and one for ground water.

A continuation of the current surface water monitoring program is proposed in **GRSA-N-040.000 Monitoring Surface Water Components of the Water Budget**. Incremental improvements would be made to this program based on available staff time and influxes of project funding. For instance, if funds became available for the expansion of the monitoring well network, monument staff will pick up the responsibility for long-term data collection, management and equipment maintenance.

One substantial addition proposed for the surface water budget program is a two year program to **GRSA-N-040.100 Monitor the Terminus of Flow of Medano and Sand Creeks**. It is suggested that the terminus of flow (the downstream point where the last stream flow sinks into the sand) could provide a very sensitive indicator of the overall hydrologic status of the creeks. Some monitoring of the Terminus of flow has already been undertaken. It is intended that the proposed intensive monitoring would provide much greater data density for analysis, thus providing a better evaluation of terminus of flow as an inexpensive and easily measured indicator.

A single SNOTELL was installed on the Medano Creek watershed in 1995. It remains to be seen if this provides adequate data for the purpose of predicting and analyzing runoff. An evaluation should be made after a few years of operation.

Groundwater Monitoring

The current network of 23 monitoring wells are centered around Medano and Sand Creeks because these have been the greatest interest. They are also areas with the fewest access problems and avoided the complexities of drilling in designated wilderness. This pattern has lead to some large gaps in the well network, a situation that is more of a deficiency because the existing well network has shown the aquifer system to be complex, showing considerable variation from location to location. Groundwater movement is also complex seasonally with aquifers along the streams filling to the surface each spring, then draining away through the fall and winter.

Major gaps in the current well network are: (1) the Sand Sheet, (2) the south boundary, and (3) the interior of the active dune field. The project statement **GRSA-N-041.200 Expand Monitoring**

Well Network to Improve Understanding of Aquifer Systems proposes seven additional monitoring wells, three along the south boundary and four on the sand sheet. No wells are proposed at this time for the main dune field due to access difficulties and the depth of sand which would necessitate drilling through 100 - 200 additional feet of sand. However, there will be an attempt to locate two of the sand sheet wells as close as possible to the dune field, to some indication of groundwater conditions there. Most of the new wells will be equipped with automated data loggers due to their remote location.

This drilling will require an Environmental Assessment to document the need to drill in wilderness.

Surface Flow and Sand Movement Relationships

Meeting management's preservation objectives for the Monument demands greater understanding of the dynamic relationship between surface water flow in the streams and movement of sand in the dune field. Researching those dynamics was rated as the highest priority project in a recent Monument planning document (National Park Service, 1994a). The surface water flow component of dune field dynamics is the most readily observable and measurable aspect of the water budget that directly affects preservation of the dune field. These dynamics include waterborne transport of sand to the upwind parts of the dune field by both Medano and Sand Creeks, leading to the crescent shape of the field and positioning the sand for recycling back onto the dune field. These creeks act as barriers to further northeastward transport of sand by wind, leading to abrupt dune-field margins along the creek channels. The sand-transport process is apparently more active on Medano Creek due to more extensive contact with the dune field margin and larger upwind sand sources. Further, since Sand Creek became entrenched into the sand sheet during the 1960's, it may have ceased to be an effective source of sand to the dune field. Though it is an extensive area, the sand sheet does not appear to be a significant sand source (Valdez, 1992).

A project has been initiated by staff of the Monument to determine the relationship of quantified surface water flow in Medano Creek to quantify sand movement therein, because of the key role that surface water flow plays in the sand-transport process, and the vulnerability of that surface flow to numerous alterations. Medano Creek was chosen as the study site since it is the major sand transporter and depositor, and is quite accessible.

Specific goals of this study are to determine:

- specific creek segments where sand is being eroded and segments where deposition is occurring;
- quantification of sand moved and comparison of that volume to quantified surface water flow;
- the role of wind action on sand on the seasonally dry parts of the creek channel.

Sources of preliminary data include a 1991 Medano Creek channel longitudinal profile (McCalpin, 1991) which identified a generally consistent gradient interrupted by a prism of sand, apparently in transport, from the Castle Creek junction southward to the Dunes picnic area. It was surmised that sand transport might be occurring in discreet prisms or packets, the dynamics of which might be related to the position of the terminus of flow. Burial of one of the groundwater monitoring wells in the Medano Creek channel only a few years after drilling is other bit of evidence to suggest significant quantities of sand move in the stream beds.

The current base-funded research effort to quantify this sand movement was begun in the fall of 1994 at the time of seasonally minimum stream discharge. A longitudinal survey of the braided channel section of Medano Creek was completed with the aid of a global positioning system in order to identify any changes from the 1991 survey that might affect sand erosion or deposition, and to determine more precisely the creek's depositional area. The braided channel was determined to be 26,830 feet long, 790 feet wide on average (1170 feet maximum and 120 feet minimum), with a 0.76 mi^2 (486 acres) area and a constant 77 feet/mile (1.5 %) gradient. *There was no evidence of a sand prism*.

The uncertainty about sand movement has led to the establishment of 24 different surveyed transects perpendicular to the Medano Creek channel. These will be measured both before spring peak stream discharge begins and again when seasonal base flow conditions return in the fall. Observed changes will allow determination of whether a depositional or

erosional environment (or possibly both) currently exists in the stream channel. The transects are spaced at 1,000-foot intervals from a point 800 feet upstream of where the braided channel currently begins to a point where the channel begins to divide and enter the sand sheet. Channel surface elevations are measured at 10 foot intervals across each transect. The changes between spring and fall will show the effect of water transport of sand; the changes between fall and spring can be attributed to wind transport. Ultimately, net sand volume changes can be calculated and correlated to measured stream discharge. The effort requires 0.1 FTE per year.

For statistical purposes, a project duration of at least five years is recommended to collect sufficient data for correlating quantified stream flow and sand transport that are observed over a variety of flow and transport conditions. Following this should be lower-intensity data collection, with surveys every two or three years to allow monitoring of long-term degradational and/or aggradational dynamics in the creek channel.

Hydrostratigraphy

A relationship with ground water extends to other scientific and scenic aspects of the Monument, including surge flow maintenance, dune field stability, and interdunal pond stability. In that regard, the ground-water component of the water budget may be just as important as the surface water component.

Data available to characterize the ground-water component of the water budget include those from well grids in Sand and Medano Creeks, seven other wells in the Monument, and data from some geophysical studies. These are insufficient for the desired understanding of the regional aquifer location and volume characteristics. Additional data are needed concerning recharge, the aquifer zone's sedimentology, hydraulic conductivities, and mechanisms of water travel in the recharge zone. One of these data needs has been developed into a project statement at this time, **GRSA-N-041.100 Investigate Hydrostratigraphy Beneath Medano Creek**. The other needs are equally important, but until the nature of the aquifer's construction is known, and realistic techniques are developed to investigate it, they cannot be researched effectively.

Subsurface conditions in this sandy setting are have proven very difficult to investigate. Vehicle travel onto the sand is difficult, but an obstacle that can be overcome. Seismic sensing, a technique widely used in the petroleum industry to map strata, has been ineffective here for two reasons: (1) the unconsolidated sand attenuates the seismic signal, and (2) the differences between aquifers and aquitards are apparently very minor, too subtle to be imaged with all techniques tried to date. Contrast the differences between rock layers such as sandstone, limestone, mudstone, shale and granite, which are usually imaged by seismic techniques, with the apparent differences in strata under Medano Creek which might be unconsolidated sand, unconsolidated sand with some silt, unconsolidated sand that is somewhat compacted, etc., and it becomes apparent that any subsurface sensing technique will be tested to its limits in this setting.

A relatively new technique called high-resolution seismic reflection may hold some promise, as could ground penetrating radar. Both are advocated by people familiar with their use, and both are touted as having the ability to detect subtle differences in strata or degree of saturation, and to image shallow strata. Some further investigation of these techniques, and probably some field testing, will be needed before a large scale imaging project is undertaken. Monument staff will request technical assistance from the Geologic Resources Division in evaluating various techniques.

Regardless of the method for imaging the subsurface, actual cores will be necessary to fully interpret the images. Cores will provide the only method that will permit the strata to undergo a "hands on" inspection. For this reason the project statement included in this plan proposed collecting several core samples as the next logical step in understanding the hydrostratigraphy below Medano Creek.

Unfortunately taking core samples is another technique often frustrated by the sand. Dry sand has no integrity. Wet sand holds together well and is easy to penetrate. Saturated sand, below the water table (of which there are as many as three under Medano Creek), has a tendency to flow out of the core sampler and/or trap the drilling tool. Three core drilling techniques have been proposed that could overcome these difficulties: continuous coring, which vibrates core stems through saturated sand up to 120 feet below

the water table; dual wall reverse circulation rotary drilling, reportedly can penetrate 800 feet to 1000 feet of saturated sand
(Driscoll, 1986 and Greg Hadlock, Utah State University, Logan, UT, personal commun., 1995); and hydraulic punch drilling (the Hurricane System) which has been used to successfully core unconsolidated soils to depths of over 80 feet (Rod Perkins, Tamarack Environmental Services, Inc., personal commun. 1997). The latter was used to develop the cost estimate in the project statement, though some weighing of the relative merits and costs remains before initiating a contract for the work.

Interdunal Pond Evaluation

The Monument's interdunal ponds have diminished markedly in recent years. Although these ponds were still considered a significant wetland resource as recently as 1964 (National Park Service, 1994a), it has been noticed since the mid-1960's that they have been largely diminishing and not refilling with water. Photographic evidence between 1936 and 1992 and some brief narratives demonstrate that over 90% of the ponds have dried up and not returned in the past three decades. Available data suggest strongly that timely, pro-active investigation of the remaining ponds is the only approach that might identify viable alternatives for countering this trend. These small ponds exist primarily in the western parts of the dune field and further west on the sand sheet.

Complexities and unknowns relative to both the existence of the ponds and their diminishment leave many fundamental questions unanswered, disparities that should be resolved before an integrated management policy towards these ponds can be developed. Sparse evidence available to date allow several possible reasons for the changes in interdunal ponds. These are:

- Short- or long-term climatic change;
- Water table fluctuations due to past and present irrigation practices (flood irrigation and/or groundwater withdrawal);
- Water table fluctuations due to changes in vegetation and corresponding evapotranspiration rate change;
- Burial of interdunal ponds by dune migration;
- Destruction of seasonally flooded ponds by sand movement during dry seasons or droughts;
- Change in the relative location of the water table due to tectonism (uplift or isostatic rebound).

Additional discussion of each of these possible causes of change in the interdunal ponds have been compiled in a separate report for the Monument (Chatman, 1995b). Examination of these possibilities suggest that pond *diminishment* may have anthropogenic cause (e.g., groundwater withdrawal), natural cause (e.g., deflation, burial, or tectonism), or the ponds may be *ephemeral* creations of a climatic cycle (e.g., increased water availability during the Little Ice Age). Similarly, ponds may have *formed initially* from anthropogenic change (e.g., increased groundwater levels from subirrigation). Some combination of causes, most likely will be shown to be responsible for interdunal pond change.

Four separate actions are appropriate at this time to address the reasons for pond diminishment, and to learn more about their function. The results of each of these will help guide the immediate and long-term management of the ponds, and add another piece to the complex puzzle that makes up the physical and biological function of the dunes.

- Map the locations of current and past interdunal ponds and associated wetlands.
- Use dendrochronology to identify historic and prehistoric trends in precipitation, so that evidence gathered in other studies can be evaluated in a climatic context.
- Investigate the most likely causes for pond diminishment.
- Inventory the biologic components of pond ecosystems and evaluate their function.

The first two of these actions are currently being addressed. A project to document the Environmental History for the Monument is underway which includes obtaining and evaluating historic aerial photographs. Ten sets of aerial photographs were obtained representing the period from 1936 through 1995. Preliminary results show the number of ponds with water present at the surface dropping from 36 in 1936, to zero in 1966. This was followed by a slow rebound

until nine ponds were present in 1995. When the number of wetland features without surface water are added to the total, the trend is similar, though less pronounced, dropping from 69 in 1936, to a range of 21 - 37 wetlands present since the 1950's.

The environmental history study also includes an analysis of tree rings, historic accounts and historic photographs in order to understand long- and short-term climatic and vegetation histories.

On the 1930's photographs, the wetlands have well-developed fringing communities dominated by several species of perennial wetland plants indicating that water levels had been relatively stable for at least many decades. Thus, their relatively sudden disappearance appears to indicate a significant change in Monument hydrology, the cause of which has yet to be determined.

One of the plausible explanations for the for pond diminishment is that a severe drought in the 1950's caused the sand sheet to become unstable, and blowing sand filled most of the ponds. An investigation of this possibility is presented in project statement **GRSA-N-029.000 Determine the Cause of the Disappearance of Interdunal Ponds**. This project explores current hydrology and sediment and vegetation patterns in former ponds. Ponds, former ponds and wetlands would be mapped and surveyed, monitoring wells installed, and cores extracted and examined for sediment patterns, preserved plant materials, and ^{137}Cs content. This information would then be correlated with the climate history developed through dendrochronology and historic records.

Pond Function and Species Inventory

A compilation of the types of flora and fauna present in interdunal ponds of the Monument and a more detailed understanding of the biological function of these ponds is considered important for the management of this resource. It is reasoned that better understanding of the interdunal ponds will afford greater understanding of possible reasons for their diminishment.

The literature contains several species inventories of the northern San Luis Valley and in some cases the interdunal pond specifically. A collective evaluation of these sources might be sufficient to characterize pond biota without collecting additional field data. This approach is presented in Project Statement **GRSA-N-047.000 Review of Literature Regarding Biological Function of Interdunal Pond Wetlands**. Collective evaluations of these inventories by the appropriate science professionals should be illuminative as to the function of the ponds. If the current information turns out to be deficient, then this project will point out areas where additional work is needed.

Floral and faunal inventories of Great Sand Dunes Monument wetlands include those of macroinvertebrate and vertebrates (Zuckerman, 1984); all fauna (Daniel, 1960a); all flora (McArthur and Sanderson, 1992); and all species (Daniel, 1960b). The Rio Grande Valley segment of the U.S. Geological Survey's National Water-Quality Assessment Program (NAWQA) includes a 1991 inventory of benthic invertebrates from a sampling and measurement station on Medano Creek at the National Park Service boundary. Five other studies may provide information relevant to species identification at Monument wetlands. These include insect inventories completed in the Monument by O'Neill (no date) and Triplehorn (1974) and a small mammal survey by Organ and Halfpenny (1977). It may be possible to delineate vegetation types within specific interdunal ponds of the Monument and surrounding areas with color infrared photography data and U.S. Fish and Wildlife Service assessments utilized for its 1:24,000-scale National Wetlands Inventory maps.

Related studies should be incorporated into the evaluation process, including Ramaly (1942) and Keen (1971), which inventory Valley-wide flora and fauna, respectively. A State of Colorado 1992 and 1993 field season biological inventory includes sampling at Crestone, CO, two sites on the Baca Grant, and several sites southeast of Fort Garland, CO (Bob Owen, State of Colorado, Water Quality Control Division, personal commun., 1993). Useful vegetation delineation may be possible using spring and fall satellite imagery of southwestern Colorado that has been acquired by the National Park Service. Also useful may be the hydric soils inventory of Alamosa, Saguache, and Conejos Counties (Wilson, 1990), and an on-going Alamosa River watershed study that examines salinity, pollution, and river channel problems outside of Monument watersheds, work undertaken by the U.S. Department of Agriculture's Natural Resource Conservation Service (George Wilson, Natural Resource Conservation Service, personal commun., April 1995).

Water Rights

Protecting surface water and groundwater rights of Great Sand Dunes National Monument is a complex issue that is tied closely to all other preservation issues. Tasks related to water rights protection will be addressed by staff of the National Park Service's Water Resources Division, Water Rights Branch, Fort Collins, CO, on an as-needed basis. Most water rights actions are initiated by the state or private entities, and this approach maintains the flexibility needed to respond to quickly and consistently.

Regional Approach to Water Resources Management

The National Park Service can successfully accomplish the overall water resources objectives and implement the actions identified in this plan only by adopting a more regional approach to water resources management.

To achieve this goal, it is recommended that Monument staff participate in the water resources management process and interact with the major water resource management agencies in the Valley. These are:

- Rio Grande Water Conservation District;
- Conejos Water Conservation District;
- Bureau of Reclamation divisions managing and maintaining the Closed Basin Project;
- U.S. Department of Agriculture's Natural Resource Conservation Service;
- Colorado State Soil Conservation Board.
- Colorado Water Quality Control Division
- Office of the Colorado State Engineer

The Rio Grande Water Conservation District has jurisdiction over work with water quantity and quality, and irrigation water in the entire Rio Grande watershed, including large areas of New Mexico and Texas. The agency was a major force in the legal actions against the AWDI proposal to pump large quantities of groundwater from the Rio Grande watershed and export it from the San Luis Valley. The responsibilities of the two water conservation districts will continue to grow. In a few years, the Rio Grande Water Conservation District and the Conejos Water Conservation District will take over the operation and maintenance of the Closed Basin Project from the Bureau of Reclamation (Mike Cassell, U.S. Bureau of Land Management, Alamosa, CO, personal commun., April 1995). The Closed Basin Project is the largest water resource management structure in the entire San Luis Valley.

Water Quality Issues

While both surface water and ground-water resources are present, the Water Resources Management Plan scoping process focused on surface water quality. Project recommendations, below, address several of those surface water quality issues, including expanding upon the existing surface water quality baseline, supporting application for an outstanding waters classification, monitoring to determine future water quality trends, and determining the effect of various recreational activities on water quality. Other water quality issues detailed below include obtaining State of Colorado "Recreational 1" classification for Medano Creek water; maintenance of potable water quality within standards; and evaluating potential contamination from mine sites, landfills, and a firing range.

Baseline Water Quality

Of the waters of Great Sand Dunes National Monument, a reasonable water quality baseline is available only for Medano Creek. Data from the existing U.S. Geological Survey NAWQA monitoring station were collected monthly between September 1992 through late 1995. Available data include stream flow quantification and water quality monitoring for 29 physical or chemical constituents. Further, bottom sediments were analyzed once for 39 inorganic chemicals, and 100 synthetic organic chemicals, including pesticides and volatile organic compounds. Characterization of the benthic environment was accomplished as well as a survey of fish species present (U.S. Geological Survey, NAWQA database, Albuquerque, NM, 1995). The data will serve as a base for comparison when NAWQA sites are re-sampled in approximately ten years.

Ground-water quality is partially illuminated through samples from a few wells, but any future development of a ground-water quality baseline will be based primarily on compliance monitoring of public water supplies or individual research project requirements.

A separate project for a baseline inventory of surface water quality is not proposed at this time, because a

substantial part of an inventory can be accomplished within the project presented below for acquisition of an outstanding waters designation.

Outstanding Waters Classification

Acquisition of an "Outstanding Waters" classification for several of Great Sand Dunes National Monument's surface waters would provide the highest level of regulatory protection provided for under the Clean Water Act, and State of Colorado implementation of the act. Considering the importance of water resources to the other resources of the Monument, recreation activities and Monument operations, the level of protection offered by an outstanding waters designation is desirable and should be pursued.

A Project Statement titled **GRSA-N-042.000 Determine Baseline Water Quality for Outstanding Waters Designation**, is proposed to gather the data needed to demonstrate eligibility for an outstanding waters classification. This inventory of water quality is also designed to provide a water quality baseline of almost all surface water sources in the Monument.

In order to qualify for an outstanding waters designation in the state of Colorado, a water source must meet three tests.

1. Representative data must demonstrate that the existing quality meets standards 12 parameters selected from those designated to protect Aquatic Life Class 1, Recreation Class 1, and (for nitrate) domestic water supplies.

2. The waters must, in the opinion of the State Water Quality Control Commission, "have exceptional recreational or ecological significance, and have not been modified by human activities in a manner that substantially detracts from their value as a natural resource." Waters in the Monument meet this test by being, among other things, "a significant attribute of a National Monument."

3. The waters require additional protection to that provided under current water quality classifications and protected uses.

The specific numeric standards that must be met are presented in Appendix B, part 8. They include standards for dissolved oxygen, pH, fecal coliform bacteria, un-ionized ammonia, and cadmium, copper, lead, manganese, selenium, silver, and zinc (State of Colorado, 1995a). Hardness must also be measured in order to evaluate the standards for some metals.

With the water quality data collected to date, no stream segments in the Monument can be completely characterized relative to those numeric standards. Even though the segment of Medano Creek characterized by data from a U.S. Geological Survey station has been tested more thoroughly than any other segments in the Monument, data are absent or inadequate for fecal coliform bacteria, nitrate and un-ionized ammonia content. In addition, maximum lead level was *exceeded* in one sample; while two others contain zero lead (Appendix 2; Table 4).

For all of the other required parameters, Medano Creek meet Outstanding Waters criteria.

It is apparent that more sampling is needed for all the Outstanding Waters criteria metals, particularly lead, and that water hardness values must also be obtained. Additional dissolved oxygen content sampling should be undertaken at the lower-gradient, shallower, braided segment of Medano Creek. The dissolved oxygen content there is likely to be lower than at the upstream station.

It would be logical and administratively more efficient for the Monument and Rio Grande National Forest to make a joint petition to the Water Quality Control Commission for outstanding waters designations for their shared streams. Most of the streams in the Monument flow directly from U.S. Forest Service lands, many of them flowing from designated wilderness. As the study design is prepared for the proposed water quality inventory, it should ensure that the sample sites selected are representative of the reaches of stream managed by both agencies. If this is not possible under the requested funding, supplemental funding from the U.S. Forest Service would be sought.

If additional analyses prove that individual stream segments are within the limits of the 12 parameters discussed, above and should Outstanding Waters designation be assigned to any of those stream segments, the Monument and the State of Colorado would then have the responsibility to meet requirements of the Antidegradation Rule. The Rule states that waters shall be maintained and protected at their existing quality,

and no further water quality degradation is allowable. Any water quality degradation that might be planned in the future would be subject to the Antidegradation Review process (State of Colorado, 1995a).

Recreational Activities and Surface Water Quality

The volume of Monument visitors seeking water-related recreational activity continues to increase each year. There is no database or monitoring in place to determine the effects of this recreational water use on water quality, yet there are State of Colorado standards for designated-use classified surface waters and other public health standards that are applicable to these waters. Contact recreation in the seasonally congested public wading area in Medano Creek and increasing backcountry (primitive) camping in Medano and Sand Creek watersheds both have the potential to impact water quality and place visitors at risk.

Two projects are proposed to address water quality concerns. The most urgent need is for **GRSA-N-033.000 Prevent Fecal Contamination of Medano Creek**, which proposes the installation of two composting toilets at day use areas where improper disposal of human waste has been a chronic problem. The second project examines the impact of backcountry campsites and water-based recreation on bacterial water quality. **GRSA-N-043.000 Determine Effects of Water-based and Backcountry Recreation on Water Quality** includes a two-year program of intensive sampling of indicator bacteria intended to produce a statistically viable baseline of water quality conditions. This would be combined with sanitary surveys of backcountry an recreation sites.

Potable Water Supply

Moving Well No. 2

Relocation of water supply Well No. 2 has been proposed, based detection of 18 mg/L of a nitrate compound in a single sample from a water supply tank, collected in 1989. Excessive nitrate content was not reproducible in 7½ years of subsequent testing (Ayers, no date; Great Sand Dunes National Monument file data), so that one sample is considered and anomaly which does not justify moving the well. Pumping tests run on the well in 1992 demonstrate that nitrate levels increase after pumping but are still below the State maximum contaminant level for nitrate (Ayers, no date). The pumping tests suggest that nitrate is drawn into the well field during pumping. Installation of an automated electric pump operation switch on the well in the summer of 1994 may be another reason why the nitrate level in the well has remained within compliance. The device allows for more frequent engaging of the pump for shorter periods of duration. This reduces the cone of depression of the water table around the well during its operation and decreases influx of any foreign substances, such as nitrate, into the well field.

Absorption Field-to-Well Minimum Distances.--In the course of preparing this Water Resources Management Plan, it was suggested that Well No. 2 would have to be moved, regardless of the resolution of the nitrate analysis question, because the Colorado State Engineer's Office was issuing new regulations for minimum distances between wells and various sewage treatment fields. The new regulations, effective on April 1, 1995, call for a minimum distance between such facilities of 100 feet (increased from 25 feet). Great Sand Dunes National Monument facilities are within compliance of these new regulations. Well No. 2 is 520 feet from the campground absorption field.

Sustaining Mandatory Potable Water Supply Testing

Potable water supplies of the Monument must be maintained within specific standards. Specific monitoring required is based on the size of the resident population or the number of service connections in the water supply system (State of Colorado, 1994b). The Monument's residential water supply system (PWSID 202300) is very close to both service connection and resident population levels that will trigger reclassification of that system and require more stringent testing in the areas of:

- Inorganic substances;
- Pesticides, herbicides, PCBs, SOCs, VOCs, and other chemicals;
- Separate lead and copper tests;
- Gross alpha particles and radionuclides.

The monitoring that is done at the Monument must be re-evaluated when either the number of service

connections increases by two (to 15 total) or the resident population increases by two (to 25 total).

Obtaining Recreation 1 Classification for Medano Creek

Designation of Medano Creek as "Recreation 2" water does not accurately reflect actual utilization of those waters. Recreation 2 waters are designated to protect "limited contact recreation," where ingestion of water, as occurs in swimming activities, is not likely to occur. Medano Creek *is* utilized as a contact recreational area, which visitors use for activities such as body surfing in the creek's surge flow.

The vehicle for proposing change is the triennial review of State waters, a charge of the State Water Quality Control Commission. This review is due again for Great Sand Dunes National Monument waters in 1997. *All* numeric standards currently in place for the Recreation 1 and Recreation 2 waters in the Monument are identical (Table 3), so no petition for an interim classification change is warranted.

Evaluating Potential Contamination from Landfills and Firing Range

The three, inactive National Park Service landfills within the Monument boundary have been evaluated by the Rocky Mountain Region's Regional Hazardous Materials Coordinator and found to contain no immediate hazardous materials dangers, although some further action will be taken at one of the three sites. None of the sites are located such that they could contaminate potable water supplies of the Monument, surface waters of Medano Creek, or the Denton Springs wetlands. The actions already taken have or will resolve the various components of this issue.

The inactive, two-acre small weapons firing range, formerly used by the National Park Service and others probably contains some unquantified amount of lead from spent bullets in the local soil. Whether this presents a hazard to water resources has not been determined. A simple test to characterize the hazard is recommended. Two sites should be chosen where targets and impact berms were thought to have been when the range was in use, along with one down-gradient site where spent bullets are thought not to have landed. Sifting of a one cubic yard or one-half cubic yard soil sample from each of the sites will help to characterize the quantity of lead present. Lead is one of the more stable metals in the class of metallic environmental contaminants, migrating only small distances relative to many other metals, such as copper and zinc, under like moisture and acidity conditions. Should an environmental problem be indicated by the test, methodology developed for decontaminating U.S. military firing ranges (Johnson et al., 1993; Johnson and McDonald, no date) can be consulted. Decontamination methods that may be applicable include mine beneficiation-type gravity concentration of soils and impact berms and weak acid leaching. The U.S. Environmental Protection Agency's (USEPA) Toxicity Characteristic Leaching criteria contains standards for measuring the success of the operation (Johnson et al., 1993).

Water Quality Related to Mineral Development

Mineral-development activities that potentially could affect water quality of the Monument are in three categories:

- current petroleum exploration on the Baca Grant and recent gold exploration there;
- past mining within the Monument in the Cold Creek watershed;
- past mining activity outside the Monument boundary but within watersheds that drain into the Monument.

Most mines and prospects within and near the Monument are thought not to represent any potential for water quality degradation.

Concerning activities on the Baca Grant, it is recommended that the status of petroleum exploration and any restart of gold exploration be monitored, particularly in the light of proximity of exploration targets to the Monument boundary. Forging an information-exchange partnership with Lexam Explorations, Inc. would be beneficial. A paper by Robbie Gries, hired by Lexam as a consultant to help explain the oil shows, was recently published, the first publishing of scientific data about the discovery. Future mineral development activities related to the tract should be monitored through regular contact with the Colorado State Oil and Gas Conservation Division, Denver, CO (Bruce Heise, National Park Service, Geologic Resources Division,

Denver, CO, personal commun., June 1995), and possibly with the Saguache County Commissioner's office for data on well permits and mine plans.

Most of the lode mining *within* the Monument occurred in the Cold Creek watershed on a small, unnamed tributary of Cold Creek (Figure 2). The iron-oxide enriched zones at three groups of prospect excavations in this watershed (Figures 2 and 18), all north of the main Cold Creek drainage channel, should be investigated in the field further to assure that they are not sources of water quality degradation. The following data should be gathered at the sites:

- Proximity of drainage channels;
- Presence of any effluent mine water;
- pH of any stream surface waters nearby;
- Water quality sampling of effluent mine water, if above characteristics prove positive.

The workings are thought to be the source of at least some of the iron-oxide cementation of sediment that occurs occasionally in Sand Creek. Iron-oxides alone are not detrimental, but in this geologic environment the mineral group potentially could carry heavy-metal ion concentrations or be indicative of sulfide minerals, which, in turn, can generate acids when exposed to water. Mitigating the potential for water quality degradation problems are the facts that there is little surface flow in Cold Creek, and rock-chip samples from the sites are generally devoid of concentrations of toxic materials.

Lode-type mineral excavations *outside* of the Monument that require some additional field study include the Myrtle K Mine and mill site on Sand Creek (Figure 2). Due to the presence of sulfides and a mill and dump adjacent to the creek, a site assessment that parallels that prescribed above for the Cold Creek prospects area is recommended for the Myrtle K site to assure that no undetected water quality degradation is occurring or affecting waters of the Monument.

Some historical information is suggestive of copper loading in Mosca Creek, possibly related to releases of mineral processing reagents, but recent, limited water quality testing provides no indication of degraded water quality in Mosca Creek (sites detailed further in Chatman (1995c)). Should poor water quality be detected in the future, the metallized part of the Mosca Creek watershed, including the old prospect workings (Figure 2), should be investigated more closely.

An upstream site from the Monument that should be examined now is the easternmost working (an adit) in North Arrastre Creek (Figure 2). An abandoned, small mill was reported to the south of the adit. Information is lacking about the milling method employed or the presence of tailings and reagents. Contents of the steel drum reported at the adit opening are unknown (U.S. Bureau of Mines field notes, Denver, CO, May 14, 1982). Condition of the site should be verified with a field examination, and a decision made at that time about the need for water quality testing upstream and downstream from the mine.

Funding and Staff

Units of the national park system can generally operate under two types of funding Ä "soft funding", which is granted for specific short-term projects, and "base funding" to support the long-term operation of the unit. In order to be effective, tasks such as program management, monitoring, and coordination with other agencies, must be supported with base funds. This permits staff to build personnel knowledge of the resource, establish and maintain relationships with other professionals, and maintain consistency in long-term programs. In contrast, short term projects are best accomplished with soft funding, thus maintaining year-to-year flexibility.

The water resources program in Great Sand Dunes National Monument is currently accomplished by the following contributions from permanent staff:

- Superintendent	0.1 FTE
- Resource Management Specialist (GS-11)	0.3 FTE
- Geologist (GS-9)	0.7 FTE

This level of support is generally adequate to accomplish the current water resources program, which includes monitoring of:

23 Monitoring wells
3 Automated stream gauges
2 Manual gauges
7 Manual stream flow sites
Limited terminus of flow monitoring
Semiannual sand surveys

Proposed additions include monitoring of: terminus of flow (expanded), 7 additional wells, fecal coliform in recreation waters, physical and chemical parameters (in 5-7 yr cycles), interdunal ponds and wetlands. Several other actions are also anticipated. The Monument will become more active in regional water management by sharing information and concerns with other agencies. Changes in the number of visitors and their patterns of use will require a response. Enhancing interpretation of water resources will require additional communication and evaluation of information bases. Program management will continue to be a major effort. Issues such as interdunal ponds, understanding aquifers, and fecal contamination are unlikely to be resolved completely in the near future, even when the projects proposed in this plan are implemented. Coordination with other agencies will continue to be an important task.

In order to accomplish the additional workload, and to free up the Monument's geologist to devote adequate attention to the geologic program (reducing the geologist's water commitment from 0.7 FTE to 0.5 FTE), it is proposed that a GS-7 Hydrologic or Physical Sciences Technician be added to the Monument's permanent staff. With benefits and support costs, this will require an additional $50,000 in the Monument's annual operations budget.

This workload analysis included using the NPS Natural Resource Management Assessment Program (NR-MAP), and service-wide analysis of workload based on various attributes of park resources. This is a useful analysis that indicates the Monument should be devoting about 1.1 full-time equivalent positions to water resources management. However, NR-MAP underestimates the actual workload because it is not capable of recognizing the complexity of ground and surface interactions, the magnitude of threats to water resources, the responsibilities associated with decreed water rights, and the additional workload for wells not yet installed. Adding these considerations leads to a combined commitment to water resources of 2.0 full-time equivalent positions.

Other Issues

Re-incorporation of Indian Springs

Indian Springs (S. center, sec. 26, T. 41 N., R. 12 E.) is considered important not only for its associated wetland and wildlife, but also for numerous archeological sites (mostly animal kill sites) as old as about 9,500 B.C. Re-incorporation of the land into the Monument is considered important because the area could then be managed in conjunction with the other Monument eolian wetlands, and the preservation and control of the archaeological sites in the parcel could be better maintained. Currently the land is used for grazing.

The area was part of Great Sand Dunes National Monument from the time of the initial proclamation of 1932, but was later removed from the Monument, along with 8,280 acres on the south and west sides of the Monument, by Presidential Proclamation No. 3138, signed by President Dwight D. Eisenhower on June 7, 1956. The State of Colorado has ownership and managed the area since 1956. The land is currently leased by the State of Colorado for bison grazing to Hisa Ota, owner of Rocky Mountain Bison, Inc., and the Medano Ranch, a property that adjoins the Monument to the west.

In order to be reincorporated into the Monument, the land must be appraised for value and reacquired through purchase or land exchange. Additionally, Congressional action is needed to authorize a boundary change to the Monument. Appraisal costs can reach $50,000 for such a parcel. Colorado currently derives revenue from leasing the land and does not want to lose those revenues. Land exchange is more likely than purchase, because of the potential costs involved. The most likely avenue for land exchange is utilization of U.S. Bureau of Land Management land, some of which adjoins other State lands in the region. Nevertheless, the expended dollars for this action could become considerable.

It is recommended that cost estimates for the appraisal be obtained, and the willingness of the State of Colorado and the U.S. Bureau of Land Management to participate in a land exchange be explored. Only then will the feasibility and approximate costs of the action be known. The current lessee has expressed a willingness to give up the lease in order to facilitate transfer of the land back into the Monument.

Interpretation of Water Resources

When people think of a National Monument to sand dunes, few imagine water as an important part of the picture. Even those who come to play in Medano Creek and marvel at the picturesque contrast between

streams, sand dunes and high mountains, cannot know through pure intuition the importance of the streams in creating and maintaining the dunes. Gaining an appreciation for the interactions between sand, ground and surface water, and the other resources dependent on all of them, not only enhances a visitors enjoyment of the Monument, it also gives them an appreciation for the delicate balance that exists and its vulnerability to changes in the hydrology. It is for these reasons that interpretation of water resources plays a key role in the management and protection of the Monument.

In recognition of this, a position of Interpretation - resource management liaison has been established in the Monument. The primary responsibility for this position is to facilitate information transfer between the scientific community, the Monument's professional resource managers, and its professional interpreters.

Other actions such as the preparation of publications, briefing papers, exhibits, and audio/visual programs could also improve the interpretation of water resources. However, specific actions along these lines are not proposed at this time in this document because the exhibit space and programs offered in the Visitor Center are currently undergoing a complete revision. Park staff are proceeding with a separate planning process to ensure that the water resources interpretive materials in that facility are updated and enhanced. Once that is completed, then other gaps in the interpretive program can be identified and a proposal developed to correct them. To facilitate that process, a partial project statement entitled **GRSA-I-048.000 Enhance Interpretation of Water Resource Issues** is included as a template for developing future proposals.

Well Permits

To facilitate monitoring of shallow ground-water levels, Great Sand Dunes National Monument had 23 monitoring wells drilled between 1990 and 1997. Most of those wells (eleven) monitor Medano Creek or the water levels at the base of the dune field near Medano Creek. There are seven wells on Sand Creek, two on Mosca Creek, and three on the sand sheet on the western part of the Monument boundary.

Permits from the Colorado State Engineer's Office are required for all of the wells because they have been installed on a semi-permanent basis, and are to be used for a period of time exceeding one year. Well A had an existing permit, so it was issued an amended permit in November 1996. All of the 20 other operational wells were issued separate permits in December 1996. A record of completion must be filed within one year of the permit, which in this case will be only a paper work exercise, since the wells are already completed.

"404" Permits

The recreational four-wheel-drive vehicle route along Medano Creek (Figure 2) that passes through the Monument on the way to the Rio Grande National Forest includes seven crossings of the creek. One crossing (Shockey's Crossing) is inside the Monument and all others are within the National Forest. Monument staff monitors all the crossings, including those in the National Forest, and maintains them as the need arises. Most work is done annually, primarily in the spring, with a backhoe.

Making a determination of whether the Monument is within regulatory compliance in the process of maintaining Medano Creek vehicle crossings was identified as an issue in the Water Resources Management Plan scoping process. Section 404 of the Clean Water Act requires permits under certain conditions, when digging, dredging, and other stream crossing maintenance is done, primarily when adding or removing sediment from the stream bed or causing increased turbidity. These activities are permitted through the Department of the Army, Corps of Engineers (COE).

In recent years maintenance actions have been performed on only the one crossing in the Monument and four of the crossings in the National Forest. The others have not required any maintenance. The maintenance work is small-scale, never moving as much as 10 cu yd of material. No foreign material is added to Medano Creek; the erosion scours and tire ruts in the stream bed are simply refilled with other Medano Creek sediment from a nearby part of the stream bed. The crossings for this single-lane, unimproved road are small, with none wider than about ten feet.

These characteristics allow maintenance of the stream crossings in compliance with Section 404 of the Clean

Water Act, under COE Nationwide Permit No. 3 for the "maintenance, repair, rehabilitation or replacement of any previously authorized, currently serviceable, structure or fill." Current nationwide permits are described in the Federal Register of December 13, 1996, p. 65914.

Written confirmation that this activity falls under Nationwide Permit No. 3 was received from the COE in March 1995 (permit number 1995-30054). Nationwide permits were revised and renewed in February 1997. A verbal confirmation was obtained that this activity still falls under Nationwide Permit No. 3, and that no further regulatory action is needed until the permits again are revised on February 11, 2002.

Fisheries Management

The Colorado Department of Wildlife's Monte Vista, CO, office has undertaken restoration of Rio Grande cutthroat trout (*Oncorhynchus clarki virginalis*), a fish species native to the Rio Grande Basin, to the entire lengths of Medano Creek and Little Medano Creek (Figure 2). The action was initiated because the cutthroat trout was listed by the State of Colorado as an endangered species. Over a period of many years, Medano Creek in particular had been overtaken by exotic species of German brown trout (*Salmo trutta*), brook trout (*Salvelinus fontinalis*), and rainbow trout (*Oncorhynchus mykiss*), introduced by early settlers. In approximately the year 1890, one such settler, Ulysses Herard, established a rainbow trout hatchery on the creek. Not only did cutthroat trout become hybridized with the rainbow trout, but also, the aggressive and prolific German brown and brook trout species negatively affected cutthroat trout populations.

Beginning in 1985, the Colorado Division of Wildlife removed the fish populations of Medano Creek and Little Medano Creek with the fish toxicant *Rotenone*. In 1987 it was determined that no fish remained alive following the chemical reclamation process, and pure strains of the cutthroat trout from the Forbes Ranch and nearby National Forest land southeast of the Monument were collected and used to re-stock Medano Creek, Medano Lake (in the Rio Grande National Forest), and Little Medano Creek. Medano Creek was re-stocked with 2,400 cutthroat trout in the first year, and another 265 fish in 1988. As a result of the success of the re-stocking operation in Medano Creek and in other water bodies in Colorado, the Colorado Division of Wildlife was able to change the status of the Cutthroat Trout from "endangered" to a "species of special concern."

In the summer of 1996, a second native fish species that had been extirpated from Medano Creek was re-established there: the Rio Grande sucker (*Castostomus plebeius*), an endangered species in Colorado, according to the State listing. Some time will be allowed for re-establishment of the Rio Grande sucker after re-stocking; then, the State Division of Wildlife will re-stock the third of the three fish species that were native to Medano Creek: the Rio Grande chub (*Gila pandora*). It is thought that the Rio Grande chub, a heartier species, might overrun the Rio Grande sucker if both were re-stocked at the same time. Up-to-date status of the re-stocking operation can be obtained from Colorado Division of Wildlife, Monte Vista, CO.

Summary of Project Statements

Ten specific project statements developed for this Water Resources Management Plan are listed below in order of current priority, and are summarized in the following Table (Table 11). These Priorities, however, are likely to change as tasks are completed, more is learned about the water resources, and decisions are made internally and externally affecting the relative urgency of the various issues.

The full text of the project statements are presented in Appendix A. They will be inserted into the Natural and Cultural Resources Management Plan of the Monument, among the other resource management priorities.

GRSA-N-042.000 DETERMINE BASELINE WATER QUALITY FOR OUTSTANDING WATERS DESIGNATION

GRSA-N-041.100 INVESTIGATE HYDROSTRATIGRAPHY BENEATH MEDANO CREEK

GRSA-N-043.000 DETERMINE EFFECTS OF WATER-BASED AND BACKCOUNTRY RECREATION ON WATER QUALITY

GRSA-N-041.200 EXPAND MONITORING WELL NETWORK TO IMPROVE UNDERSTANDING OF AQUIFER SYSTEMS

GRSA-N-048.000 ENHANCE INTERPRETATION OF WATER RESOURCES ISSUES

GRSA-N-040.100 MONITOR TERMINUS OF FLOW OF MEDANO AND SAND CREEKS

GRSA-N-033.000 PREVENT FECAL CONTAMINATION OF MEDANO CREEK

GRSA-N-029.000 DETERMINE THE CAUSE OF THE DISAPPEARANCE OF INTERDUNAL PONDS

GRSA-N-047.000 REVIEW OF LITERATURE REGARDING BIOLOGICAL FUNCTION OF INTERDUNAL POND WETLANDS

GRSA-N-040.000 MONITORING SURFACE WATER COMPONENTS OF THE WATER BUDGET

Table 11. Summary of Project Statements

Complete project statements are presented in Appendix A.

PROJECT	SUMMARY OF PROBLEM	SUMMARY OF PROPOSED ACTIONS
GRSA-N-042.000 **Determine Baseline Water Quality for Outstanding Waters Designation**	An "Outstanding Waters" designation by the State of Colorado would provide the highest level of regulatory protection available of monument waters. State regulations require data demonstrating that water quality criteria are met for 12 specific parameters, before a designation can be considered. By being a significant attribute of a National Monument, waters in the Monument waters in the monument meet one of the other key tests prescribed by the state.	A two-year quality inventory is proposed, which will: 1) demonstrate eligibility for outstanding waters; and 2) document water quality conditions all Monument waters. Major actions in this proposal are: 1. Exploration of a joint effort with the US Forest Service to seek a designation for the entire length of Mosca and Sand Creeks and their tributaries. 2. Sample and analyze: perennial streams (8 sites, 3 chem samples/yr + 15 bacteria samples/yr); seasonal streams (6 sites, 1 sample/yr); and an interdunal pond (1 site, 3 samples/yr). 3. Use the inventory as a basis for designing a long-term monitoring protocol.

PROJECT	SUMMARY OF PROBLEM	SUMMARY OF PROPOSED ACTIONS
GRSA-N-041.000 **Investigate Hydrostratigraphy Beneath Medano Creek**	Surface flow in Medano Creek is made possible by the presence of relatively impermeable layers, or aquitards which slow the downward percolation of water. These are apparently subtle, difficult to detect, and appear to be variable in both lateral and vertical distribution. Some ground water is pumped near the Monument, and there are serious proposals to pump and export much more. One of the key considerations for the courts and other decision makers is the nature and extent of the link between surface flow and water in the regional aquifer. A better understanding of the hydrostratigraphy would greatly enhance the ability to understand and predict the potential impacts of existing and proposed pumping. Several techniques have been tried to develop an image of the subsurface stratigraphy, most experiencing little or no success. High-resolution seismic reflection may hold some promise, as could ground penetrating radar. Core samples will be needed to fully utilize any of the other imaging techniques.	Four deep core samples will be taken, to a depth of about 150 feet. This limited number is planned because drilling and recovering a core sample from this unconsolidated sand, that is dry near the surface, wet and saturated at depth, poses some difficulties. Drilling will use one of the following techniques: Continuous Coring Dual Wall Reverse Circulation Rotary Drilling Hydraulic Punch Drilling (Hurricane System) Once a technique is successful, additional cores may be needed, depending on the variability of the strata.
GRSA-N-043.000 **Determine Effects of Water-based and Backcountry Recreation on Water Quality**	Potential sources of fecal contamination of streams include water play, backcountry campsites, livestock grazing and wildlife. Full and partial-body contact recreation is a popular activity for visitors during the summer months, so the potential for disease transmission is great if significant levels of contamination exist. The Monument has 7 backcountry campsites, all located near streams, and none of these have toilet facilities. The most used campsites receive and average of 1 - 1.5 campers per night during the summer season. Past bacterial monitoring of the streams is very limited, but indicated that possibility of some problems, and a pattern of increasing contamination downstream toward reaches where water play is greatest.	A two-year program of intensive sampling for indicator bacteria is proposed, followed by a long-term monitoring program. Intensive monitoring will be conducted at ten sites, 5 times/month, for a four month season. This will be coupled with sanitary surveys backcountry and frontcountry visitor use areas. An annual report will be produced. The results of this study will be used to design a much smaller-scale long-term monitoring program.

PROJECT	SUMMARY OF PROBLEM	SUMMARY OF PROPOSED ACTIONS
GRSA-N-041.200 **Expand Monitoring Well Network to Improve Understanding of Aquifer Systems**	The current knowledge of the ground-water system provided by the existing monitoring network and past studies, indicates that it is a very complex system. The current 23 monitoring wells are concentrated near the Monument boundary, due to ease of access and designated wilderness for 87% of the Monument, and provide little information about groundwater conditions on the sand sheet, in the interior of the active dune field, and along the south boundary.	Seven additional monitoring wells will be drilled and instrumented, 4 on the Sand Sheet, and three along the south boundary. Data Collection will be automated due to the remote locations of these wells. The need for the Sand Sheet wells will be documented in an Environmental Assessment due to their location in designated in wilderness.
GRSA-I-048.000 **Enhance Interpretation of Water Resource Issues**	Water is often a controversial issue in this area, with several serious proposals to export large quantities of ground water from the San Luis Valley. It is also crucial to the development and maintenance of the dunes and other natural features in the Monument. As part of a remodeling of the visitor center, an exhibit is currently being developed for the updating of all exhibits. Much has been learned about water resources since the exhibits were originally developed, and these concepts can be incorporated in the new exhibits. A collateral duty position to provide liaison between the resource management and interpretative staffs has been established.	Now actions are proposed beyond current activities to update visitor center exhibits. Once this is completed, it will be possible to identify gaps in the interpretive messages and facilities, and develop a proposal to address them.

PROJECT	SUMMARY OF PROBLEM	SUMMARY OF PROPOSED ACTIONS
GRSA-N-041.100 **Monitor Terminus of Flow of Medano and Sand Creeks**	The distance the water flows on the surface before sinking into the sand beds of Sand and Medano Creeks, called the *terminus of flow*, can be used as a fine-tuned indicator of the net flow into and out of the system. The dune system is maintained largely due to a balance of surface and ground water, which are closely linked - the sand being such a porus medium that the perched ground-water table must be filled with each years runoff before surface flows can occur. The distance and duration of surface flow is a critical determinant of the amount of sand transported by the creeks and where it is deposited. It is also an indicator of the amount of water entering the ground water system. Monitoring of the terminus of flow is a logical and cost effective addition to the current surface and ground-water monitoring program.	Initiate terminus of flow monitoring of Sand and Medano Creeks. This will be project funding for two years, after which it will be added to the base funded monitoring program. Each stream will be monitored with GPS equipment every other day between April 1 and August 30 every year. Analysis will include an assessment of the sensitivity of this monitoring as an indicator of overall hydrologic condition. Data management and preparation of an annual report will also be included.
GRSA-N-033.000 **Prevent Fecal Contamination of Medano Creek**	Fecal contamination of Medano Creek is suspected at two popular day-use areas, which have no toilet facilities. An initial survey of fecal coliform counts in 1995 produced two samples with 49 and one with 79 colonies/100 ml. The Monument is pursuing state designation of Medano Creek as "Outstanding Waters" and a "Recreation 1" classification. These important designations could be jeopardized by continued fecal contamination in these day-use areas, in addition to the health hazards posed to visitors.	The installation of two composting toilets, one in each area, is proposed. Bacterial water quality would be monitored to document any changes in water quality, and to improve the database that will be used to support the Outstanding Waters designation.

PROJECT	SUMMARY OF PROBLEM	SUMMARY OF PROPOSED ACTIONS
GRSA-N-029.000 **Determine the Cause of the Disappearance of Interdunal Ponds**	Interdunal ponds are unusual wetland features created where the ground-water table surfaces in the midst of a dune field. Over 100 interdunal ponds were reported in 1932, but only 9 remain. They are vulnerable because they are shallow features, ground-water dependent and in a shifting landscape. Supporting studies include an ecological history of the Monument, and two dendrochronology studies looking into past climates and ground water conditions. Interdunal ponds provide habitat for numerous species, though an inventory of these has yet to be conducted.	A study is proposed to determine whether the disappearance of the ponds is: (1) a result of a severe drought in the 1950's (2) a result of some other scenario, possibly a gradual lowering of the shallow groundwater table. The study includes documenting the location and elevation of the existing and former ponds, installation of several monitoring wells, a survey of vegetation, extracting sediment cores and examining them for organic material, sedimentation patterns, former wetland surfaces, and cesium^{137}. This information will be correlated with tree-ring data currently being collected.
GRSA-N-047.000 **Review of Literature Regarding the Biological Function of Interdunal Pond Wetlands**	Interdunal ponds are rare resources, found where the surface of the sand dips below the ground-water table. The ponds have diminished from nearly 100 in 1932, to only 9 today. They are vulnerable because they are shallow features, ground-water dependent, and in a shifting landscape. The hydrology of these ponds, and reasons for their disappearance, are being investigated in other projects, primarily GRSA-N-030.000. Aquatic and wetland plants, herpetofauna, insects, and mammals have been observed using these ponds, yet little has been done to document these biological communities.	A review of the extensive body of literature pertaining to the biology of the San Luis Valley will be done to glean information pertinent to the biology of the interdunal ponds. The results of this review should point to field research needs.

PROJECT	SUMMARY OF PROBLEM	SUMMARY OF PROPOSED ACTIONS
GRSA-N-040.000 **Monitoring Surface Water Components of the Water Budget**	Sand and water form a balanced system responsible for the stability of the dune system. Surface and ground water are closely linked - the sand being such a porus medium that the perched ground-water table must be filled with each years runoff before surface flows can occur. Ground and surface waters are threatened by proposals to pump and export vast quantities of ground water from nearby lands. Groundwater pumping for other purposes in the valley is also a long- and short-term threat. The Monument has a water rights decree specifying specific quantities of stream flow for Sand and Medano Creeks. In order to understand the hydrologic system, a long-term record of flows is needed due to substantial year-to-year and long-term variability in the amount and timing of runoff, and the need to document flows protected by water rights.	Maintain automated stream discharge gauges on larger perennial streams and manual gauges on smaller steams. Make periodic manual discharge measurements on seasonal streams and as necessary to maintain accurate rating curves for automated gauges. Maintain a QA/QC plan for the monitoring program. Maintain a current database an produce an annual hydrology report. Institute limited monitoring of the terminus of flow of Medano Creek. Acquire snowpack data from SNOTEL installed in 1995.

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ACKNOWLEDGEMENTS

The initiative and efforts of Great Sand Dunes National Monument management and staff in the areas of water resources research and water rights protection is hereby acknowledged. In addition, several National Park Service employees provided assistance or information that became important in the preparation of this report. These individuals include Fred Bunch, Barb Irwin, Bruce Hart, Mark Seaton, Sue Judis, Linda Kelly, Tom Morin, and Kathy Brown, all of Great Sand Dunes National Monument; Lynn Cudlip, Curecanti National Recreation Area; Chris English, Yosemite National Park; Paul Christensen, Dean Tucker, and Scott Grover, all of the Water Resources Division, Fort Collins, CO; Tara Williams, Canyonlands National Monument; Chris Theriault and George McKay, Rocky Mountain Region, Denver, CO. Several employees of other Federal agencies and of the State of Colorado also provided essential information, including Buddy Wilson, U.S. Department of Agriculture, Natural Resource Conservation Service, Alamosa, CO), Wayne Williams (Colorado Water Resources Division, Water District 35, Alamosa, CO), Greg Parsons, Bob Owen, John Farrell, and John Schurlitek (Colorado Department of Health, Water Quality Control Division, Denver, CO), Denis Healy and Lisa Carter (U.S. Geological Survey Water Resources Division, NAWQA Program, Albuquerque, NM), and John Collins (U.S. Public Health Service, Denver, CO).

The authors would also like to acknowledge Sandy Vana-Miller, Rocky Mountain support Office, who provided a through review and edit of the manuscript.

APPENDICES

Appendix A. Project Statements

Project Statement GRSA-N-042.000

Last Update: 06/26/95 Priority: 1
Initial Proposal: 1995 Page Num: 103

Title: **DETERMINE BASELINE WATER QUALITY FOR OUTSTANDING WATERS DESIGNATION**

Funding Status: Funded: 0.00 Unfunded: 35.9

Servicewide Issues : N 11 (WATER QUAL-EXT)
N 20 (BASELINE DATA)

N-RMAP Program codes : Q00, Q01, Q02

10-238 Package Number :

Problem Statement

A baseline inventory of water quality conditions is needed in order to meet the state requirement for demonstrating high water quality in order achieve an "Outstanding Waters" designation. The establishment of a credible baseline will also provide the ability to monitor the effects of any future pollution from activities such as mineral development, or NPS facilities.

The designation of Outstanding Waters offers the highest level of water quality protection available under the Clean Water Act and Colorado Regulations. This designation is designed to prevent any degradation from existing conditions. The following excerpt from *Colorado Basic Standards and Methodologies for Surface Water* (State of Colorado, 1995a) presents the states requirements.

Waters May be designated outstanding waters where the (Water Quality Control) Commission makes all of the following determinations:

(i)The existing quality for each of the following parameters is equal to or better than that specified for the protection of Aquatic Life Class 1, Recreation Class 1, and (for nitrate) domestic water supply uses.

The determination of existing quality shall be based on adequate representative data, from samples taken within the segment in question. Data must be available for each of the 12 parameters listed.

(ii)The waters constitute an outstanding natural resource, based on the following:

(A)The waters are a significant attribute of a ... National Monument...

(iii)The water requires protection in addition to that provided by the combination of water quality classifications and standards and the protection afforded reviewable water under section 3.1.8(3).

Meeting criteria (i) will require a more substantial water quality baseline than currently exists. Specific parameters specified in the regulations are dissolved oxygen, pH, fecal coliform bacteria, un-ionized

ammonia, and cadmium, copper, lead, manganese, selenium, silver, and zinc (State of Colorado, 1995a). The measurement of hardness is also necessary in order to evaluate the standards for several metals. The state does not specify a number of samples. It can be assumed that the data base should have some statistical credibility and document conditions under the range of flows that typically occur.

The current water quality baseline consists of a total of 33 samples from Medano Creek all collected between 1990 and 1995. Samples were analyzed for as many as 30 parameters, or as few as 15. This base permits that conclusion that Medano Creek has generally very high water quality. Additional samples are necessary to evaluate seasonal and year-to-year variability, other streams in the Monument, and to meet the requirements necessary to justify and outstanding waters designation.

Medano and Sand Creeks clearly meet criteria (ii). A credible case could be made for other tributary streams, and interdunal ponds do as well. Achieving criteria (iii) is based on the potential for mineral development upstream of the Monument, and the potential for NPS activities (camping, lodging and recreation) to degrade water quality.

Maintenance of existing high levels of surface water quality in Great Sand Dunes National Monument was identified as a critical issue in the Water Resources Management Plan scoping process conducted in 1995. This can be facilitated through expansion of the existing, limited surface water quality baseline to include other Monument drainages.

Monument Setting

Great Sand Dunes National Monument is located on the eastern side of the San Luis Valley, a remarkably flat valley in south central Colorado, at the head of the Rio Grande Rift. The monument sits at the base of the Sangre De Cristo Mountains where a unique combination of climate, topography and hydrology has allowed the creation and maintenance of the nations tallest inland sand dunes. The valley is cold in the winter, warm in the summer, and is relative dry. In contrast, the mountains, which rise to over 14,000 feet, receive much more precipitation, and support several streams that flow around the dunes before sinking into the valley floor. The entire hydrologic system maintains a delicate balance, cycling sand from the downwind side of the dune field to the upwind side, at roughly the same rate that the wind carries it in the opposite direction.

Threats

There has been a history of prospecting and mine operation on the watersheds of both Sand and Medano Creeks including several of their tributaries. Though there is no active mining at this time, the potential remains to activate existing or new mining claims. The current lull in mining activity is actually desirable, because a proposal for an outstanding waters designation would not threaten any current mining operations.

Backcountry waste disposal has been identified as a concern in the Monument and a potential water contaminate. Improper waste disposal of human waste has been sited as a problem at two popular day use areas, prompting a proposal to install composting toilets at these sites as proposed in GRSA-N-033.000.

Limited fecal coliform monitoring conducted in 1995 (30 samples from 10 sites) did not identify dramatic problems, but 4 of the samples produced over 30 colonies/100ml, raising concern that an avenue for fecal contamination may exist. A separate project to expand the fecal coliform monitoring and perform sanitary surveys of backcountry campsites is proposed (GRSA-N-043.000). The water play that occurs in Medano Creek and dispersed camping and recreation that occurs upstream of the park on Forest Service lands are also a potential source of fecal contamination.

Monument Commitment

The Monument is willing to accept and work within the greatly restricted opportunities for effluent discharge that would go along with an outstanding waters designation. There are currently no discharges to surface waters, and none are planned. Though fecal contamination from backcountry users is a potential problem, the Monument is committed to prevent chronic problems from occurring or correct them if they do.

Many of the streams other than Medano Creek flow directly from US Forest Service wilderness into the Monument. As such the wilderness reaches of these streams might also qualify for outstanding waters designations. A water quality monitoring program that supported a joint petition for designation would benefit both agencies.

Description of Recommended Project or Activity

The monument will pursue an outstanding waters designation to gain the highest level of water quality protection available. The administrative procedures leading to an outstanding waters designation are not clearly stated in the regulations, but in most states involve making a proposal to the Water Quality Control Commission.

A dual purpose water quality inventory is proposed, which will provide the baseline documentation necessary to: 1) demonstrate eligibility for outstanding waters status in the Monument's perennial streams, and 2) document water quality conditions all Monument waters including perennial streams, seasonal streams, and interdunal ponds.

Major actions in this proposal are:

1. Prior to finalizing the study plan, explore the possibility if a joint effort with the National Forest to seek a designation for the entire length of Medano and Sand Creeks and their tributaries.

2. Gather baseline water quality data to determine the water quality condition of streams in the monument, and to demonstrate high quality waters.

3. Use the baseline inventory as a basis for designing a long-term monitoring protocol.

Analytes and Characteristics. The following list of parameters was developed based on the parameters

required for and outstanding waters designation, and the more general Colorado Water Quality Standards. (The State of Colorado standards encompass 26 constituents, but in actual practice, only 12 essential characteristics are monitored regularly by the State of Colorado Water Quality Control Division.) Discharge is added to the list because many parameters vary in relation to it, and the Monument already monitors discharge regularly at several sites.

Measured in the Field

- Discharge (measured in the field)
- Dissolved Oxygen (measured in the field)
- pH (measured in the field)
- Specific conductance

Laboratory Analysis (dissolved concentration in a filtered sample, except for iron)

- cadmium
- lead
- copper
- zinc
- manganese
- sulfate ion
- fecal coliform
- nitrate + nitrite
- selenium
- silver
- un-ionized ammonia
- calcium
- magnesium
- alkalinity

- iron (total recoverable, unfiltered sample)

Sampling Sites and Frequency. Proposed sample sites are listed in the following table along with sample frequency. Three samples per year would be collected from 8 sites on perennial streams, and one interdunal pond. Seasonal streams would be sampled once per year. Sampling for fecal coliforms would be done five times per month in the perennial streams, for a three month season.

Proposed Sampling Sites	Number of Sites	Number of Samples per year	
		Chemical Analysis	Fecal Coliform (also: pH, DO, and Conductance)
Perennial Streams Sand Cr. - at monument boundary Sand Cr. - at the Baca Grant Medano Cr. - below Mosca Cr. Medano Cr. - below Garden Cr. Mosca Cr. Morris Gulch Denton Sp. N. Arrastre Cr. - below mining	8	3/site 24 total	15/site 120 total
Seasonal Streams Garden Creek Sawmill Canyon Horse Canyon Castle Creek Little Medano Creek Cold Creek	6	1/site 6 total	0 0 total
Interdunal Pond 1 site TBA	1	3/site 3 total	0 0 total

Costs. It is assumed that this project will be conducted primarily by park staff with samples sent to an outside laboratory. The project would continue for two years of sampling followed by data analysis, report preparation, and petitioning the state for outstanding waters designations.

One-time equipment purchases include pH and dissolved oxygen meters, filtering apparatus, a field processing hood, and minor amounts of reagents, for a combined cost of about $2,000.

Sampling supplies will cost about $20 per chemical sample.

Laboratory fees for the samples run by the Colorado Water Quality Control Division are about $150 per sample (Bob Owen, Colorado Water Quality Control Division, Denver, CO).

Fecal coliform testing will cost about $10 per sample

Personnel costs would be incurred primarily by a temporary GS-7 hydrologic technician hired for this project. It will require four days of staff time to collect, prepare and transport each run of chemical sample. Two days will be required for each coliform sample run. Data entry would require about 5 days, data analysis about 6 days, and report writing about 10 days over the duration of the project.

Cost Breakdown

	Year 1	Year 2
Project Management (GS-9, Perm.)	$1,000	$1,000
Personnel cost (GS-7, temporary)	$7,600	$9,200
Vehicle	$ 750	$ 750
Equipment	$2,000	0
Supplies ($20/Chemical Sample)	$ 660	$ 660
Laboratory Analysis ($150/Chemical Sample)	$4,950	$4,950
($10/Coliform Sample)	$1,200	$1,200
Total	$18,160	$17,760

BUDGET AND FTEs:

----------FUNDED----------

Source	Activity	Fund Type	Budget ($1000s)	FTEs
1997			0.00	0.0
		Total:	0.00	0.0

----------UNFUNDED----------

	Activity	Fund Type	Budget ($1000s)	FTEs
Year 1	MON	One-time	18.1	0.4
Year 2	MON	One-time	17.8	0.4
		Total:	35.9	0.8

Compliance codes: EXCL

Explanation: (516 DM2 App. 1.6)

End of data

Project Statement GRSA-N-041.100

Last Update: 06/07/95 Priority: 2
Initial Proposal: 1995 Page Num: 109

Title: **INVESTIGATE HYDROSTRATIGRAPHY BENEATH MEDANO CREEK**

Funding Status: Funded: 0.0 Unfunded: 13.5

Servicewide Issues : N 12 (WATER FLOW)
N 13 (WATER RIGHTS)

N-RMAP Program codes : Q00, Q01, Q02

10-238 Package Number :

Problem Statement

The subsurface distribution of permeable and impermeable layers may be very important in determining the nature of stream flow in Medano Creek, yet the usual methods for exploring stratigraphy are problematic or completely ineffective in this setting. Stream flow in Medano Creek is considered critical to the long-term stability of the dune field, so a project to collect a limited number of core samples is proposed as the next logical step investigating the hydrostratigraphy.

Monument Setting

Great Sand Dunes National Monument is located on the eastern side of the San Luis Valley, a remarkably flat valley in south central Colorado, at the head of the Rio Grande Rift. The monument sits at the base of the Sangre De Cristo Mountains where a unique combination of climate, topography and hydrology has allowed the creation and maintenance of the nations tallest inland sand dunes, covering about 39 mi^2. The valley is cold in the winter, warm in the summer, and receives little precipitation. In contrast, the mountains, which rise to over 14,000 feet, receive much more precipitation, supporting several streams that flow around the dunes before sinking into the valley floor. The entire hydrologic system maintains a delicate balance, cycling sand from the downwind side of the dune field to the upwind side, at roughly the same rate that the wind carries it in the opposite direction. These high mountains are also the source for most of the water that maintains the water table at or near the land surface in much of the valley. Irrigated agriculture is a predominant land use in the valley.

Groundwater

Groundwater is a critical resource in Great Sand Dunes National Monument. The major streams, Sand and Medano Creeks, flow in porous sandy beds where large amounts of water can quickly infiltrate into the ground. In order to exhibit surface flow these streams must apparently fill one or more shallow perched aquifers with each snowmelt season, a process likened to filling a leaky cup because the aquatards that support the perched aquifers do not form a complete barrier. The ability of these streams to sustain surface flow is important because it is the major mechanism for moving sand from the down wind side of the dunes to the upwind side, thus maintaining the dune field.

The current understanding of the Monument's hydrostratigraphy is derived in part from inference from the overall aquifer system in the northern San Luis Valley, referred to as the Closed Basin because there are no surface streams flowing out of the area, and in part from subsurface studies in Medano Creek. Collectively, these limited data suggest the following:

The current knowledge of the ground-water system provided by the existing monitoring network and past studies, indicates that it is a complex system. Depositional patterns at the mountains edge has created a subsurface containing irregular layers of greater and lesser permeability, and groundwater conditions that differ considerably from the central parts of the valley which have been studied extensively.

Recharge zones occur along the margins of the Closed Basin in locations such as the Monument (Hearne, 1988). Surface water flow of Medano and Sand Creeks completely infiltrates into the aquifers and continues to flow down gradient (westward), and may reappear on the surface at the playa lakes in the center of the Closed Basin or at several ponds and springs along the way. This infiltrating water also may recharge deep aquifers which are confined in most of the San Luis Valley, because the confining clay layers appear to be absent beneath the recharge zones (Harmon, 1989).

Much of the ground water research has been centered around a grid of monitoring wells placed in the Medano Creek channel. In drilling the wells, some boreholes, and observing groundwater characteristics afterward, five hydrostratigraphic units were identified, creating two perched unconfined aquifers over a confined aquifer (Lachmar, et. al., 1995)(Hadlock, 1995). As these shallow aquifers fill to the surface with each springs runoff, Medano and Sand Creeks flow further down stream, eventually transporting sand collected on the north and west sides of the active dune field to the west side.

Sand Creek was found to be generally an influent stream, but with seasonally effluent segments near the Sangre de Cristo Mountain front.

Wells on the sand sheet indicate that the water table there is within tens of feet of the surface and fluctuates seasonally by several feet.

Threats

The major threats to resources in the monument that are dependent on the water table are the continued use of water for irrigated agriculture in the valley, and recurrent proposals to pump and sell large amounts of water from land holdings just north of the monument. Irrigated agriculture has been an important land use in the San Luis Valley since the 1800's. Though drops in the ground-water table have not been documented in the monument vicinity due to lack of a long-term record, it is possible that pumping for irrigation is a cause of some lowering of the water table, or is an aggravating factor during periods of drought.

The current proposal for water harvesting, made by Stockmans Water Inc., includes the pumping of roughly 100,000 acre-feet of water per year, and the transport of that water to Colorado's front range cities. It is very similar to an unsuccessful proposal for pumping from the same tract made in 1986. These companies would be pumping deep ground water from aquifers that are thought to be hydrologically connected to the shallow ground water.

Investigative Techniques

Past Attempts to characterize the Hydrostratigraphy of Medano Creek have met with limited success. The possibility of using geophysical exploration and drilling methods in the further investigation of aquifers and aquitards has been suggested. However, the thick unconsolidated sand attenuates seismic signals, making identification of even obvious boundaries, such as between the bedrock and overlying sand, difficult. Imaging the subtle differences between the layers of sand will be next to impossible with standard geophysical techniques.

Ground penetrating radar and electrical resistivity have been used to identify water table surfaces. Electrical resistivity sensing may be an effective way to sense the position of multi-layered aquifers. Radar can give excellent resolution but the high operation frequencies limit subsurface penetration to shallow depths (30 feet, maximum).

High-resolution seismic refraction may be shown to be the most effective geophysical technique for deeper hydrostratigraphic delineation (Eric Harmon, HRS Water Consultants, Inc., Lakewood, CO, personal commun., 1995). The method has the potential to detect the subtle physical changes between layers of pure sand and silty sand, to depths of 500 feet or more; essential to its successful operation is effective transfer of energy into the ground. Explosives or an accelerated weight source are the most commonly used sources of energy.

Drilling has been done in the past, but recovering complete core samples below the water table has been difficult using standard split-spoon core collection techniques, even when the hollow stem auger was equipped with a pneumatic valve to prevent saturated sand from flowing into the auger. Other possibilities for core collection are continuous coring, which vibrates core stems through material up to 120 feet below the water table. Dual wall, reverse circulation, rotary drilling, has been recommended (Greg Hadlock, Utah State University, Logan, UT, personal commun., 1995), because this drilling method reportedly can successfully penetrate 800 feet to 1000 feet of saturated sand (Driscoll, 1986). Another technique which has been advocated is hydraulic punch drilling (the Hurricane System) (Rod Perkins, Tamarack Environmental Services, Inc., personnal commun. 1997), which has been used to successfully core unconsolidated materials to depths of over 80 feet.

Geophysical exploration and other remote sensing techniques are quicker, less destructive, and provides larger coverage than drilling, but drilling and core retrieval provides samples from known depths that can be identified. Physical properties can be tested directly, which can be more precise than remote sensing inherent with geophysical methods. Probably the strongest reason for collecting core samples at this time, is that the core samples can greatly improve the accuracy of interpretation of geophysical data.

Therefore, this project proposes test drilling of at least four core holes to depths approaching 80 feet. IF the coring is successful, then an examination of the cores and their physical properties can guide the selection of subsurface imaging techniques, and/or indicate whether a larger scale grid of core holes is a more appropriate approach.

Description of Recommended Project or Activity

The objective of this project is to gain an understanding of the stratigraphy underlying Medano Creek so that hydrologic data can be interpreted effectively.

A core drilling project is proposed in order to:

1. Test the technology in this setting, and

2. Obtain samples of the strata that will be necessary to properly interpret future images collected through ground penetrating radar, or a more extensive coring project.

Elements of the project are:

Drill 4 core holes do a depth of about 150 feet or to the base of the valley alluvium where the regional ground water table is penetrated. A combination of a hydraulic ram (Hurricane System) and Hollow Stem Auger should be employed to reach this depth.

Have the cores interpreted and preserved by a professional Geologist. These will be labeled and maintained in the monument's museum collection.

Case the holes and maintain them as monitoring wells.

Follow up this work by assessing the practicality of using ground-penetrating radar or high-resolution seismic refraction to image the kinds of strata that are collected.

Equipment to perform this project is available in Denver, Colorado. Cost estimates assume round-trip travel from Denver to the Monument. This coring technology has been used to sample various contaminated sites to similar depths, and appears well suited to unconsolidated material because the core sample is collected in a solid lexan tube.

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BUDGET AND FTEs:

----------FUNDED----------

Source	Activity	Fund Type	Budget ($1000s)	FTEs
1995			0.0	0.0
		Total:	0.0	0.0

----------UNFUNDED----------

	Activity	Fund Type	Budget ($1000s)	FTEs
Year 1	RES	One-Time	13.5	0.0
		Total:	13.5	0.0

Compliance codes: EXCL

Explanation: 516 DM2 App. 1.6

End of data

Project Statement GRSA-N-043.000

Last Update: 06/22/95 Priority: 3
Initial Proposal: 1995 Page Num: 114

Title: **DETERMINE EFFECTS OF WATER-BASED AND BACKCOUNTRY RECREATION ON WATER QUALITY**

Funding Status: Funded: 0.00 Unfunded: 32.34

Servicewide Issues : N 11 (WATER QUALITY)
S 10 (VISITOR HEALTH/SAFETY)

N-RMAP Program codes : Q00, Q01

10-238 Package Number :

Problem Statement

The existence of fecal contamination from human waste disposal at backcountry campsites and day-use areas, and its impact on water based recreation have not been well documented. Survey level bacterial monitoring conducted in 1995, indicated that there may well be contamination problems. This initial survey needs to be expanded in order to improve the understanding of water quality conditions, guide management actions, and to monitor the results of those actions.

Monument Setting

Great Sand Dunes National Monument is located on the eastern side of the San Luis Valley, a remarkably flat valley in south central Colorado, at the head of the Rio Grande Rift. The monument sits at the base of the Sangre De Cristo Mountains where a unique combination of climate, topography and hydrology has allowed the creation and maintenance of the nations tallest inland sand dunes, covering about 39 mi^2. The valley is cold in the winter, warm in the summer, and receives little precipitation. In contrast, the mountains, which rise to over 14,000 feet, receive much more precipitation and support several streams that flow around the dunes before sinking into the valley floor. The streams are popular with visitors for their scenic values and as places for water-based recreation.

Importance of Water Quality

The Monument is pursuing and "Outstanding Waters" classification for surface waters and will seek to obtain a "Recreational 1" classification for Medano Creek from the state. To qualify, waters must have "exceptional recreational and ecological significance, without modification by human activities in a manner that substantially detracts from their value as a natural resource." Specific numeric standards apply to streams being considered which include fecal coliform bacteria counts. The State of Colorado has established a standard of a geometric mean of 200 colonies/100 ml of sample, based on a minimum of 5 samples in a 30-day period. Fecal coliform bacteria, which are not generally harmful, are used as an indicator organism for the presence of an avenue for fecal contamination and other harmful pathogens in the water. If an outstanding waters designation is to be assigned to Medano Creek, waters would have to be maintained and protected at their existing quality, and no further water

quality degradation would be allowed if it would interfere with existing classified uses.

Assuring suitable water quality at Great Sand Dunes National Monument, with regard to compliance with public health standards for bacteriological content of recreational water, was identified as a critical issue in the Water Resources Management Plan scoping process. The presence of numerous users of the public wading areas, where some primary contact recreational water use also takes place, strongly supports the need to make certain that this water meets State standards.

Medano Creek, and other waters of the Monument serve as sources of drinking water for backcountry users. There are six designated backcountry campsite areas in the Medano Creek watershed and three in the Sand Creek watershed for which the monument issues permits for about 1,000 campers per year, mostly during the summer season. The three most heavily used sites, Buck Creek, Escape Dunes, and Indian Grove, experience about 1.5 campers/night through the summer. Though this use rate is not heavy compared to some other NPS sites, it shows that there are frequently people in the backcountry, who without sanitary facilities are both potential sources of fecal contamination, and at risk from it.

Knowledge of Water Quality and Threats

The only bacterial water quality data available for park streams was collected in 1995 when a total of 30 samples were collected from 10 sites over a three month period. Every Sample produced at least one colony/100 ml, and the geometric mean for all samples was 4.8 colonies/100 ml. Though the overall numbers are not alarming, individual samples had levels of 79, 49 (twice), and 33 colonies/100 ml. These higher levels of bacterial contamination were clustered around areas of high visitor use, and during periods of relatively low flow, raising concern that people recreating may be the source of contamination and may be experiencing an unacceptable level of exposure.

With the completion of the Sand Creek trail in the summer of 1994, and proposed future connections with the Wet Mountains hiking trails, backcountry camping in the Sand Creek watershed, and likely the Medano Creek watershed, will continue to increase. These areas already experienced a large increase in use between fiscal 1993 and fiscal 1994, when usage by campers in the Sand Creek watershed increased 45%, and use in the Medano Creek watershed increased 54%. It is important to establish a baseline water quality database as soon as possible, so that the effects of projected continued increase in use of these areas can be assessed.

There is little in the way of development or human use on the watershed upstream of the Monument, leading to the conclusion that the only sources of fecal contamination are wildlife and human activities in the Monument.

Description of Recommended Project or Activity

A two year intensive sampling program is proposed in order to provide a solid quantitative baseline of bacterial water quality, coupled with a sanitary survey of each of the backcountry and frontcountry visitor-use areas. This will be followed by a scaled back long-term monitoring program.

The objectives of this project are:

To document the current bacteriological conditions of Medano and Sand Creeks,

To determine if sanitary problems exist, and the nature of those problems, or

To document high water quality in support of an Outstanding Waters Designation,

To provide a quantitative basis for decision making, and

To provide a basis for designing a long-term monitoring program.

Elements of the Project

- Sampling Design

The monitoring program will include a minimum of ten sites (in most cases these will be the same as those monitored in 1995) sampled five times per month, during the four-month season of highest visitor use. In addition, duplicate samples will be collected at the three sites with the highest levels of water-based recreation. Of the five sample days in a month, at least three should be weekend days, when visitation is at its highest. This intensive monitoring will proceed for a period of two years, with 260 samples collected each year for a total of 520 samples.

Other parameters measured at the time of sampling will include discharge, air temperature, park visitation for that day, number of backcountry campers, and turbidity.

Samples will be transported on ice to an EPA Certified laboratory in Alamosa, CO for analysis.

- Training

Technical assistance will be requested from the Water Resources Division for training of park staff in proper techniques for sample collection and handling.

A manual of monitoring protocols will be prepared.

- Sanitary Surveys

Technical assistance will be requested from the regional USPHS sanitarian in the design and conduct of sanitary surveys of each of the backcountry campsites and frontcountry water play areas. The sanitary surveys will be conducted in August of the first year of sampling, when visitor use should be at its peak.

• Reports

The data will be analyzed at the conclusion of each sampling season and an annual report prepared by Monument staff. In addition to an analysis and presentation of the data, reports will include the results of the sanitary surveys, and recommendations for improving the monitoring program and guiding the management of the Monument..

• Long-term Monitoring

The results of the intensive monitoring program will be used to design a long-term monitoring program. It is envisioned that this will include fewer sampling sites (possibly 3) and a shorter season (possibly 2 months), but sampling at the same 5 samples/month rate. It should also include annual checks of all backcountry and front country sites for the presence of human waste disposal problems, and a section in the annual water quality report.

This project can be conducted by hiring additional monument staff, or by contracting through a University of Consulting Firm. The Budget is estimated assuming the latter with salaries equivalent to GS-7 and 9.

Cited references

State of Colorado. 1994a. Classifications and Numeric Standards for Rio Grande Basin, 3.6.0. Colorado Department of Health-Water Quality Control Commission, Denver, CO. 45 pp.

U.S. Environmental Protection Agency. 1986. Ambient Water Quality Criteria for Bacteria. EPA440-5-84-002. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, D.C.

PROPOSED BUDGET BREAKDOWN	1998		1999	
Personnel				
GS-7 Hydrologic Technician - seasonal	$3,300		$2,800	
GS-9 Geologist - permanent	$3,050		$2,200	
Breakdown of Personnel				
Sample collection and transport	20	days	20	days
Project Management	5	"	5	"
Data Analysis	4	"	5	"
Report Writing	10	"	10	"
Sanitary Surveys	5	"	0	"
Training	6	"	0	"
Total Labor for both years - 90 days	50	days	40	days

Laboratory Analysis (260 Samples/yr @ $25ea)	$6,500	$6,500
Travel	$1,300	$1,300
Indirect Costs 20%	$2,830	$2,560
Totals	$16,980	$15,360

BUDGET AND FTEs:

----------FUNDED----------

Source	Activity	Fund Type	Budget ($1000s)	FTEs
		==========		
		Total:	0.00	0.0

----------UNFUNDED----------

	Activity	Fund Type	Budget ($1000s)	FTEs
Year 1	RES	One-Time	16.98	0.2
Year 2	RES	One-Time	15.36	0.2
Year 3	MON	Recurrent	1.20	0.05
Year 4	MON	Recurrent	1.20	0.05
		==========		
		Total **for 2-yr proj**.:	32.34	0.4

Compliance codes: EXCL

Explanation: (516 DM6 App. 1.6)

End of data

Project Statement GRSA-N-041.200

Last Update: 06/07/95 Priority: 4
Initial Proposal: 1995 Page Num: 119

Title:**EXPAND MONITORING WELL NETWORK TO IMPROVE UNDERSTANDING OF AQUIFER SYSTEMS**

Funding Status: Funded: 0.0 Unfunded: 29.2

Servicewide Issues : N 12 (WATER FLOW)
N 13 (WATER RIGHTS)

N-RMAP Program codes : Q00, Q01, Q02

10-238 Package Number :

Problem Statement

An expansion of the Monument's current groundwater monitoring network is needed in order to improve our ability to document the condition of this important resource. The current monitoring network is of great value to the Monument, but has some notable gaps in the distribution and depth of wells which could be filled by adding several new wells, in this case 7 are proposed.

Monument Setting

Great Sand Dunes National Monument is located on the eastern side of the San Luis Valley, a remarkably flat valley in south central Colorado, at the head of the Rio Grande Rift. The monument sits at the base of the Sangre De Cristo Mountains where a unique combination of climate, topography and hydrology has allowed the creation and maintenance of the nations tallest inland sand dunes, covering about 39 mi^2. The valley is cold in the winter, warm in the summer, and receives little precipitation. In contrast, the mountains, which rise to over 14,000 feet, receive much more precipitation, supporting several streams that flow around the dunes before sinking into the valley floor. The entire hydrologic system maintains a delicate balance, cycling sand from the downwind side of the dune field to the upwind side, at roughly the same rate that the wind carries it in the opposite direction. These high mountains are also the source for most of the water that maintains the water table at or near the land surface in much of the valley. Irrigated agriculture is a predominant land use in the valley.

Groundwater

Groundwater is a critical resource in Great Sand Dunes National Monument. The major streams, Sand and Medano Creeks, flow in porous sandy beds where large amounts of water can quickly infiltrate into the ground. In order to exhibit surface flow these streams must fill one or more shallow perched aquifers with each snowmelt season, a process likened to filling a leaky cup because the aquatards that support the perched aquifers do not form a complete barrier. The ability of these streams to sustain surface flow is important because it is the major mechanism for moving sand from the down wind side of the dunes to the upwind side, thus maintaining the dune field.

The current understanding of the Monument's hydrostratigraphy is derived in part from inference from the overall aquifer system in the northern San Luis Valley, referred to as the Closed Basin because there are no surface streams flowing out of the area, and in part from subsurface studies in Medano Creek. Collectively, these limited data suggest the following.

The current knowledge of the ground-water system provided by the existing monitoring network and past studies, indicates that it is a complex system. Depositional patterns at the mountains edge has created a subsurface containing irregular layers of greater and lesser permeability, and groundwater conditions that differ considerably from the central parts of the valley which have been studied extensively.

Recharge zones occur along the margins of the Closed Basin in locations such as the Monument (Hearne, 1988). Surface water flow of Medano and Sand Creeks completely infiltrates into the aquifers and continues to flow down gradient (westward), and may reappear on the surface at the playa lakes in the center of the Closed Basin or at several ponds and springs along the way. This infiltrating water also may recharge deep aquifers which are confined in most of the San Luis Valley, because the confining clay layers appear to be absent beneath the recharge zones (Harmon, 1989).

Much of the ground water research has been centered around a grid of monitoring wells placed in the Medano Creek channel. In drilling these wells and observing groundwater characteristics afterward, three different shallow aquifers and two shallow aquitards have been delineated (Hadlock, 1995). An investigation of the extent and nature of these perched aquifers is proposed in GRSA-N-041.000. As these shallow aquifers fill to the surface with each springs runoff, Medano and Sand Creeks flow further down stream, eventually transporting sand collected on the north and west sides of the active dune field to the west side.

Sand Creek was found to be generally an influent stream, but with seasonally effluent segments near the Sangre de Cristo Mountain front.

Wells on the sand sheet indicate that the water table there is within tens of feet of the surface and fluctuates seasonally by several feet.

Threats

The major threats to resources in the monument that are dependent on the water table are the continued use of water for irrigated agriculture in the valley, and recurrent proposals to pump and sell large amounts of water from land holdings just north of the monument. Irrigated agriculture has been an important land use in the San Luis Valley since the 1800's. Though drops in the ground-water table have not been documented in the monument vicinity due to lack of a long-term record, it is possible that pumping for irrigation is a cause of some lowering of the water table, or is an aggravating factor during periods of drought.

The current proposal for water harvesting, made by Stockmans Water Inc., includes the pumping of roughly 100,000 acre-feet of water per year, and the transport of that water to Colorado's front range cities. It is very similar to an unsuccessful proposal for pumping from the same tract made in 1986. These companies would be pumping deep ground water from aquifers that are thought to be hydrologically connected to the shallow ground water.

Current Monitoring Network

The current monitoring network consists of 23 wells, concentrated near Sand Creek (7 wells) and Medano Creek (13 wells), which are intended to provide insight into the ground and surface water interactions near these important streams. They are also clustered near the creeks and roads because of the difficulty in getting drilling equipment into more remote areas, and the complexities of drilling in designated wilderness. Three additional wells are located along the western boundary of the Monument on an area that is relatively flat called the Sand Sheet, for the purpose of detecting any changes in the shallow groundwater table from pumping activities to the west. Three of the wells monitor the regional aquifer at a depths of 70 to 130 feet, the remainder monitor various shallow perched aquifers at depths of 3 to 25 feet. Thirteen of the wells have automated data loggers, and the remainder are monitored intermittently.

Gaps in the Current Monitoring Network

The current network provides little information about groundwater conditions in the interior of the Monument and on the western sand sheet. Simple extrapolations can be made, but these are likely to be faulty due to the complex nature of the hydrogeology and water movements along the mountain front. Obvious gaps in the current network are:

(1) <u>The Sand Sheet</u>. This is an area west of the active dune field, where the topography is more gentle and the sandy soils are more stable. A shallow water table exists here which surfaces at several wetland features and interdunal ponds. The stability of these features is dependent on a relatively stable groundwater table. The fact that the number of interdunal ponds has dropped from 36 in 1936 to only 9 in 1996, shows that the water table is probably not stable and that these valuable resources are threatened. It is proposed to drill 4 new wells on the sand sheet that are close to the active dune field, and deep enough to intersect the regional ground water table.

(2) <u>The South Boundary</u>. Private campgrounds, motels and guest ranches have been developed south of the monument in recent years. The current ground water monitoring network is not designed to be able to detect changes in the water table in this area that might be caused by pumping, or diversion of surface water. It is proposed to drill 3 new wells along this boundary to intersect the regional water table and any perched aquifers that are encountered.

(3) <u>The interior of the Active Dune Field</u>. Due to its location along the mountain front, this is probably a recharge zone, and the nature of the aquifer(s) is likely to be complex, making extrapolation from the margins of the dunefield a poor substitute for actual data. Unfortunately getting drilling equipment into prospective drilling sites in the dunes poses monumental logistical problems.
Even tracked vehicles have difficulty moving over the loose sand, and blowing sand makes helicopter use

difficult at best. Therefore, no new wells are proposed for the active dune field at this time. It is hoped that the new wells on the sand sheet will provide some insights into groundwater conditions under the active dunes.

Monument staff maintain and manage data from the current well network. The addition of these wells could be easily absorbed into the current workload, particularly as more wells are automated.

Description of Recommended Project or Activity

Seven additional wells would be drilled in order to improve the spacial and depth distribution of monitoring wells in the Monument's Program. Four wells would be drilled on the sand sheet near the active dune field, and three would be drilled along the south boundary of the monument. Each of these would be drilled deep enough to intersect the regional groundwater table, or be drilled into a shallow aquifer and clustered with a deeper well.

The frequency of measurements taken from these wells will depend on the remoteness of the wells, stability of the water table, and the quality of well data. Three of the wells would be equipped with automatic data loggers to collect frequent measurements, while others would be measured manually on a bi-weekly or monthly basis. Data will be managed along with the Monument's other well data, and incorporated into an annual report on the condition of groundwater resources.

Well sites would be accessed using a tracked vehicle, balloon tired vehicle, or a combination of one of these pulled by a caterpillar tractor.

Some of the wells on the sand sheet will have to be located in designated wilderness in order to monitor groundwater conditions away from the immediate vicinity of the Monument boundary. Consistent with NPS Management Policies, an examination of the need for this intrusion into wilderness, and use of the "minimum tool" will be conducted in an Environmental Assessment. Well heads and data loggers, both in and outside wilderness, will be painted and maintained to minimize their visual intrusion.

Costs for 7 wells are based on: Drilling costs of $25/foot of well including casing, drilling rig and crew costs of $1,100/day, 700 feet of well to be drilled, 1 day of travel time to and from the job, one day of travel time between wells on the sand sheet, ½ day of travel time between wells along the south boundary, and data logging equipment costs about $1,000/well.

Budget Breakdown

$25/foot @ 700 feet of well	$17,500
2 days of travel time to and from the job	$2,200
Access 1 day of equipment cost/well for dunes and sand sheet	$4,400
Access 1 day total for boundary	$1,100
4 data loggers	$4,000
Total	$29,200

Literature cited

Hadlock, G. L. 1995. Groundwater and Surface-Water Interactions along Lower Medano Creek, Great Sand Dunes National Monument, Colorado. M. S. Thesis. Geology Department. Utah State University, Logan Utah. 69 pp.

Harmon, E. J. and M. F. Hajicek. 1992. Schlumberger Soundings and Sand-Column Resistivity Testing for Determining Stream-Aquifer Connection, Great Sand Dunes National Monument, Colorado. Submitted to National Park Service.

Hearne, G. A., and J. D. Dewey. 1988. Hydrologic Analysis of the Rio Grande Basin north of Embudo, New Mexico, Colorado and New Mexico. U.S. Geological Survey Water Resources Investigations Report 86-4113. 244 pp.

BUDGET AND FTEs:

----------FUNDED----------

Source	Activity	Fund Type	Budget ($1000s)	FTEs
1997			0.00	0.0
		Total:	0.00	0.0

----------UNFUNDED----------

	Activity	Fund Type	Budget ($1000s)	FTEs
Year 1	MON	One-Time	29.2	0.0
		Total:	29.2	0.0

Compliance codes: EA

Explanation: An environmental Assessment will be prepared to address the need for drilling and maintaining monitoring wells in wilderness.

End of data

Project Statement GRSA-I-048.000

Last Update: 06/16/95 Priority: 5
Initial Proposal: 1995 Page Num: 124

Title: **ENHANCE INTERPRETATION OF WATER RESOURCES ISSUES**

Funding Status: Funded: Unfunded:

Servicewide Issues : N 12 (WATER FLOW)
N 24 (OTHER)

N-RMAP Program codes : I00, Q00

10-238 Package Number :

Problem Statement

Interpretation of water resources to visitors at Great Sand Dunes National Monument is an important responsibility due to the critical role that water plays in the physical and biological processes of the dune field. Visitor understanding and appreciation of why the dunes are located where they are, the physical processes affecting the dunes today, and the threats to Monument resources, is dependent on a basic understanding the interaction between the sand, ground water and surface water.

Monument Setting

Great Sand Dunes National Monument is located on the eastern side of the San Luis Valley, a remarkably flat valley in south central Colorado, at the head of the Rio Grande Rift. The monument sits at the base of the Sangre De Cristo Mountains where a unique combination of climate, topography and hydrology has allowed the creation and maintenance of the nations tallest inland sand dunes. The valley is cold in the winter, warm in the summer, and is relatively dry. In contrast, the mountains, which rise to over 14,000 feet, receive much more precipitation, supporting several streams that flow around the dunes before sinking into the valley floor. The entire hydrologic system maintains a delicate balance, cycling sand from the downwind side of the dune field to the upwind side, at roughly the same rate that the wind carries it in the opposite direction.

Status of Water Resources Interpretation

The Visitor Center at Great Sand Dunes National Monument is currently undergoing renovation, which will include an upgrading of exhibits. It was built in the early 1960's to serve as a focal point for visitor orientation, information and provide an introduction to Monument resources. Current exhibits were installed in 1981 and 1982. The exhibits do not fully tell the story of water and its role as a recreational, cultural, and natural resource at the Monument and they do not reflect current research findings.

Beginning in 1990, *Friends of the Dunes* took on a project for capital improvement of the Visitor Center that will have long-term significance in the interpretation of resources management issues for the Monument visitor. *Friends of the Dunes* obtained funding from private sources to support

planning and design of an expanded Visitor Center and updated exhibits. Key partners in this project include the Alamosa County Lodging Tax Board, Southwest Parks and Monuments Association, and various private contributors. Phase One (a new entrance and restroom facility) was completed in 1996. Design Development and Construction Drawings (a new exhibit area, modified interior and additional office space) for Phase Two were under preparation in April 1995. A proposed exhibit plan for the Visitor Center was completed in April 1995.

Within the scope of the Visitor Center expansion, water as a critical park resource will be interpreted through new exhibits. The new exhibit plan calls for: 1) an exhibit wall that tells the story of water as a resource; 2) a touchscreen computer that has a section devoted to water (completed and installed); 3) an area set aside for changeable exhibits that will highlight current research findings; 4) a carpet pattern the mimics a creek flowing through the sand.

Currently, personal interpretive services communicate the role of water at Great Sand Dunes National Monument. Evening programs, walks and porch talks often highlight current management strategies for water resources and interpret the role of water in the formation of the dunes. Improvement to the exhibits can only enhance interpretive programming.

The Monument has established a collateral duty for one of the interpretive positions to provide a liaison between the Resource Management and Interpretative staffs. This should enhance the exchange of current information about water resources, and the issues facing them. Water and its use are often a matter of considerable controversy in this area. It is recognized by the NPS as a resource crucial for the preservation of the Monument, but it is also a basis for ranching, agriculture and tourism industries in the San Luis Valley. There have been several proposals to pump very large quantities of ground water from the valley and export it to Colorado's front range cities. With the controversy surrounding water, it is important that its interpretation be supported by current and accurate information.

Description of Recommended Project or Activity

Actions in addition to the designation and support of an interpretation liaison and updating the Visitor Center exhibits will be necessary. However, specific actions along these lines are not proposed at this time in this document because the exhibit space and programs offered in the Visitor Center are currently undergoing a complete revision. Park staff are proceeding with a separate planning process to ensure that the water resources interpretive materials in that facility are updated and enhanced. Once that is completed, then other gaps in the interpretive program can be identified and a proposal developed to correct them. Actions such as the preparation of publications suitable for professional interpreters or a general audience, briefing papers, exhibits, and audio/visual programs, will be considered. In the interim, this Project Statement is provided as a template for developing future proposals.

Compliance codes:
Explanation:

End of data

Project Statement GRSA-N-040.100

Last Update: 05/01/95 Priority: 6
Initial Proposal: 1997 Page Num: 126

Title: **MONITOR TERMINUS OF FLOW OF MEDANO AND SAND CREEKS**

Funding Status: Funded: 5.0 Unfunded: 30.2

Servicewide Issues : N12 (WATER FLOW)
N13 (WATER RIGHTS)

N-RMAP Program Codes : Q00

10-238 Package Number :

Problem Statement

Monitoring of the "terminus of flow" (the point where surface flows sink into the sandy stream bed) offers a sensitive and cost effective indicator of surface and ground water conditions.

Monument Setting

Great Sand Dunes National Monument is located on the eastern side of the San Luis Valley, a remarkably flat valley in south central Colorado, at the head of the Rio Grande Rift. The monument sits at the base of the Sangre De Cristo Mountains where a unique combination of climate, topography and hydrology has allowed the creation and maintenance of the nations tallest inland sand dunes, covering about 39 mi^2. The valley is cold in the winter, warm in the summer, and receives little precipitation. In contrast, the mountains, which rise to over 14,000 feet, receive much more precipitation and support several streams that flow around the dunes before sinking into the valley floor. The entire hydrologic system maintains a delicate balance, cycling sand from the downwind side of the dune field to the upwind side, at roughly the same rate that the wind carries it in the opposite direction. Runoff from the mountains maintains the water table at or near the land surface in much of the valley. Irrigated Agriculture is the predominant land use in the valley.

Sand and Medano Creeks

Sand and Medano Creeks are the major rivers in the Monument. They flow out of the Sangre de Cristo Mountains at the north and east edge of the dune fields, and flow around the dunes before sinking into the sand on the floor of the San Luis Valley. The substrate in this portion of the valley is so porous that the base flows occurring in fall and winter cannot maintain surface flow much beyond the edge of the mountains. As the shallow ground water table is filled by runoff from snowmelt each spring, the creeks can sustain surface flow extending farther and farther into the valley. The location of the point where water in the channel sinks into the sand is directly dependent on the amount and duration of the runoff. In a typical year surface flow will extend 5 or 6 miles around the dunes and onto the valley floor.

The nature of this stream flow system is important because:

1. These stream cycle sand from the downwind side of the dunefield to the upwind side, thus maintaining the dune field at its present location and permitting the growth of the tallest sand dunes in North America. However, the streams can only move sand when they have water flowing on the surface and the distance and duration of this flow is a key determinant of the amount of sand transported and where it is deposited.

2. Shallow ground water tables are dependent on annual recharge to fill them to near the ground surface. This shallow water stabilizes some portions of the dune field and supports 20 - 30 wetland features including 9 interdunal ponds.

The flow characteristics of Sand and Medano Creeks vary considerably from year to year. Mean annual precipitation at the Monument is 10.5 inches, while in one third of the years precipitation is either less than 7.5 inches or greater than 12.5 inches. Mountain snowpacks can be similarly variable, and the timing of runoff adds another complicating factor.

Attempting to monitor and understand this system can be difficult and expensive. The Monument monitors stream discharge, snow pack and groundwater conditions, which provide data that are useful for documenting conditions and protecting the quantified water rights for the Monument. However, when attempting to understand the whole sand and water system, these individual data sets provide only a small part of the picture. In this particular setting, the terminus of flow is a characteristic that combines precipitation, melt patterns, infiltration, antecedent conditions, and evapotranspiration into one easily monitored parameter.

Description of Recommended Project or Activity

The location of the terminus of flow will be monitored every other day for both Sand and Medano Creeks. Data will be collected from April 1 through August 30 for each of two years. Park staff will document the location of the terminus of flow with park GPS equipment. This is a two year project that will be followed by a base-funded long-term monitoring program.

This will be useful information to provide to visitors along with other resource updates in the Visitors Center.

The budget includes ½-time for a GS-7 Hydrologic Technician from April 1 through September 30 ($13,600/yr), and $1,500/yr for a vehicle.

At the end of that time a data analysis will determine how terminus of flow correlates or complements other data sets that have been gathered. A recommended design for the long-term monitoring will also be developed, and presented in a final report.

Project Statement GRSA-N-040.100

Last Update: 05/01/95 Priority: 6
Initial Proposal: 1997 Page Num: 128

BUDGET AND FTEs:

----------FUNDED----------

	Source	Activity	Fund Type	Budget ($1000s)	FTEs
1997	PKBASE-NR	MON	Recurrent	5.0	0.1
			Total:	5.0	0.1

----------UNFUNDED----------

		Activity	Fund Type	Budget ($1000s)	FTEs
Year 1		MON	One-time	15.1	0.5
Year 2		MON	One-time	15.1	0.5
			Total:	30.2	1.0

Compliance codes: EXCL

Explanation: 516 DM2 App. 1.6

End of data

Project Statement GRSA-N-033.000

Last Update: 03/24/97 Priority: 7
Initial Proposal: 1997 Page Num: 129

Title: **PREVENT FECAL CONTAMINATION OF MEDANO CREEK**

Funding Status: Funded: 0.00 Unfunded: 7.50

Servicewide Issues : C71 (VISITOR IMPACTS)
S10 (VISITOR HEALTH/SAFETY

N-RMAP Program codes : Q00

10-238 Package Number :

Problem Statement

Fecal contamination of Medano Creek is a concern in two popular day-use areas. The installation of two composting toilets is proposed alleviate the problems. This action would be accompanied by bacterial monitoring to document the impacts of the new toilets.

Assuring suitable water quality with regards to compliance with public health standards for bacteriological content in recreational waters was identified as a critical issue in the scoping process for the Great Sand Dunes NM Water Resources Management Plan. Of special concern are the Sand Pit and Castle Creek day use areas located along the Medano Pass Road and adjacent Medano Creek, one of the Monument's primary water resources. Both areas receive considerable recreational day-use, but have no sanitary facilities, and improper disposal of human waste is a recurring problem.

The Monument is pursuing and "Outstanding Waters" classification for surface waters and will seek to obtain a "Recreational 1" classification for Medano Creek from the state. To qualify, waters must have "exceptional recreational and ecological significance, without modification by human activities in a manner that substantially detracts from their value as a natural resource." Specific numeric standards apply to streams being considered which include fecal coliform bacteria counts. If and outstanding waters designation is to be assigned to Medano Creek, waters would have to be maintained and protected at their existing quality, and no further water quality degradation would be allowed if it would interfere with existing classified uses.

Severity of Resource Threat, Problem, or Need(s):

Current USGS/NAWQA data indicates existing water quality is excellent. The creek, a shallow, narrow stream is habitat for the endangered Rio Grande Sucker, and Rio Grande Cutthroat Trout (a species of special concern), and is being considered as a future stocking location for the endangered Rio Grande Chub.

The State of Colorado's minimal standard for this water is 200 Fecal Coliform Bacteria Colonies (FCBC)/100 ml of water. Continued and increased use of this area by the public without proper sanitary facilities would endanger the future classification of Medano Creek as an Outstanding, Recreational 1

stream due to the risk to public health as visitors recreate in the creek. Ensuring continued high water quality is of extreme importance to fish and macroinvertebrates as well. The coliform source is likely due to the improper disposal of human waste in the day-use areas. By providing self-composting toilets fecal sources should be substantially reduced.

Problem Definition and Information Base:

FCBC sampling conducted in 1995 showed several peaks corresponding to different data and flow rates of the stream. In June of 1995, while flowing at 70 cfs, a peak of about 9 FCBC/100 ml was noted downstream of the day-use areas. Though low, this value could be expected at these relatively high flows at the beginning of the visitor use season. A second sampling in August, at a flow of 10 cfs, showed peaks of 50 FCBC/100 ml at both the Sand Pit and Campground Trail. In October, with a flow of 2.5 cfs, a peak of 80 FCBC/100 ml was documented at the north boardwalk. This data would strongly suggest a presence of a source of fecal contamination at or upstream of the popular day-use areas.

Since these surveys were very limited in scope and duration, the actual amount of fecal contamination could be greater than documented. More extensive water quality monitoring and sanitary surveys should be conducted, as proposed in GRSA-N-042.000.

Problem Resolution:

Install 2 Rometic Trailside Composters (male & female) at each day-use area; construct a wooden screen around each and erect signing. The toilets would be located away from the creek and outside of the wilderness boundary, using existing trees as a visual screen. Toilets would be cleaned regularly and the composting process monitored and maintained. FCBC monitoring would be conducted at 4 or more locations along Medano Creek and at a frequency of 5 times per month in order to monitor the effectiveness of the project.

Transferability:

The results of installing self-composting toilets should be a definite reduction in improper disposal of human waste, and a resulting reduction in FCBC. Such an improvement should allow the nomination of Medano Creek as an Outstanding recreational 1 water to proceed without complication in the near future. If a substantial reduction in FCBC can be documented, such methods could be used for other parks with similar water quality and visitor use conflicts.

Cost Effectiveness:

Romtec has stated that for 1998 costs of the units, including shipping, will be approximately $1,500 each. Lumber and hardware to build the screening are estimated to be approximately $250 each and would include treated lumber, stain, and hardware. Lab work for 15 sets of fecal coliform samples would be $1,500 and signing would cost about $200. Total material & laboratory costs = $8,700.

Labor for installation, maintenance and sampling.

Project Support:

The costs of labor, installation and maintenance, as well as conducting sanitary surveys and monitoring will be contributed from park base programs. The estimated support contribution is $2,000 or 19% of the total project cost of $10,700.

BUDGET AND FTEs:

----------FUNDED----------

Source	Activity	Fund Type	Budget ($1000s)	FTEs
		Total:	0.0	0.0

----------UNFUNDED----------

	Activity	Fund Type	Budget ($1000s)	FTEs
Year 1	MIT	One-time	8.70	0.10
		Total:	8.70	0.10

(Optional) Alternative Actions/Solutions and Impacts

N/A

Compliance codes: EXCL

Explanation: 516 DM6 APP. 7.4 C(11)

End of data

Project Statement GRSA-N-029.000

Last Update: 03/26/97 Priority: 8
Initial Proposal: 1994 Page Num: 132

Title: **DETERMINE THE CAUSE OF THE DISAPPEARANCE OF INTERDUNAL PONDS**

Funding Status: Funded: 8.0 Unfunded: 39.44

Servicewide Issues : N 12 (WATER FLOW)
N 20 (BASELINE DATA)

N-RMAP Program codes : Q00, Q01

10-238 Package Number :

Problem Statement

This proposed study is intended to determine whether the marked disappearance of interdunal ponds in Great Sand Dunes NM is the result of a temporary drought in the 1950's. The cause of the disappearance needs to be ascertained in order to protect the remaining ponds, determine the desirability and feasibility of restoring the lost wetlands, and improve our understanding of ground and surface water resources in this part of the monument.

Monument Setting

Great Sand Dunes National Monument is located on the eastern side of the San Luis Valley, a remarkably flat valley in south central Colorado, at the head of the Rio Grande Rift. The monument sits at the base of the Sangre De Cristo Mountains where a unique combination of climate, topography and hydrology has allowed the creation and maintenance of the nation's tallest inland sand dunes, covering about 39 mi^2. The valley is cold in the winter, warm in the summer, and receives little precipitation. In contrast, the mountains, which rise to over 14,000 feet, receive much more precipitation and support several streams that flow around the dunes before sinking into the valley floor. The entire hydrologic system maintains a delicate balance, cycling sand from the downwind side of the dune field to the upwind side, at roughly the same rate that the wind carries it in the opposite direction. These high mountains are also the source for most of the water that maintains the water table near the land surface in much of the valley. Irrigated agriculture is the predominant land use in the valley.

Interdunal Ponds

Some of the shallow basins in the western portion of the dune field, which has a much more moderate topography and is known as the sand sheet, may extend below the ground-water table to form "interdunal ponds." A study to document the environmental history of the Monument is currently underway, and includes the digitization of historic aerial photographs showing the ponds. Ten sets of aerial photographs were obtained representing the period from 1936 through 1995. Preliminary results show the number of ponds with water present at the surface dropping from 36 in 1936, to zero in 1966. This was followed by a slow rebound until nine wetlands with water visible at the surface were present in 1995. When the number of wetland features without surface water are added to the total, the trend is a little less pronounced, dropping from 69 in 1936, to a range of 21 - 37 wetlands present since the 1950's.

The environmental history study will also include analysis of tree rings, historic accounts and historic photographs in order to understand long- and short-term climatic and vegetation histories, thus complementing this proposed study of interdunal ponds.

On the 1930's photographs, the wetlands are identifiable as elongated ponds with well-developed fringing communities dominated by bulrush (Schoenoplectus lacustris), smartweed (Persicaria amphibia), spikerush (Eleocharis palustris) and rushes (e.g. Juncus arcticus). The presence of these communities indicate that the wetland's water levels were relatively stable. In addition, the communities were large and supported dense stands of vegetation, indicating that they had been intact for at least many decades. Thus, their relatively sudden disappearance appears to indicate a significant change in Monument ecosystems, the cause of which has yet to be determined.

The two most likely explanations for the disappearance of the ponds are:

1. widespread and relatively permanent lowering the regional ground-water table so that it no longer intersects the surface in this area, or

2. a temporary lowering of the ground-water table caused by a severe drought in the 1950's, that, caused the vegetation to dieback, destabilized the sand sheet and allowed wind-blown sand to fill the ponds and bury the wetlands. This second hypothesis is an example of a short-term perturbations with permanent effects.

Threats

The major threats to resources in the monument that are dependent on the water table are the continued use of water for irrigated agriculture in the valley, and recurrent proposals to pump and sell large amounts of water from land holdings just north of the monument. Irrigated agriculture has been an important land use in the San Luis Valley since the 1800's. Though drops in the ground-water table have not been documented in the monument vicinity due to lack of a long-term record, it is possible that pumping for irrigation is a cause of some lowering of the water table, or is an aggravating factor during periods of drought.

The current proposal for water harvesting, made by Stockmans Water Inc., includes the pumping of roughly 100,000 acre-feet of water per year, and the transport of that water to Colorado's front range cities. It is very similar to an unsuccessful proposal for pumping from the same tract made in 1986. These companies would be pumping deep ground water from aquifers that are thought to be hydrologically connected to the shallow ground water.

Droughts cycles are a normal occurrence in the arid west, and this study proposes to test the possibility that a severe drought in the 1950's caused or contributed to the loss of interdunal ponds in the monument. The current study of the Monument's ecologic history will be using tree-ring dating

techniques to understand the historic occurrence of droughts in this area. This information will be available to help understand the role of the 1950's drought relative to other historic droughts.

Related Activities

The Monument has an extensive ground and surface water monitoring program, consisting of 23 monitoring wells and 13 stream gauge sites. The vast majority of the monitoring wells are located near the two major streams in the Monument, Medano and Sand Creeks, with the intent of documenting the complex relationship between stream flow and the shallow and deep aquifers. The sand sheet is poorly represented in the current monitoring program, having only three wells, one of which is close enough to Sand Creek to be influenced by its seasonal fluctuations. The additional wells proposed in this project will add greatly to the understanding of ground water in this remote portion of the Monument. When this two-year study is complete, some of the wells could be maintained as part of the long-term monitoring network.

Description of the Recommended Project or Activity

The Objective of this study is to determine the cause of the disappearance of interdunal ponds and associated wetlands. It will be accomplished by comparing the hydrology and stratigraphy of the remaining ponds with several former ponds.

This two-year project, funded at $15,000/year, will investigate the hypotheses that the wetlands disappeared during the severe drought of the early 1950's which resulted in short-term water table decline, vegetation dieback, and enough sand movement to fill the wetland basins and bury the wetlands, but not enough deflation to create new interdunal depressions deep enough to intersect the water table.

Testing these hypothesis will provide scientific information to answer the question of why the wetlands disappeared. In addition, it will provide an understanding of the sensitivity of the Great Sand Dunes ecosystems to either regional water table decline from existing and proposed projects, or to climate variability.

METHODS

1. Using Global Positioning Systems, locate the exact position of both existing and former wetlands in the field (these have already been determined initially via an aerial photograph time series analyzed in the ongoing ecological history study).

2. Using numbered stakes, identify the boundaries of a number of these wetland sites to determine their shape relative to existing dune topography.

3. Install ground-water monitoring wells in 10 or more former wetland sites, and install a broader grid of monitoring wells in the area of the lost wetlands, including up-gradient and down-gradient of the study area. These wells would be installed by hand with augers, or where necessary, well-points

would be driven. Wells will be monitored by hand regularly (approximately weekly) during the spring, summer, and fall of the two study years.

4. If possible, water levels in at least one lost wetland site would be continuously monitored as well as one ground-water monitoring well upgradient from each of these sites. Since this proposal has a modest budget, an attempt would be made to borrow this equipment from the NPS Water Resources Division, or use existing park equipment.

5. Water levels in an area where existing wetlands occur would also be surveyed and monitored. A broader grid of monitoring wells would also be installed similar to that described above for the area where wetlands were lost, and ground-water levels would be monitored at similar times. This step would serve as a reference area for comparison to the area where wetlands disappeared.

6. Existing wetlands would be surveyed in the field to collect data on the relationships between different vegetation types and water depths, or hydrologic regime.

7. During the first spring-summer, intact cores would be extracted from the locations where wetlands were lost. Cores will be collected with a piston corer that can reach to more than 5 meters deep. The cores would be analyzed to: a) identify the elevations of the former wetland surfaces, b) collect sediment above, at, and below that buried vegetation surfaces, and c) identify to the species the seeds, leaves, stems and other macrofossils that are preserved in the organic detritus of the former wetland surfaces.

8. Using the macrofossil data, reconstruct the vegetation of each former wetland.

9. Analyze the hydrologic regimes of the former wetlands using the well data, and determine if the depth to water table matches the historic wetland surfaces as determined by the cores.

10. If a burial event is inferred, analyze sediments collected above the former wetland surface for ^{137}Cs (an isotope of cesium that is most abundant in sediment deposited in the 1950's when above ground nuclear testing was at its peak) to determine the relative timing of the burial.

11. All study wells and surfaces will be surveyed for elevation relative to each other with a "Total Station" so that water levels can be compared across the study area and related to the elevations of existing and former wetland surfaces.

12. Examine tree ring records and weather data in the San Luis Valley to determine patterns of regional climate or human development that may have affected the dunes.

Project Statement GRSA-N-029.000

Last Update: 03/26/97 Priority: 8
Initial Proposal: 1994 Page Num: 136

PROPOSED BUDGET BREAKDOWN	1998	1999
Salaries		
Principal Investigator	3,500	3,500
Research Assistant	8,000	8,000
Expenses		
Travel	800	600
Meals	300	250
PVC pipe	150	-
Cs dating	500	-
TOTAL EXPENSES	13,250	12,350
CSU overhead through NPS coop (15%)	1,988	1,853
TOTAL BUDGET PER YEAR	15,238	14,203

BUDGET AND FTEs:

----------FUNDED----------

	Source	Activity	Fund Type	Budget ($1000s)	FTEs
1995	PKBASE-NR	RES	One-time	8.00	0.10
			Total:	8.00	0.10

----------UNFUNDED----------

		Activity	Fund Type	Budget ($1000s)	FTEs
Year 1		RES	One-time	15.24	0.00
Year 2		RES	One-time	14.20	0.00
			Total:	29.44	0.00

Compliance codes: EXCL
Explanation: (516 DM6 App. 1.6)

End of data

Project Statement GRSA-N-047.000

Last Update: 06/16/95 Priority: 9
Initial Proposal: 1995 Page Num: 137

Title: **REVIEW OF LITERATURE REGARDING BIOLOGICAL FUNCTION OF INTERDUNAL POND WETLANDS**

Funding Status: Funded: 0.0 Unfunded: 13.2

Servicewide Issues : N 12 (WATER FLOW)
N 20 (BASELINE DATA)

N-RMAP Program codes : Q00, Q01, Q02

10-238 Package Number :

Problem Statement

Wetlands and open water are rare among arid dune fields. Those in Great Sand Dunes National Monument are called "interdunal ponds." Their rather rapid disappearance has been documented and is the subject of several studies. An inventory of the biological resources associated with interdunal ponds is needed in order to better understand their importance and function, and to guide efforts to preserve them.

Monument Setting

Great Sand Dunes National Monument is located on the eastern side of the San Luis Valley, a remarkably flat valley in south central Colorado, at the head of the Rio Grande Rift. The monument sits at the base of the Sangre De Cristo Mountains where a unique combination of climate, topography and hydrology has allowed the creation and maintenance of the nations tallest inland sand dunes, covering about 39 mi^2. The valley is cold in the winter, warm in the summer, and receives little precipitation. In contrast, the mountains, which rise to over 14,000 feet, receive much more precipitation and support several streams that flow around the dunes before sinking into the valley floor. The entire hydrologic system maintains a delicate balance, cycling sand from the downwind side of the dune field to the upwind side, at roughly the same rate that the wind carries it in the opposite direction. These high mountains are also the source for most of the water that maintains the water table at or near the land surface in much of the valley, which surfaces as interdunal ponds in the western portion of the dune field.

Status of Interdunal Ponds

Interdunal ponds at Great Sand Dunes National Monument numbered nearly one-hundred individual ponds when the Monument was originally proclaimed in 1932 (based on analysis of historic aerial photographs), but in 1995 just nine ponds remain. A study of the possible cause of the loss the ponds is proposed for investigation in another Project Statement (GRSA-N-030.000), and other projects looking into climatic and ecologic history if the Monument could shed some light on the question.

This Project Statement addresses a more basic need, that is, to gather baseline information about the various flora and fauna present and the biological function of the ponds. In the longer term, this information may be useful in assessing reasons for pond diminishment, but in the shorter term, the information may illuminate the best ways to manage these wetland resources. It is important these resources be understood soon, before they disappear entirely. Protection of wetlands is an important National Park Service goal, under Executive Order 11990 (Protection of Wetlands, May 24, 1977).

Being in an arid environment, these ponds are apparently important sources of water and wetland habitat for a variety of species. The desire of some mammals find these ponds is demonstrated by the presence of beavers in one pond, even though there is a mile or more of sand between the pond and any other permanent surface water. Their isolation may have given rise to unusual plant and animal communities.

Description of Recommended Project or Activity

The objective of this project is to review published and unpublished literature that might provide insights into the species present and biological function of the interdunal ponds, thus providing a basis for future field studies.

A substantial amount of published and unpublished literature exists for inventories and investigations of the hydrology and biological resources of the San Luis Valley. Unfortunately few of these focus specifically on the interdunal ponds, and none take a collective approach to assemble all of the available information regarding the ponds. One of the first needs is to assemble and survey the available literature for insights offered into the biology of the interdunal ponds. It is thought that these existing sources will provide a substantial body of information about interdunal ponds, and point out deficiencies that should be the subject of field investigations.

A list of literature to be examined should include at a minimum:

Monument inventories and data sources, including:
- Zuckerman, 1984
- Daniel, 1960a
- McArthur and Sanderson, 1992
- Daniel, 1960b

U.S. Geological Survey National Water-Quality Assessment Program (NAWQA) 1991 inventory at Medano Creek (unpublished)
- O'Neill (no date)
- Triplehorn, 1974
- Organ and Halfpenny 1977
- USFWS color infrared aerial photography database (unpublished)
- Historic Aerial Photographs assembled for the Ecological History Study (underway)

Valley-wide studies and data sources, including:
Ramaly, 1942
Keen, 1971
Colorado 1992 and 1993 inventory (unpublished) (Bob Owen, State of Colorado, Water Quality Control Division, personal commun., 1993)
Satellite imagery of southwestern Colorado acquired by the NPS
Wilson, 1990
U.S. Department of Agriculture's Natural Resource Conservation Service's Alamosa watershed study (unpublished) (George Wilson, Natural Resource Conservation Service, personal commun., April 1995).

Upon completion of the inventory compilation, the data should be assessed collectively to determine information about biological function of the ponds. A report of findings should be prepared.

This project is best conducted through a University. The budget includes 3 weeks time for a Ph.D. Biologist, and 16 weeks for a Graduate Student. Travel and Overhead costs are also included.

Literature cited

Daniel, J. C. 1960a. The Animals of Great Sand Dunes National Monument and their General Ecological Position, *a section in* Great Sand Dunes Research Project. Adams State College, Alamosa, CO. pp. 51-55.

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Keen, V. F. 1971. Fauna of the San Luis Valley *in* James, H. L., ed., Guidebook of the San Luis Basin, Colorado. New Mexico Geological Society Guidebook, 22nd Field Conference. pp. 137-139.

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Ramaly, F. 1942. Vegetation of the San Luis Valley in southern Colorado. University of Colorado Studies Series D. 1:4. pp. 231-277.

Triplehorn, B. W. 1974. Insects at Great Sand Dunes. Unpublished. Available at Great Sand Dunes National Monument, pamphlet file.

Wilson, G. A. 1990. Wetland Inventory Progressing. The Colorado Conservator, v. 6, No. 3, Spring 1990. p. 3.

Zuckerman, L. D. 1984. Limnology of a Seasonally Intermittent Stream Perched on Deep Sand Deposits in Great Sand Dunes National Monument, Final Report. Contract No. CX1200-1-B019, Colorado Cooperative Fishery Research Unit, Colorado State University, Fort Collins, CO. 73 pp.

BUDGET AND FTEs:

----------FUNDED----------

Source	Activity	Fund Type	Budget ($1000s)	FTEs
1995			0.00	0.0
		Total:	0.00	0.0

----------UNFUNDED----------

	Activity	Fund Type	Budget ($1000s)	FTEs
Year 1	RES	One-Time	13.20	0.0
		Total:	13.20	0.0

Compliance codes: EXCL

Explanation: (516 DM2 App. 1.6)

End of data

Project Statement GRSA-N-047.000

Last Update: 06/16/95 Priority: 9
Initial Proposal: 1995 Page Num: 141

Title: **MONITORING SURFACE WATER COMPONENTS OF THE WATER BUDGET**

Funding Status: Funded: 12.5 Unfunded: 0.0

Servicewide Issues : N 12 (WATER FLOW)
N 13 (WATER RIGHTS)

N-RMAP Program codes : Q00, Q01, Q02

10-238 Package Number :

Problem Statement

Delineation of the Monument water budget was identified during the Water Resources Management Plan scoping process as the most critical water resources issue facing the Monument. A water budget is an accounting of the annual sums of all sources of water that enter Great Sand Dunes National Monument. Water plays an essential role in preservation of the dune field and other features of scenic and scientific interest, and is a key objective in the management of Great Sand Dunes National Monument. Though several aspects of the water budget are currently being monitored, gaps in the data collection limits the utility of the information.

Monument Setting

Great Sand Dunes National Monument is located on the eastern side of the San Luis Valley, a remarkably flat valley in south central Colorado, at the head of the Rio Grande Rift. The monument sits at the base of the Sangre De Cristo Mountains where a unique combination of climate, topography and hydrology has allowed the creation and maintenance of the nations tallest inland sand dunes, covering about 39 mi^2. The valley is cold in the winter, warm in the summer, and receives little precipitation. In contrast, the mountains, which rise to over 14,000 feet, receive much more precipitation and support several streams that flow around the dunes before sinking into the valley floor. The entire hydrologic system maintains a delicate balance, cycling sand from the downwind side of the dune field to the upwind side, at roughly the same rate that the wind carries it in the opposite direction. These high mountains are also the source for most of the water that maintains the water table at or near the land surface in much of the valley. Irrigated Agriculture is the predominant land use in the valley.

Sources of surface water in the Monument are snow melt, rainfall, and ground-water (where the water table intercepts the topographic surface to become surface flow). Each year, runoff from the mountains flows down to the dune field, gradually fills the local groundwater table, and which in turn supports the surface flow of Sand and Medano Creeks around the dune field and toward the valley floor. The point where stream flow actually sinks into the valley floor is called the *terminus of flow*, and its location is a valuable indicator of hydrologic conditions. Another unusual feature of Monument' streams is the occurrence of *surge flow*, a very unusual condition where stream flow is not

constant but produces noticeable pulses of water as much as 8 - 12 inches high that proceed downstream every minute or so. These are possible only in steams that are fast, steep, with little turbulence, and an abundance of sandy sediment. The surge flows in Great Sand Dunes National Monument are considered some of the worlds finest examples of this phenomena.

Threats

Insufficient water occurring as surface flow in the channels of Sand and Medano Creeks will hamper or destroy *surge flow*, and can move the terminus of flow of the creeks upstream to points where that surface flow can no longer maintain the sand-recycling process that continually rebuilds the dune field. Changes in the surface flow of Sand or Medano Creeks or their tributaries (mainly Little Medano, Mosca, Cold, Buck, Garden, and Castle Creeks, drainages in Horse and Sawmill Canyons, Morris Gulch, and the SE. 1/4 of sec. 23, T. 41 N., R. 73 W.) will alter the balances maintaining the dune field and the seasonal surge flow.

Delineation of the Monument's overall water budget, i.e., an annual accounting of all sources of water that enter the Monument, including snow pack melt from the Sangre de Cristo Mountains, stream discharge, rainfall, and ground water, is an effective way to quantify minimum amounts of water that are needed for natural maintenance of the scenic and scientific features. In order to successfully delineate the water budget, periodic measurement of snow pack, stream discharge, and rainfall are necessary.

The most important component of the Monument water budget, in terms of quantity, is that of snow pack; melt water provides approximately 60% to 70% of the total water that flows into the Monument (James McCalpin, consultant, written commun., May 1995). The water budget is susceptible to change from climatic alteration, such as severe or prolonged drought, and change from anthropogenic actions, such as surface water flow diversion upstream from the Monument and changes due to ground water withdrawal. Precisely determined baseline values for the water budget will allow the detection and quantification of future changes, direct investigations of the causes, and better position the Monument to protect scenic and scientific resources through such avenues as the assertion of water rights litigation.

Current Inventory and Monitoring

The stream discharge record for Medano Creek is the most extensive, as it was measured nearly continuously at the first "Boundary" Parshall flume from June 1991 until November 1992, when the stilling well froze, and again from March 1993 until May 1993, when the device was destroyed by large stream flow. A replacement "Boundary" Parshall flume was installed by Monument personnel in 1992, used for sporadic data collection until May 1994, and upgraded in May 1994 with a data pod, allowing for continuous stream discharge and water temperature measurements. A second gauging station on Medano Creek, the "Castle Creek" Parshall flume, was the source of some stream discharge data collection between June 1991 and April 1992, when it was undermined by the water flow. The device was not replaced. The Sand Creek Parshall flume was installed by Monument personnel in

1992, and since that time (except for winter months due to freezing) has been sending automatically collected stream discharge data to a WaterTalk satellite connection to the Colorado Division of Water Resources offices in Denver, CO. All these stream discharge data have been acquired and incorporated into the Monument database. Data from current measurements are added to the database at regular intervals. These measurements includes at one permanent flume each on Sand Creek and Medano Creek, and weirs on Little Medano and Buck Creeks. Mosca Creek's gauging station was installed and operated by the U.S. Geological Survey for four years, was the source of highly intermittent readings collected between October 1967 and September 1968; these data are available in 1995 through the STORET database.

Precipitation monitoring, in operation at the Monument's weather station since 1947, has resulted in daily measurements of rainfall and snowfall since that time. The 1950 to 1994 subset of that data were compiled into the National Climatic Center's database in Asheville, NC and subsequently have been retrieved into the Monument's database. Data from current precipitation measurements are added to the database at regular intervals.

Description of Recommended Project or Activity

Tasks related to surface flow, (i.e. snow pack, stream discharge, and precipitation) are addressed in this Project Statement. This is an on-going project currently implemented predominantly by Monument staff through funds from the park base. Additional funding and support are provided by other state and federal agencies.

The objectives of this project are to:

•Build a long-term data base to support current and future understanding of the water resources of the monument.

•Gather data to support quantified water rights granted to the NPS

•Gather data that is both consistent and high in quality

Elements of the current monitoring program are:

<u>Snow pack monitoring</u>

A SNOTEL monitoring station was installed on the Medano Creek watershed in the Sangre de Cristo Mountains in 1995. The Natural Resource Conservation Service performs calibration and maintenance checks on the site 2 - 3 times a year. Other agencies contributing funds for the installation were the Natural Resource Conservation Service, Bureau of Reclamation and the Rio Grande Water Conservation District.

Project Statement GRSA-N-047.000

Last Update: 06/16/95 Priority: 9
Initial Proposal: 1995 Page Num: 144

Stream discharge monitoring

Current activities are:

* Automated stream gauging stations are maintained on Sand and Medano Creeks, the largest streams in the Monument.

* Manual gauges are maintained at Buck, Mosca and Little Medano Creeks, and planned for installation on Cold Creek in 1997. An expansion of the automated gauging network to some of these streams is planned in 1997.

* Periodic manual field measurements of stream discharge are conducted for streams that flow seasonally including Garden and Castle Creeks, Sawmill and Horse Canyons, Morris Gulch Creek and Morris Gulch Spring, and one unnamed stream, with a portable flume or pygmy meter.

* A quality-assurance/quality control (QA/QC) plan is maintained for the stream discharge measurements that are made, including construction of rating curves for monitored streams, and the use of flow meters or other equipment to check the gauging equipment for accurate functioning; verification that field personnel making stream discharge measurements and that personnel interpreting the collected data are properly trained.

* data is regularly entered into the Monument database and periodically transferred to the STORET database.

* Data is compiled and interpreted in an Annual Hydrology Report.

* The terminus-of-flow monitoring of Medano Creek is monitored during the spring and summer. An expansion of this monitoring is proposed in another project statement (GRSA-N-041.100).

The current program requires 8 - 10 days/month for park staff (GS-9) to accomplish. The budget below also includes cost for a vehicle.

BUDGET AND FTEs:

	----------FUNDED----------				
	Source	Activity	Fund Type	Budget ($1000s)	FTEs
1997	PKBASE-NR	MON	Recurrent	12.5	0.5
			==========		
			Annual Total:	12.5	0.5

Project Statement GRSA-

N-047.000

Last Update: 06/16/95 Priority: 9

Initial Proposal: 1995 Page Num: 145

----------UNFUNDED----------

Activity	Fund Type	Budget ($1000s)	FTEs
Year 1			
	==========		
	Total:	0.00	0.0

Compliance codes: EXCL

Explanation: (516 DM2 App. 1.6)

End of data

Project Statement GRSA-

N-047.000

Last Update: 06/16/95 Priority: 9

Initial Proposal: 1995 Page Num: 146

Appendix B. Water Quality Use Classification and Standards for the State of Colorado and National Park Service

Appendix B, part 1. Colorado Surface Water Quality Standards for Organic Substances.
Excerpted from State of Colorado, 1995a, pp. 25-31.

BASIC STANDARDS FOR ORGANIC CHEMICALS (in micrograms per liter)				
Parameter/CAS No.	**Human Health Based[1]**		**Aquatic Life Based[4]**	
	Water Supply[2]	**Water+Fish[3]**	**Acute**	**Chronic**
Acenaphthene 83-32-9	---	---	1,700	520
Acenaphthylene (PAH) 208-96-8	---	0.0028	---	---
Acrolein 107-02-8	---	---	68	21
Acrylonitrile[C] 107-13-1	---	0.058	7,500	2,600
Alachlor 15972-60-8	2[M]	---	---	---
Aldicarb 116-06-3	3[M]	---	---	---
Aldicarb Sulfone 1646-88-4	1	---	---	---
Aldicarb Sulfoxide 1646-87-3	4[M]	---	---	---
Aldrin[C] 309-00-2	0.002	0.00013	1.5	---
Anthracene (PAH) 120-12-7	---	9,600	---	---
Atrazine 1912-24-9	3	---	---	---
Benzene[C] 71-43-2	1.0	1.0	5,300	---
Benzidine[C] 92-87-5	0.0002	0.00012	2,500	---
Benzo(a)anthracene (PAH)[C] 56-55-3	---	0.0044	---	---
Benzo(a)pyrene (PAH)[C] 50-32-8	0.0044	0.0044	---	---
Benzo(b)fluoranthene (PAH)[C] 205-99-2	---	0.0044	---	---
Benzo(k)fluoranthene (PAH)[C] 208-08-9	---	0.0044	---	---
Benzo(g,h,i)perylene (PAH) 191-24-2	---	0.0044	---	---
BHC Hexachlorocyclohexane 608-73-1	---	---	100	---
Bromodichloromethane (HM) 75-27-4	---	---	11,000	---
Butyl benzyl phthalate 85-68-7	---	3000	---	---
Carbofuran 1563-66-2	36	---	---	---
Carbon tetrachloride[C] 56-23-5	0.3	0.25	35,200	---
Chlordane[C] 57-74-9	0.03	0.00058	1.2	0.0043
Chlorethyl ether (BIS-2)[C] 111-44-4	0.03	0.03	---	---
Chlorobenzene 108-90-7	100	100	---	---
Chloroform (HM)[C] 67-66-3	---	---	28,900	1,240
Chlorolspopropyl ether (BIS-2) 39638-32-9	---	1,400	---	---
4-Chloro-3-methylphenol 59-50-7	---	---	30	000
Chloronapthalene 2 91-58-7	---	---	2,300	620
Chlorophenol 2 95-57-2	---	120	4,380	2,000
Chloropyrifos 2921-88-2	---	---	0.083	0.041
Chrysene (PAH) 218-01-9	---	0.0044	---	---
DDD[C] 72-54-8	---	0.00083	0.6	---
DDE[C] 72-55-9	0.1	0.00059	1,050	---
DDT[C] 50-29-3	0.1	0.00059	0.55	0.001
Dalapon 75-99-0	200[M]	---	---	---
Demeton 8065-48-3	---	---	---	0.1

BASIC STANDARDS FOR ORGANIC CHEMICALS (in micrograms per liter)				
Parameter/CAS No.	Human Health Based[1]		Aquatic Life Based[4]	
	Water Supply[2]	Water+Fish[3]	Acute	Chronic
Dibenzo(a,h)anthracene (PAH) 50-70-3	---	0.0044	---	---
1,2 Dibromo-3-Chloropropane (DBCP) 96-12-8	0.2[M]	---	---	---
Dichlorobenzene 1,2 95-50-1	620	620	---	---
Dichlorobenzene 1,3 541-73-1	620	400	---	---
Dichlorobenzene 1,4 106-37-6	75[M]	75	---	---
Dichlorobenzidine[C] 91-94-1	---	0.039	---	---
Dichloroethane 1,2[C] 107-06-2	0.4	0.4	118,000	20,000
Dichloroethylene 1,1 75-35-4	7	0.057	---	---
Dichloroethylene 1,2-cis 156-59-2	70	---	---	---
Dichloroethylene 1,2-trans 156-60-5	100	100	---	---
Dichloromethane 75-09-2	5	5	---	---
Dichlorophenol 2,4 120-83-2	21	21	2,020	365
Dichlorophenoxyacetic acid (2,4-D) 94-75-7	70	---	---	---
Dichloropropane 1,2[C] 78-87-5	0.56	0.56	23,000	5,700
Dichloropropylene 1,3 542-75-6	---	10	6,060	244
Dieldrin[C] 60-57-1	0.002	0.00014	1.3	0.0019
Diethyl phthalate 84-66-2	---	23,000	---	---
Diisopropylmethylphosphonate 1445-75-6	8	---	---	---
Dimethylphenol 2,4 105-67-9	---	540	2,120	---
Dimethyl phthalate 131-11-3	---	313,000	---	---
Di-n-butyl phthalate 84-74-2	---		---	---
Dinitrophenol 2,4 51-28-5	14	14	---	---
Dinitro-o-cresol 4,6 534-52-1	---	13	---	---
Dinitrotoluene 2,4 121-14-2	---	0.11	---	---
Dinitrotoluene 2,6 606-20-2	---	---	33-	23-
Dinoseb 88-85-7	7	---	---	---
Dioxin (2,3,7,8 TCDD)[C] 1746-01-6	$2.2x10^{-7}$	$1.3x10^{-8}$	0.01	0.00001
Diphenylhydrazine 1,2[C] 122-66-7	0.05	0.047	270	---
Di(2-ethylhexyl)adipate 103-23-1	400	---	---	---
Di(2-ethylhexyl)phthalate 117-81-7	6[M]	---	---	---
Diquat 65-00-7	20	---	---	---
Endosulfan 115-29-7	---	---	0.11	0.056
Endosulfan sulfate 1031-07-8	---	110	---	---
Endothall 145-73-3	100	---	---	---
Endrin 72-20-8	2	---	0.09	0.0023
Endrin aldehyde 7421-93-4	0.2[M]	0.2	---	---
Ethylbenzene 100-41-4	680	680	32,000	---
Ethylene Dibromide 106-93-4	0.05[M]	---	---	---
Ethylhexyl phthalate (BIS-2)[C] 117-81-7	---	1.8	---	---
Fluoranthene (PAH) 206-44-0	---	300	3,980	---
Fluorene (PAH) 86-73-7	---	1300	---	---

BASIC STANDARDS FOR ORGANIC CHEMICALS (in micrograms per liter)				
Parameter/CAS No.	**Human Health Based[1]**		**Aquatic Life Based[4]**	
	Water Supply[2]	**Water+Fish[3]**	**Acute**	**Chronic**
Glyphosate 1071-83-6	700	---	---	---
Guthion 86-50-0	---	---	---	0.01
Heptachlor[C] 76-44-8	0.008	0.00021	0.26	0.0038
Heptachlor epoxide[C] 1024-57-3	0.004	0.001	0.26	0.0038
Hexachlorobenzene[C] 118-74-1	1.0[M]	0.00075	---	---
Hexachlorobutadiene 87-68-3	1.0	0.45	90	9.3
Hexachlorocylohexane,Alpha[C] 319-84-6	0.006	0.0039	---	---
Hexachlorocyclohexane,Beta 319-85-7	---	0.014	---	---
Hexachlorocyclohexane, Gamma (Lindane) 58-89-9	0.2	0.019	1.0	0.08
Hexachlorocyclohexane, Technical[C] 608-73-1	---	0.012	---	---
Hexachlorocyclopentadiene 77-47-4	50[M]	50	7	5
Hexachloroethane 67-72-1	---	1.9	980	540
Ideno(1,2,3-cd)pyrene(PAH)[C] 193-39-5	---	0.0044	---	---
Isophorone 78-59-1	40	36	117,000	---
Malathion 121-75-4	---	---	---	0.1
Methoxychlor 72-43-5	40	---		0.03
Methyl bromide (HM) 74-83-9	---	48	---	---
Methyl chloride (HM)[C] 74-87-3	---	5.7	---	---
Mirex 2385-85-5	---	---	---	0.001
Naphthalene (PAH) 91-20-3	---	---	2,300	620
Nitrobenzene 98-95-3	3.5	3.5	27,000	---
Nitrosodibutylamine N	---	0.0064	---	---
Nitrosodiethylamine N	---	0.0008	---	---
Nitrosodimethylamine N[C] 62-75-9	---	0.00069	---	---
Nitrosodiphenylamine N[C] 86-30-6	---	5.0	---	---
Nitrosopyrrolidine N	---	0.016	---	---
N-Nitrosodi-n-propylamine[C] 621-64-7	---	0.005	---	---
Oxamyl(vydate) 23135-22-0	200	---	---	---
PCBs[C] 1336-36-3	0.005	0.000044	2.0	0.014
Pentachlorobenzene 608-93-5	6	3.5	---	---
Pentachlorophenol[C] 87-86-5	1.0[M]	0.28	9[6]	5.7[6]
Phenanthrene (PAH) 85-01-8	---	0.0028	---	---
Phenol 108-95-2	---	---	10,200	2,560
Picloram 1918-02-1	500	---	---	---
Pyrene (PAH) 129-00-0	---	960	---	---
Simazine 122-34-9	4	---	---	---
Styrene 100-42-5	100	---	---	---
Tetrachlorobenzene 1,2,4-5 95-95-3	2	---	---	---
Tetrachloroethane 1,1,2,2[C] 79-34-5	---	0.17	---	2,400
Tetrachloroethylene 127-18-4	5	0.8	5,280	840
Toluene 108-88-3	1,000	1,000	17,500	---

BASIC STANDARDS FOR ORGANIC CHEMICALS (in micrograms per liter)				
Parameter/CAS No.	**Human Health Based[1]**		**Aquatic Life Based[4]**	
	Water Supply[2]	**Water+Fish[3]**	**Acute**	**Chronic**
Toxaphene[C] 8001-35-2	0.03	---	0.73	0.0002
Trichlorobezene 1,2,4 120-82-1	70	---	250	50
Trichloroethane 1,1,1 71-55-6	200	200	---	---
Trichloroethane 1,1,2 79-00-5	3	0.6	9,400	---
Trichloroethylene[C] 79-01-6	5	2.7	45,000	21,900
Trichlorophenol 2,4,6[C] 88-06-2	2	2	---	970
Trichlorophenoxyproprionic acid (2,4,5-tp) 93-72-1	50	---	---	---
Trihalomethanes (total)[7]	100	100	---	---
Vinyl Chloride[C] 75-01-4	2[M]	2	---	---
Xylenes (total) 1330-2-7	10,000	---	---	---

[1] All standards are chronic or 30-day standards. They are based on information contained in EPA's Integrated Risk Information System (IRIS) and/or EPA lifetime health advisories for drinking water using a 10^{-6} incremental risk factor unless otherwise noted.

[2] Only applicable to segments classified for water supply.

[3] Applicable to all Class 1 aquatic life segments or Class 2 aquatic life segments designated by the commission after rulemaking hearing. These class 2 segments will generally be those where fish of a catchable size and which are normally consumed are present, and where there is evidence that fishing takes place on a recurring basis. The Commission may also consider additional evidence that may be relevant to a determination whether the conditions applicable to a particular segment are similar enough to the assumptions underlying the water plus fish ingestion criteria to warrant the adoption of water plus fish ingestion standards for the segment in question.

[4] Applicable to all aquatic life segments.

[5] PQL's for the constituents listed above can be found at Section 6.9.2(12) of the regulations for the State Discharge Permit System.

[6] Standards are pH dependent. Those listed are calculated for pH = 7.0.

Acute = $e^{[1.005(pH)-4.83]}$; Chronic = $e^{[1.005(pH)-5.29]}$.

[7] Total trihalomethanes are considered the sum of the concentrations of bromodichloromethane (CAS No. 75-27-4), dibromochloromethane (CAS No. 124-48-1), tribromomethane (bromoform, CAS No. 75-25-2) and trichloromethane (chloroform, CAS No. 67-66-3).

[C] Carcinogens classified by the EPA as A, Bi, or B2.

[M] Drinking water MCL.

CAS No. = Chemical Abstracts Service Registry Number, (HM) = Halomethanes, (PAH) = Polynuclear Aromatic Hydrocarbons.

Appendix B, part 2. Colorado Numeric Standards for Ground-Water Quality for Bacteria, Inorganic Substances, and Radiological Characteristics.

Tables 1, 2, 3 and 4 are excerpted from State of Colorado, 1995b, pp. 22-25.

TABLE 1 Human Health Standards			
Contaminants			**Standards**
Biological	**Total Coliforms**		**K[a] 1 org/100 ml**
Inorganic	**Antimony**	**(Sb)[d]**	**0.006 mg/l**
	Asbestos		**30000 fibers/Liter[1]**
	Arsenic	**(As)[d]**	**0.05 mg/l**
	Barium	**(Ba)[d]**	**1.0 mg/l**
	Beryllium	**(Be)[d]**	**0.004 mg/l**
	Cadmium	**(Cd)[d]**	**0.005 mg/l**
	Chromium	**(Cr)[d]**	**0.05 mg/l**
	Cyanide [Free]	**(CN)**	**0.20 mg/l**
	Fluoride	**(F)[d]**	**4.0 mg/l**
	Lead	**(Pb)[d]**	**0.05 mg/l**
	Mercury	**(Hg)[d]**	**0.002 mg/l**
	Nickel	**(Ni)[d]**	**0.1 mg/l**
	Nitrate	**(NO_3)[d]**	**10.0 mg/l as N**
	Nitrite	**(NO_2)[d]**	**1.0 mg/l as N**
	Total Nitrate + Nitrite		**10.0 mg/l as N**
	Selenium	**(Se)[d]**	**0.01 mg/l**
	Silver	**(Ag)[d]**	**0.05 mg/l**
	Thallium	**(Tl)[d]**	**0.002 mg/l**
Radiological[bd]	**Alpha Emitters - Gross Alpha Particle Activity (excluding Radon and Uranium)**		**15 Pci/l**
	Beta and Photon Emitters		**4 mrem/year**

[1] Chronic or 30-day standard based on information contained in EPA's Integrated Risk Information System (IRIS) using a 10^{-6} incremental risk factor.

Other notes follow Table 4.

TABLE 2 Secondary Drinking Water Standards			
Contaminants		**Level**	
Chlorophenol	**(Cl)[d]**	**0.0002**	**mg/l**
Chloride		**250**	**mg/l**
Color		**15 color units**	
Copper	**(Cu)[d]**	**1**	**mg/l**
Corrosivity		**Noncorrosive**	
Foaming Agents		**0.5**	**mg/l**
Iron	**(Fe)[d]**	**0.3**	**mg/l**
Manganese	**(Mn)[d]**	**0.05**	**mg/l**
Odor		**3 threshold odor numbers**	
pH			**6.5 - 8.5**
Phenol		**0.300**	**mg/l**
Sulfate	**(SO_4)[d]**	**250**	**mg/l**
Zinc	**(Zn)[d]**	**5**	**mg/l**

See notes following Table 4

TABLE 3 Agricultural Standards			
Contaminants		**Level**	
Aluminum	**(Al)[df]**	**5.0**	**mg/l**
Arsenic	**(As)[d]**	**0.1**	**mg/l**
Beryllium	**(Be)[d]**	**0.1**	**mg/l**
Boron	**(B)[dg]**	**0.75**	**mg/l**
Cadmium	**(Cd)[d]**	**0.01**	**mg/l**
Chromium	**(Cr)[d]**	**0.1**	**mg/l**
Cobalt	**(Co)[d]**	**0.05**	**mg/l**
Copper	**(Cu)[d]**	**0.2**	**mg/l**
Fluoride	**(F)[d]**	**2.0**	**mg/l**
Iron	**(Fe)[d]**	**5.0**	**mg/l**
Lead	**(Pb)[df]**	**0.1**	**mg/l**
Lithium	**(Li)[dh]**	**2.5**	**mg/l**
Manganese	**(Mn)[d]**	**0.2**	**mg/l**
Mercury	**(Hg)[df]**	**0.01**	**mg/l**
Nickel	**(Ni)[d]**	**0.20**	**mg/l**
Nitrite	**(NO_2-N)[df]**	**10**	**mg/l as N**
Nitrite & Nitrate	**(NO_2+NO_3-N)[df]**	**100**	**mg/l as N**
Selenium	**(Se)[d]**	**0.02**	**mg/l**
Vanadium	**(V)[d]**	**0.1**	**mg/l**
Zinc	**(Zn)[d]**	**2.0**	**mg/l**
pH		**6.5 - 8.5**	**mg/l**

See notes following Table 4

TABLE 4 TDS Water Quality Standards	
Background TDS Value (mg/l)	**Maximum Allowable TDS Concentrations**
0 - 500	**400 mg/l or 1.25 times the background level, whichever is least restrictive**
501 - 10,000	**1.25 times the background value**
10,001 or greater	**No limit**

a K Means less than. When the Membrane Filter Technique is used for analysis, the average of all samples taken within a year must be less than 1 organism per 100 milliliters of sample. When the Filter Tube Method is used for analysis, the limit is less than 2.2 org/100 ml.

b If the identity and concentration of each radionuclide in a mixture are known, the limiting value would be derived as follows: Determine, for each radionuclide in the mixture, the ratio between the quantity present in the mixture and the limit specified. The sum of such ratios for all radionuclides in the mixture shall not exceed "1" (i.e., unity). A radionuclide may be considered as not present in a mixture if the ratio of the concentration to the limit does not exceed 1/10 and the sum of such ratios for all radionuclides considered as not present in the mixture does not exceed 1/4.

c ND Means none detected using an approved analytical method with the lowest detection limit for the parameter.

d Measured as dissolved concentration. The sample water shall be filtered through a 0.45 micron membrane filter prior to preservation. The total concentration (not filtered) may be required on a case-by-case basis if deemed necessary to characterize the pollution caused by the activity.

e If two or more radionuclides are present, the sum of their annual dose equivalent to the total body or to any organ shall not exceed 4 mrem per year. Except for Tritium and Strontium 90 the concentration of man-made radionuclides causing 4 mrem total body or organ dose equivalents shall be calculated on the basis of a 2-liter-per-day drinking water intake using the 168-hour data listed in "Maximum Permissible Body Burden and Maximum Permissible Concentration of Radionuclides in Air or Water for Occupational Exposure," NBS Handbook 69, as amended, August 1963, US Department of Commerce.

f These more stringent levels are necessary to protect livestock watering. Levels for parameters without this footnote are set to protect irrigated crops at the same level. Where a party can demonstrate that a livestock watering use of ground water is not reasonably expected, the applicable standard for lead is 5.0 mg/l.

g This level is set to protect the following plans in ascending order of sensitivity: Pecan, Black Walnut, Persian (English) Walnut, Jerusalem Artichoke, Navy Bean, American Elm, Plum, Pear, Apple, Grape (Sultanina and Malaga), Kadota Fig, Persimmon, Cherry, Peach, Apricot, Thornless Blackberry, Orange, Avocado, Grapefruit, and Lemon. Where a party can demonstrate that a crop watering use of ground water is not reasonably expected, the applicable standard for boron is 5.0 mg/l.

h This level protects all crops, except citrus which do not grow in Colorado and therefore a more stringent level of protection is not required.

Appendix B, part 3. Colorado Numeric Standards for Ground-Water Quality for Organic Chemicals.
Excerpted from State of Colorado, 1995b, pp. 9-14.

GROUND WATER ORGANIC CHEMICAL STANDARDS (in micrograms per liter)		
Parameter	**CAS No.**	**Standard[1]**
Alachlor		2.0[M]
Aldicarb	116-06-3	3.0[M]
Aldicarb Sulfone	1646-88-4	2.0[M]
Aldicarb Sulfoxide	1646-87-3	4.0[M]
Aldrin[C]	309-00-2	0.002
Atrazine	1912-24-9	3.0[M]
Benzene[C]	71-43-2	5.0
Benzidine[C]	92-87-5	0.0002
Benzo(a)pyrene	50-32-8	0.2[M]
Bromodichloromethane (HM)	75-27-4	0.3
Bromoform (HM)[C]	75-25-2	4
Carbofuran	1563-66-2	36
Carbon tetrachloride[C]	56-23-5	0.3
Chlordane[C]	57-74-9	0.03
Chlorethyl ether (BIS-2)[C]	111-44-4	0.03
Chlorobenzene	108-90-7	100
Chloroform (HM)[C]	67-66-3	6
DDE[C]	72-55-9	0.1
DDT[C]	50-29-3	0.1
Dalapon	75-99-0	200[M]
1,2-Dibromo-3-Chloropropane (DBCP)	96-12-8	0.2[M]
Dibromochloromethane (HM)	124-48-1	14
Dichlorobenzene 1,2	95-50-1	600[M]
Dichlorobenzene 1,3	541-73-1	620
Dichlorobenzene 1,4	106-37-6	75[M]
Dichloroethane 1,2[C]	107-06-2	0.4

GROUND WATER ORGANIC CHEMICAL STANDARDS (in micrograms per liter)		
Parameter	**CAS No.**	**Standard[1]**
Dichloroethylene 1,1	75-35-4	7
Dichlorethylene 1,2-cis	156-59-2	70[M]
Dichloroethylene 1,2-trans	156-60-5	100[M]
Dichloromethane	75-09-2	5[M]
Dichlorophenol 2,4	120-83-2	21
Dichlorophenoxyacetic acid (2,4-D)	94-75-7	70
Dichloropropane 1,2[C]	78-87-5	0.56
Dieldrin[C]	60-57-1	0.002
Diisopropylmethylphosphonate	1445-75-6	8
Dinitrophenol 2,4	51-28-5	14
Dinoseb	88-85-7	7[M]
Dioxin (2,3,7,8 TCDD)[C]	1746-01-6	2.2×10^{-7}
Diphenylhydrazine 1,2[C]	122-66-7	0.05
Diquat	85-00-7	20[M]
Di(2-ethylhexyl)adipate	103-23-1	400[M]
Di(2-ethylhexyl)phthalate	117-81-7	6[M]
Endothall	145-73-3	100[M]
Endrin	72-20-8	0.2
Endrin aldehyde	7421-93-4	0.2[M]
Ethylbenzene	100-41-4	680
Ethylene Dibromide	106-93-4	0.05[M,1]
Glyphosate	1071-83-6	700[M]
Heptachlor[C]	76-44-8	0.008[1]
Heptachlor epoxide[C]	1024-57-3	0.09[1]
Hexachlorobenzene[C]	118-74-1	1[M]
Hexachlorobutadiene	87-68-3	1.0
Hexachlorocyclohexane,Alpha[C]	319-84-6	0.006
Hexachlorocyclohexane, Gamma (Lindane)	58-89-9	0.2[M]

GROUND WATER ORGANIC CHEMICAL STANDARDS (in micrograms per liter)		
Parameter	**CAS No.**	**Standard[1]**
Hexachlorocyclopentadiene	77-47-4	50[M]
Isophorone	78-59-1	1,050
Methoxychlor	72-43-5	40
Nitrobenzene	98-95-3	3.5
Oxamyl (vydate)	23135-22-0	200[M]
PCBs[C]	1336-36-3	0.005[1]
Pentachlorobenzene	608-93-5	6
Pentachlorophenol[C]	87-86-5	1.0[1.M]
Picloram	1918-02-1	500[M]
Simazine	122-34-9	4[M]
Styrene	100-42-5	100[M]
Tetrachlorobenzene 1,2,4-5	95-94-3	2
Tetrachloroethylene	127-18-4	5
Toluene	108-88-3	1,000
Toxaphene[C]	8001-35-2	0.03
Trichlorobenzene 1,2,4	120-82-1	70[M]
Trichloroethane 1,1,1	71-55-6	200
Trichloroethane 1,1,2	79-00-5	3[1]
Trichloroethylene[C]	79-01-6	5
Trichlorophenol 2,4,6[C]	88-06-2	2
Trichlorophenoxyproprionic acid (2,4,5-tp)	93-72-1	50
Vinyl Chloride[C]	75-01-4	2[M]
Xylenes (total)	1330-20-7	10000[M]

1 All standards are chronic or 30-day standards. They are based on information contained in EPA's Integrated Risk Information System (IRIS) and/or EPA lifetime health advisories for drinking water using a 10^{-6} incremental risk factor unless otherwise noted.

2 PQL's for the constituents listed above can be found at section 6.9.2(12) of the Regulations for the State Discharge Permit System.

[C]Carcinogens classified by the EPA as A, B1, or B2.

[M]Drinking water MCL.

CAS No. = Chemical Abstracts Service Registry Number, (HM) = Halomethanes

Appendix B, part 4. Colorado and National Park Service Drinking Water Maximum Contaminant Levels for Inorganic Chemicals.

State of Colorado		National Park Service			
Primary Inorganic Analysis (from State of Colorado 1994b, p. 32)		Secondary Inorganic Analysis (from NPS-83, National Park Service, 1993, p. 24)		General Mineral Analysis[1] (from NPS-83, National Park Service, 1993, p. 24)	
Contaminant	MCL mg/l unless noted	Contaminant	MCL mg/l unless noted	Contaminant	MCL mg/l unless noted
Antimony (Sb)	0.006	Aluminum	0.05-0.2	Alkalinity	30-500
Arsenic (As)	0.05	Chloride	250.0	Calcium	75-200
Asbestos	7.0[2]	Color	15.0 (color units)	Hardness	<200
Barium (Ba)	2.0	Copper	1.3	Hydrogen sulfide	[3]
Beryllium (Be)	0.004	Corrosivity	Non-corrosive	Magnesium	50-150
Cadmium (Cd)	0.005	Fluoride	2.0	Phosphate	<0.2
Chromium (Cr)	0.1	Foaming agents	0.5		
Cyanide (CN) (free)	0.2	Iron	0.3		
Fluoride (F)	4.0	Manganese	0.05		
Mercury (Hg)	0.002	Odor	TON		
Nickel (Ni)	0.1	pH	6.5-8.5 (pH scale)		
Nitrate (as N)	10.0	Silver	0.1		
Nitrite (as N)	1.0	Sulfate	250.0		
Total Nitrogen[4] (as N)	10.0	Total dissolved solids	500.0		
Selenium (Se)	0.05	Zinc	5.0		
Sodium (Na)	<200				
Thallium (Th)	0.002				

[1] Includes measurement of potassium, specific conductance, and temperature (at the source) to facilitate corrosion control; no numeric standards.

[2] Million fibers longer than 10 microns per liter of sample.

[3] Test at source only when necessary.

[4] Expressed in State of Colorado standards as total nitrate plus nitrite (State of Colorado, 1994b, p. 32).

Appendix B, part 5. National Park Service Maximum Contaminant Levels for Organic Chemicals in Drinking Water.

Standards from National Park Service Public Health Management Guideline, NPS-83 (National Park Service, 1993, pp. 5, 25 and 26).

Contaminant	MCL mg/l	Contaminant	MCL mg/l
Alachlor (Lasso)	0.002	Carbon Tetrachloride	0.005
Atrazine (Antranex, Crisazina)	0.003	Di (2 ethylhexyl) adipate	0.4
Carbofuran	0.04	Di (2 ethylhexyl) phthalate	0.006
Chlordane	0.002	o-Dichlorobenzene	0.6
2, 4-D (Formula 40)	0.07	para-Dichlorobenzene	0.075
Dalapon	0.2	1,2-Dichloroethane *	0.005
Dibromochloropropane	0.0002	1,1-Dichloroethylene *	0.007
Dinoseb	0.007	cis-1,2-Dichloroethylene *	0.07
Diquat	0.02	trans-1,2-Dichloroethylene *	0.1
Endothall	0.1	Dichloromethane	0.005
Endrin	0.002	1,2-Dichloropropane	0.005
Ethylenedibromide	0.00005	Ethylbenzene	0.7
Glyphosate	0.7	Hexachlorobenzene	0.001
Heptachlorepoxide	0.0002	Hexachlorocyclopentadiene (HEX)	0.05
Heptachlor (H-34, Heptox)	0.0004	Monochlorobenzene	0.1
Lindane	0.0002	Styrene	0.1
Methoxychlor	0.04	2,3,7,8 -- TCDD (Dioxin)	3×10^{-8}
Oxamyl (Vydate)	0.2	Tetrachloroethylene (PCE) *	0.005
Pentachlorophenol	0.001	Toluene	1.0
Picloram	0.5	1,2,4-Trichlorobenzene	0.07
Polychlorinated biphenyls (PCBs) (as decachlorobiphenyl)	0.0005	1,1,1-Trichloroethane *	0.2
Simazine	0.004	1,1,2-Trichloroethane	0.005
Toxaphene	0.003	Trichloroethylene (TCE) *	0.005
2, 4-5-TP (Silvex)	0.05	Total Trihalomethanes, or bromodichloromethane + dibromochloromethane + tribromomethane (bromoform) + trichloromethane (chloroform)	0.1
Benzene	0.005	Vinyl chloride	0.002
Benzo(a)pyrene	0.0002	Xylenes (total)	10.0

* If State standards are triggered, detection institutes mandatory, quarterly re-sampling for vinyl chloride for 1 qtr.; if none detected, vinyl chloride resampling schedule is every 3 years.

Appendix B, part 6. Unregulated Volatile Organic Compounds for which All National Park Service Water Supply Systems Must Be Tested.

Excerpted from National Park Service Guideline NPS-83 (National Park Service, 1993, p. 27).)

Bromobenzene
Bromodichloromethane
Bromoform
Bromomethane
Chlorobenzene
Chlorodibromomethane
Chloroethane
Chloroform
Chloromethane
o-Chlorotoluene
p-Chlorotoluene
Dibromomethane
m-Dichlorobenzene
1,1-Dichloroethane
1,3-Dichloropropane
2,2-Dichloropropane
1,1-Dichloropropene
1,3-Dichloropropene
1,1,1,2-Tetrachloroethane
1,1,2,2-Tetrachloroethane
1,2,3-Trichloropropane

Appendix B, part 7. Unregulated Inorganic and Organic Compounds for which Some Water Supply Systems in Colorado Must Be Tested.

There is no current (1997) requirement to test water supply systems in Great Sand Dunes National Monument for these species, but they will be required if the residential system is reclassified to non-transient at some time in the future (from State of Colorado, 1994b, pp. 44).

Adicarb
Adicarb Sulfone
Adicarb Sulfoxide
Aldrin
Butachlor
Carbaryl
Dicamba
Dieldrin
3-Hydroxycarbofuran
Methomyl
Metolachlor
Metribuzin
Propachlor

Appendix B, part 8. Surface Water Standards for Outstanding Waters in the State of Colorado.

Excerpted from State of Colorado, 1995a, pp. 41-49.

Parameter	Designated Use Classification			
	Recreational Class 1	**Aquatic Life Class 1, Cold Water Biota**	**Aquatic Life Class 1, Warm Water Biota**	**Domestic Water Supply**
Dissolved oxygen (mg/L)	3.0	6.0 or 7.0 (spawning)	5.0	--
pH (standard units)	6.5 to 9.0	6.5 to 9.0	6.5 to 9.0	--
Fecal coliform (colonies/100 ml)	200	--	--	--
Ammonia, un-ionized, as N, chronic (mg/L)	--	0.02	0.06	
Nitrate, as N (mg/L)	--	--	--	10
Cadmium, dissolved, chronic (ug/L)	--	$e^{(0.7852 [\ln (\text{hardness})] - 3.490}$		--
Copper, dissolved, chronic (ug/L)	--	$e^{(0.8545 [\ln (\text{hardness})] - 1.465}$		--
Lead, dissolved, chronic (ug/L)	--	$e^{(1.417 [\ln (\text{hardness})] - 5.167}$		--
Manganese, dissolved, chronic (ug/L)	--	1,000		--
Selenium, dissolved, chronic (ug/L)	--	17		--
Silver, dissolved, chronic (ug/L)	--	*Effective March 2, 1998:* $e^{(1.72 [\ln (\text{hardness})] - 9.06}$ Trout = $e^{(1.72 [\ln (\text{hardness})] - 10.51}$		--
Zinc, dissolved, chronic (ug/L)	--	$e^{(0.8473 [\ln (\text{hardness})] + 0.7614}$		--

Appendix C. Medano Creek Water Quality Data From US Geological Survey NAWQA Program

DISTRICT CODE 35 UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 6-11-97

374752105300801 - MEDANO CREEK NEAR MOSCA, CO

WATER-QUALITY DATA

DATE	TIME	MEDIUM CODE	TEMPER-ATURE WATER (DEG C) (00010)	TEMPER-ATURE AIR (DEG C) (00020)	BARO-METRIC PRES-SURE (MM OF HG) (00025)	AGENCY COL-LECTING SAMPLE (CODE NUMBER) (00027)	AGENCY ANA-LYZING SAMPLE (CODE NUMBER) (00028)	DIS-CHARGE, INST. CUBIC FEET PER SECOND (00061)	NUMBER OF SAM-PLING POINTS (COUNT) (00063)	GAGE HEIGHT (FEET) (00065)	SPE-CIFIC CON-DUCT-ANCE (US/CM) (00095)
SEP 1992											
23...	1020	9	8.5	--	--	1028	1028	--	1	--	--
APR 1993											
14...	1000	9	0.0	0.0	550	--	80020	6.0	--	--	84
MAY											
20...	1100	9	6.0	--	560	--	80020	66	--	2.67	56
JUN											
17...	0930	9	6.5	--	559	1028	80020	57.3	--	--	43
JUL											
22...	1000	9	9.0	--	560	1028	80020	10.9	--	--	59
AUG											
19...	1000	9	11.5	--	563	1028	80020	6.40	--	--	75
SEP											
16...	1000	9	7.0	--	560	1028	80020	4.59	--	--	83
OCT											
07...	1015	9	7.5	12.0	555	1028	80020	3.01	--	0.56	94
NOV											
04...	1000	9	0.0	5.5	555	1028	80020	3.72	--	1.37	89
DEC											
09...	1100	9	0.0	2.0	556	1028	80020	3.1	--	0.46	96
JAN 1994											
21...	1100	9	0.0	3.0	565	1028	80020	3.55	--	--	100
FEB											
14...	1245	9	2.0	3.0	558	1028	80020	1.5	--	--	101
MAR											
14...	1300	9	1.5	10.5	559	1028	80020	1.97	--	0.32	98
APR											
14...	1015	9	1.0	--	555	1028	80020	4.6	--	0.51	89
MAY											
23...	1345	9	9.0	21.5	561	1028	80020	59	--	2.70	52
JUN											
20...	1230	9	12.0	14.5	564	1028	80020	18.2	--	1.15	60
JUL											
26...	1245	9	16.0	24.0	563	1028	80020	4.1	--	0.42	86
AUG											
22...	1315	9	15.5	10.0	561	1028	80020	4.75	--	0.40	83
30...	0830	9	11.0	15.5	562	1028	1028	2.7	--	0.35	101
SEP											
15...	1000	9	6.5	7.0	561	1028	80020	4.32	--	0.320	92

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WATER-QUALITY DATA

DATE	OXYGEN, DIS-SOLVED (MG/L) (00300)	OXYGEN, DIS-SOLVED (PER-CENT SATUR-ATION) (00301)	PH WATER WHOLE FIELD (STAND-ARD UNITS) (00400)	PH WATER WHOLE LAB (STAND-ARD UNITS) (00403)	CAR-BONATE WATER DIS IT FIELD MG/L AS CO3 (00452)	BICAR-BONATE WATER DIS IT FIELD MG/L AS HCO3 (00453)	NITRO-GEN, AMMONIA DIS-SOLVED (MG/L AS N) (00608)	NITRO-GEN, NITRITE DIS-SOLVED (MG/L AS N) (00613)	NITRO-GEN,AM-MONIA + ORGANIC DIS. (MG/L AS N) (00623)	NITRO-GEN,AM-MONIA + ORGANIC TOTAL (MG/L AS N) (00625)	NITRO-GEN, NO2+NO3 DIS-SOLVED (MG/L AS N) (00631)
SEP 1992											
23...	--	--	--	--	--	--	--	--	--	--	--
APR 1993											
14...	10.5	10	8.2	7.4	0	54	0.010	0.010	<0.20	0.20	<0.050
MAY											
20...	9.1	100	8.0	7.4	0	37	0.030	<0.010	<0.20	0.60	<0.050
JUN											
17...	9.10	101	8.10	7.5	--	--	0.040	<0.010	<0.20	<0.20	0.052
JUL											
22...	8.50	100	7.90	7.8	0	27	0.050	<0.010	<0.20	<0.20	<0.050
AUG											
19...	8.40	105	8.30	8.2	0	43	0.030	<0.010	<0.20	<0.20	<0.050
SEP											
16...	8.80	99	8.10	7.5	0	50	0.020	<0.010	<0.20	<0.20	<0.050
OCT											
07...	8.50	98	8.70	8.1	0	50	<0.010	<0.010	<0.20	<0.20	<0.050
NOV											
04...	10.8	102	8.10	7.1	0	45	0.020	<0.010	<0.20	<0.20	<0.050
DEC											
09...	10.7	101	8.1	7.6	0	55	<0.010	0.010	<0.20	<0.20	--
JAN 1994											
21...	10.9	101	8.10	7.6	0	55	0.020	<0.010	<0.20	<0.20	0.120
FEB											
14...	10.6	105	7.7	7.8	0	57	0.020	<0.010	<0.20	<0.20	0.110
MAR											
14...	9.7	95	7.90	7.6	0	60	0.030	<0.010	<0.20	<0.20	0.066
APR											
14...	10.4	101	7.9	7.4	0	48	0.050	<0.010	<0.20	<0.20	<0.050
MAY											
23...	8.0	94	7.8	7.1	0	27	0.050	<0.010	0.30	<0.20	<0.050
JUN											
20...	8.00	101	7.90	7.2	0	31	0.020	<0.010	<0.20	<0.20	<0.050
JUL											
26...	7.2	99	8.0	7.5	0	46	0.010	<0.010	<0.20	<0.20	<0.050
AUG											
22...	7.20	98	7.3	7.5	0	47	0.010	<0.010	<0.20	<0.20	<0.050
30...	8.10	100	7.00	--	--	45	--	--	--	--	--
SEP											
15...	8.70	96	7.70	7.5	0	52	<0.010	<0.010	<0.20	<0.20	<0.050

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WATER-QUALITY DATA

DATE	PHOS-PHORUS TOTAL (MG/L AS P) (00665)	PHOS-PHORUS DIS-SOLVED (MG/L AS P) (00666)	PHOS-PHORUS ORTHO, DIS-SOLVED (MG/L AS P) (00671)	CARBON, ORGANIC DIS-SOLVED (MG/L AS C) (00681)	CARBON, ORGANIC SUS-PENDED TOTAL (MG/L AS C) (00689)	HARD-NESS TOTAL (MG/L AS CACO3) (00900)	CALCIUM DIS-SOLVED (MG/L AS CA) (00915)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG) (00925)	SODIUM, DIS-SOLVED (MG/L AS NA) (00930)	SODIUM AD-SORP-TION RATIO (00931)	SODIUM PERCENT (00932)
SEP 1992											
23...	--	--	--	--	--	--	--	--	--	--	--
APR 1993											
14...	0.010	0.020	<0.010	2.8	0.5	38	10	3.1	3.1	0.2	15
MAY											
20...	0.060	0.020	0.010	5.2	1.2	23	6.2	1.9	2.1	0.2	16
JUN											
17...	0.020	0.010	<0.010	3.7	0.8	19	5.1	1.4	1.5	0.2	15
JUL											
22...	<0.010	<0.010	<0.010	1.9	0.6	25	7.0	1.9	1.8	0.2	13
AUG											
19...	0.010	<0.010	<0.010	2.0	0.6	32	8.9	2.4	2.3	0.2	13
SEP											
16...	<0.010	<0.010	<0.010	2.2	0.2	37	10	2.8	2.5	0.2	13
OCT											
07...	0.010	<0.010	<0.010	--	--	41	11	3.3	3.1	0.2	14
NOV											
04...	0.010	<0.010	0.010	--	--	40	11	3.1	2.5	0.2	12
DEC											
09...	<0.010	<0.010	0.010	--	--	44	12	3.5	3.1	0.2	13
JAN 1994											
21...	<0.010	<0.010	<0.010	--	--	44	12	3.4	3.2	0.2	14
FEB											
14...	<0.010	0.010	<0.010	--	--	44	12	3.4	3.2	0.2	13
MAR											
14...	<0.010	0.02	<0.010	--	--	41	11	3.2	3.1	0.2	14
APR											
14...	<0.010	<0.010	0.010	--	--	37	10	2.9	2.9	0.2	14
MAY											
23...	0.030	0.020	0.010	--	--	20	5.4	1.6	1.9	0.2	16
JUN											
20...	0.030	0.010	<0.010	--	--	27	7.7	1.9	2.0	0.2	14
JUL											
26...	0.020	<0.010	<0.010	--	--	37	10	2.9	2.7	0.2	13
AUG											
22...	0.020	0.020	<0.010	--	--	34	9.2	2.6	2.4	0.2	13
30...	--	--	--	--	--	--	--	--	--	--	--
SEP											
15...	0.020	<0.010	0.010	--	--	40	11	3.0	2.8	0.2	13

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DATE	POTASSIUM, DISSOLVED (MG/L AS K) (00935)	CHLORIDE, DISSOLVED (MG/L AS CL) (00940)	SULFATE DISSOLVED (MG/L AS SO4) (00945)	FLUORIDE, DISSOLVED (MG/L AS F) (00950)	SILICA, DISSOLVED (MG/L AS SIO2) (00955)	BORON, DISSOLVED (UG/L AS B) (01020)	IRON, DISSOLVED (UG/L AS FE) (01046)	MANGANESE, DISSOLVED (UG/L AS MN) (01056)	STRONTIUM, DISSOLVED (UG/L AS SR) (01080)	ALKALINITY WAT DIS TOT IT FIELD MG/L AS CACO3 (39086)	SOLIDS, RESIDUE AT 180 DEG. C DISSOLVED (MG/L) (70300)
SEP 1992											
23...	--	--	--	--	--	--	--	--	--	--	--
APR 1993											
14...	0.70	0.60	4.0	0.20	13	<10	120	9	53	44	71
MAY											
20...	0.70	0.50	2.8	0.10	13	--	210	9	--	30	56
JUN											
17...	0.50	0.30	2.1	0.10	9.3	--	91	5	--	--	36
JUL											
22...	0.50	0.20	2.2	0.20	9.6	--	75	7	--	20	42
AUG											
19...	0.70	0.20	2.7	0.20	10	--	130	10	--	35	45
SEP											
16...	0.80	0.40	3.0	0.20	12	--	160	12	--	41	56
OCT											
07...	0.60	0.50	3.5	0.20	12	--	210	11	--	41	73
NOV											
04...	0.70	0.50	3.6	0.20	12	--	110	12	--	37	58
DEC											
09...	0.70	0.50	4.1	0.20	13	--	80	16	--	45	64
JAN 1994											
21...	0.70	0.80	4.4	0.20	12	--	66	13	--	45	57
FEB											
14...	0.70	0.70	4.4	0.20	13	--	69	11	--	47	72
MAR											
14...	0.70	0.60	4.2	0.20	12	--	80	8	--	49	62
APR											
14...	0.70	0.50	4.0	0.20	12	--	130	8	--	40	58
MAY											
23...	0.90	0.30	2.7	0.20	11	--	230	7	--	22	48
JUN											
20...	0.60	0.30	2.5	0.20	10	--	120	7	--	26	41
JUL											
26...	0.70	0.40	3.0	0.20	13	--	140	8	--	38	62
AUG											
22...	0.80	0.40	2.5	0.20	12	--	150	9	--	39	59
30...	--	--	--	--	--	--	--	--	--	37	--
SEP											
15...	0.90	0.50	2.8	0.20	12	--	250	14	--	43	62

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DATE	SOLIDS, SUM OF CONSTI-TUENTS, DIS-SOLVED (MG/L) (70301)	SED. SUSP. SIEVE DIAM. % FINER THAN .062 MM (70331)	SAMPLE PURPOSE CODE (71999)	ELEV. OF LAND SURFACE DATUM (FT. ABOVE NGVD) (72000)	SEDI-MENT, SUS-PENDED (MG/L) (80154)	DRAIN-AGE AREA (SQ. MI.) (81024)	SAM-PLING METHOD, CODES (82398)	SAMPLER TYPE (CODE) (84164)	SPE-CIFIC CON-DUCT-ANCE LAB (US/CM) (90095)	ALKA-LINITY LAB (MG/L AS CACO3) (90410)	QUALITY ASSUR-ANCE DATA INDICA-TOR CODE (99111)
SEP 1992											
23...	--	--	--	8450	--	15.0	--	--	--	--	--
APR 1993											
14...	61	13	--	8450	13	15.0	--	--	91	42	--
MAY											
20...	46	--	--	8450	--	15.0	--	--	57	26	--
JUN											
17...	32	--	--	8450	157	15.0	--	--	45	19	--
JUL											
22...	37	--	--	8450	15	15.0	--	--	61	29	--
AUG											
19...	49	--	--	8450	18	15.0	--	--	82	38	--
SEP											
16...	56	--	--	8450	5	15.0	--	--	86	42	--
OCT											
07...	59	--	15.0	8450	19	15.0	10	3035	99	46	--
NOV											
04...	56	--	15.0	8450	10	15.0	10	3045	95	42	--
DEC											
09...	64	--	15.0	8450	16	15.0	10	3035	104	50	--
JAN 1994											
21...	68	--	15.0	8450	13	15.0	10	3035	107	52	--
FEB											
14...	66	--	15.0	8450	15	15.0	10	3035	107	49	--
MAR											
14...	65	--	15.0	8450	15	15.0	10	3035	99	47	--
APR											
14...	57	--	15.0	8450	9	15.0	10	3045	90	40	--
MAY											
23...	38	--	15.0	8450	20	15.0	10	3045	53	23	10
JUN											
20...	41	--	15.0	8450	18	15.0	10	3045	61	28	--
JUL											
26...	56	--	15.0	8450	6	15.0	10	3045	87	40	30
AUG											
22...	53	--	15.0	8450	6	15.0	10	3045	66	40	--
30...	--	--	--	8450	--	15.0	--	--	--	--	--
SEP											
15...	59	--	15.0	8450	6	15.0	10	3050	95	45	--

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374752105300801 - MEDANO CREEK NEAR MOSCA, CO

PROCESS DATE 6-11-97

WATER-QUALITY DATA

DATE	TIME	MEDIUM CODE	TEMPER-ATURE WATER (DEG C) (00010)	TEMPER-ATURE AIR (DEG C) (00020)	BARO-METRIC PRES-SURE (MM OF HG) (00025)	AGENCY COL-LECTING SAMPLE (CODE NUMBER) (00027)	AGENCY ANA-LYZING SAMPLE (CODE NUMBER) (00028)	DIS-CHARGE, INST. CUBIC FEET PER SECOND (00061)	GAGE HEIGHT (FEET) (00065)	SPE-CIFIC CON-DUCT-ANCE (US/CM) (00095)	OXYGEN, DIS-SOLVED (MG/L) (00300)	OXYGEN, DIS-SOLVED (PER-CENT SATUR-ATION) (00301)
OCT 1994												
17...	1315	9	1.0	0.0	551	1028	80020	4.5	0.400	84	10.0	98
NOV												
23...	1000	9	0.0	-7.5	565	1028	80020	2.11	0.890	98	10.4	96
DEC												
19...	1230	9	0.0	0.0	556	1028	80020	2.41	0.500	98	10.5	99
JAN 1995												
11...	1015	9	0.0	0.0	549	1028	80020	2.42	0.370	99	10.7	102
FEB												
08...	0930	9	0.5	-1.5	558	1028	80020	2.04	0.280	102	10.5	99
MAR												
22...	0915	9	1.5	2.5	552	1028	80020	6.20	0.600	75	10.0	99
APR												
12...	0945	9	0.5	0.0	560	1028	80020	8.87	0.680	74	10.4	98
MAY												
10...	0945	9	3.5	4.5	558	1028	80020	20.8	1.34	70	9.70	100
JUN												
15...	1130	9	6.5	18.5	560	1028	80020	98.9	3.51	42	8.60	95
JUL												
20...	0945	9	7.5	13.5	563	1028	80020	27.0	1.58	53	9.00	102
AUG												
03...	1010	9	9.5	18.5	563	1028	1028	--	--	63	8.3	99
16...	1000	9	9.5	12.0	560	1028	80020	10.1	0.600	74	8.40	100
SEP												
06...	1030	9	11.0	12.5	564	1028	80020	5.00	0.500	84	7.90	97
OCT												
18...	0945	9	2.5	1.5	560	1028	80020	4.00	0.340	95	10.0	100
NOV												
30...	0845	9	0.0	2.0	559	1028	80020	2.89	0.370	97	10.5	98
JAN 1996												
30...	0930	9	0.5	0.5	553	1028	80020	2.40	0.320	89	10.3	99
SEP												
04...	1000	9	10.0	12.5	561	1028	80020	2.6	0.300	92	8.10	98
SEP 1992												
23...	1100	H	8.5	--	564	1028	80020	3.20	--	94	8.50	99

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DISTRICT CODE 35 UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 6-11-97

374752105300801 - MEDANO CREEK NEAR MOSCA, CO

WATER-QUALITY DATA

DATE	PH WATER WHOLE FIELD (STAND-ARD UNITS) (00400)	PH WATER WHOLE LAB (STAND-ARD UNITS) (00403)	ALKA-LINITY WAT WH TOT IT FIELD MG/L AS CACO3 (00419)	CAR-BONATE WATER WH IT FIELD MG/L AS CO3 (00447)	BICAR-BONATE WATER WH IT FIELD MG/L AS HCO3 (00450)	CAR-BONATE WATER DIS IT FIELD MG/L AS CO3 (00452)	BICAR-BONATE WATER DIS IT FIELD MG/L AS HCO3 (00453)	NITRO-GEN, AMMONIA DIS-SOLVED (MG/L AS N) (00608)	NITRO-GEN, NITRITE DIS-SOLVED (MG/L AS N) (00613)	NITRO-GEN, AM-MONIA + ORGANIC DIS. (MG/L AS N) (00623)	NITRO-GEN, AM-MONIA + ORGANIC TOTAL (MG/L AS N) (00625)	NITRO-GEN, NO2+NO3 DIS-SOLVED (MG/L AS N) (00631)
OCT 1994												
17...	7.80	7.6	--	--	--	0	48	<0.015	<0.010	<0.20	<0.20	<0.050
NOV												
23...	7.4	7.5	--	--	--	0	53	<0.015	<0.010	<0.20	<0.20	<0.050
DEC												
19...	7.50	7.4	--	--	--	0	54	<0.015	<0.010	<0.20	<0.20	<0.050
JAN 1995												
11...	8.10	7.7	--	--	--	0	57	<0.015	<0.010	<0.20	<0.20	0.080
FEB												
08...	7.80	7.7	--	--	--	0	56	<0.015	<0.010	<0.20	<0.20	0.080
MAR												
22...	7.6	7.2	--	--	--	0	40	<0.015	<0.010	<0.20	<0.20	<0.050
APR												
12...	7.40	7.4	--	--	--	0	35	<0.015	<0.010	<0.20	<0.20	<0.050
MAY												
10...	7.40	7.7	--	--	--	0	37	<0.015	<0.010	<0.20	0.20	<0.050
JUN												
15...	7.50	7.3	--	--	--	0	21	0.020	<0.010	0.30	1.1	0.060
JUL												
20...	7.30	7.3	--	--	--	E0	29	0.020	<0.010	<0.20	<0.20	0.070
AUG												
03...	6.9	--	27	0	32	--	--	--	--	--	--	--
16...	7.50	7.6	--	--	--	0	39	0.020	<0.010	<0.20	<0.20	<0.050
SEP												
06...	7.6	7.5	--	--	--	0	45	<0.015	<0.010	<0.20	<0.20	<0.050
OCT												
18...	7.80	7.7	--	--	--	0	55	<0.015	<0.010	<0.20	<0.20	<0.050
NOV												
30...	7.70	7.7	--	--	--	0	56	<0.015	<0.010	<0.20	<0.20	<0.050
JAN 1996												
30...	7.60	7.7	--	--	--	0	56	<0.015	0.010	<0.20	<0.20	0.130
SEP												
04...	7.60	7.8	--	--	--	0	49	<0.015	<0.010	<0.20	<0.20	0.060
SEP 1992												
23...	7.20	--	--	--	--	0	56	--	--	--	--	--

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374752105300801 - MEDANO CREEK NEAR MOSCA, CO

WATER-QUALITY DATA

DATE	PHOS-PHORUS TOTAL (MG/L AS P) (00665)	PHOS-PHORUS DIS-SOLVED (MG/L AS P) (00666)	PHOS-PHORUS ORTHO, DIS-SOLVED (MG/L AS P) (00671)	CARBON, ORGANIC TOTAL (MG/L AS C) (00680)	HARD-NESS TOTAL (MG/L AS CACO3) (00900)	CALCIUM DIS-SOLVED (MG/L AS CA) (00915)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG) (00925)	SODIUM, DIS-SOLVED (MG/L AS NA) (00930)	SODIUM AD-SORP-TION RATIO (00931)	SODIUM PERCENT (00932)	POTAS-SIUM, DIS-SOLVED (MG/L AS K) (00935)	CHLO-RIDE, DIS-SOLVED (MG/L AS CL) (00940)
OCT 1994												
17...	<0.010	<0.010	<0.010	--	37	10	2.9	2.6	0.2	13	0.80	0.60
NOV												
23...	<0.010	<0.010	<0.010	--	44	12	3.4	3.1	0.2	13	0.80	0.60
DEC												
19...	<0.010	<0.010	<0.010	--	41	11	3.2	2.9	0.2	13	0.70	0.50
JAN 1995												
11...	0.020	<0.010	<0.010	--	40	11	3.1	2.9	0.2	13	0.70	0.60
FEB												
08...	<0.010	<0.010	<0.010	--	41	11	3.2	2.9	0.2	13	0.70	0.60
MAR												
22...	<0.010	<0.010	<0.010	--	32	8.7	2.6	2.5	0.2	14	0.90	0.60
APR												
12...	0.050	<0.010	<0.010	--	30	7.9	2.4	2.4	0.2	15	0.70	1.0
MAY												
10...	0.040	0.020	0.010	5.9	28	7.5	2.3	2.5	0.2	16	0.60	0.70
JUN												
15...	0.250	0.030	0.010	--	17	4.6	1.3	1.6	0.2	17	0.60	0.30
JUL												
20...	0.020	0.020	<0.010	--	22	6.2	1.7	1.8	0.2	14	0.50	0.40
AUG												
03...	--	--	--	--	--	--	--	--	--	--	--	--
16...	0.020	<0.010	<0.010	--	35	10	2.3	2.3	0.2	12	0.70	0.40
SEP												
06...	0.020	0.010	<0.010	--	37	10	2.8	2.5	0.2	13	0.90	0.30
OCT												
18...	<0.010	<0.010	0.020	--	41	11	3.2	2.7	0.2	12	0.90	0.50
NOV												
30...	<0.010	<0.010	<0.010	--	41	11	3.4	3.2	0.2	14	0.80	0.70
JAN 1996												
30...	<0.010	<0.010	<0.010	--	41	11	3.3	2.9	0.2	13	0.70	0.60
SEP												
04...	0.010	<0.010	<0.010	--	37	10	3.0	2.7	0.2	13	0.90	0.50
SEP 1992												
23...	--	--	--	--	--	--	--	--	--	--	--	--

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DISTRICT CODE 35 UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 6-11-97

374752105300801 - MEDANO CREEK NEAR MOSCA, CO

WATER-QUALITY DATA

DATE	SULFATE DIS- SOLVED (MG/L AS SO4) (00945)	FLUO- RIDE, DIS- SOLVED (MG/L AS F) (00950)	SILICA, DIS- SOLVED (MG/L AS SIO2) (00955)	ARSENIC DIS- SOLVED (UG/L AS AS) (01000)	ARSENIC TOTAL (UG/L AS AS) (01002)	BARIUM, DIS- SOLVED (UG/L AS BA) (01005)	BARIUM, TOTAL RECOV- ERABLE (UG/L AS BA) (01007)	BERYL- LIUM, DIS- SOLVED (UG/L AS BE) (01010)	BERYL- LIUM, TOTAL RECOV- ERABLE (UG/L AS BE) (01012)	BORON, DIS- SOLVED (UG/L AS B) (01020)	BORON, TOTAL RECOV- ERABLE (UG/L AS B) (01022)	CADMIUM DIS- SOLVED (UG/L AS CD) (01025)
OCT 1994												
17...	2.9	0.20	11	--	--	--	--	--	--	--	--	--
NOV												
23...	3.8	0.20	13	--	--	--	--	--	--	--	--	--
DEC												
19...	3.4	0.20	12	--	--	--	--	--	--	--	--	--
JAN 1995												
11...	3.5	0.20	12	--	--	--	--	--	--	--	--	--
FEB												
08...	2.7	0.20	12	--	--	--	--	--	--	--	--	--
MAR												
22...	2.9	0.20	12	--	--	--	--	--	--	--	--	--
APR												
12...	2.8	0.20	12	--	--	--	--	--	--	--	--	--
MAY												
10...	2.6	0.20	13	--	<1	--	<100	--	<10	--	<10	--
JUN												
15...	2.1	0.10	10	--	--	--	--	--	--	--	--	--
JUL												
20...	1.9	0.20	10	--	--	--	--	--	--	--	--	--
AUG												
03...	--	--	--	--	--	--	--	--	--	--	--	--
16...	2.3	0.20	11	<1	--	14	--	<1	--	<10	--	<1.0
SEP												
06...	2.6	0.20	13	--	--	--	--	--	--	--	--	--
OCT												
18...	2.9	0.20	12	--	--	--	--	--	--	--	--	--
NOV												
30...	2.9	0.20	13	--	--	--	--	--	--	--	--	--
JAN 1996												
30...	2.8	0.20	12	--	--	--	--	--	--	--	--	--
SEP												
04...	2.6	0.20	11	--	--	--	--	--	--	--	--	--
SEP 1992												
23...	--	--	--	--	--	--	--	--	--	--	--	--

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374752105300801 - MEDANO CREEK NEAR MOSCA, CO

WATER-QUALITY DATA

DATE	CADMIUM WATER UNFLTRD TOTAL (UG/L AS CD) (01027)	CHRO-MIUM, DIS-SOLVED (UG/L AS CR) (01030)	CHRO-MIUM, TOTAL RECOV-ERABLE (UG/L AS CR) (01034)	COBALT, DIS-SOLVED (UG/L AS CO) (01035)	COBALT, TOTAL RECOV-ERABLE (UG/L AS CO) (01037)	COPPER, DIS-SOLVED (UG/L AS CU) (01040)	COPPER, TOTAL RECOV-ERABLE (UG/L AS CU) (01042)	IRON, TOTAL RECOV-ERABLE (UG/L AS FE) (01045)	IRON, DIS-SOLVED (UG/L AS FE) (01046)	LEAD, DIS-SOLVED (UG/L AS PB) (01049)	LEAD, TOTAL RECOV-ERABLE (UG/L AS PB) (01051)	MANGA-NESE, TOTAL RECOV-ERABLE (UG/L AS MN) (01055)
OCT 1994												
17...	--	--	--	--	--	--	--	--	180	--	--	--
NOV												
23...	--	--	--	--	--	--	--	--	120	--	--	--
DEC												
19...	--	--	--	--	--	--	--	--	95	--	--	--
JAN 1995												
11...	--	--	--	--	--	--	--	--	89	--	--	--
FEB												
08...	--	--	--	--	--	--	--	--	87	--	--	--
MAR												
22...	--	--	--	--	--	--	--	--	120	--	--	--
APR												
12...	--	--	--	--	--	--	--	--	140	--	--	--
MAY												
10...	<1	--	<1	--	<1	--	2	1000	240	--	<1	20
JUN												
15...	--	--	--	--	--	--	--	--	210	--	--	--
JUL												
20...	--	--	--	--	--	--	--	--	95	--	--	--
AUG												
03...	--	--	--	--	--	--	--	--	--	--	--	--
16...	--	<1	--	<1	--	<1	--	--	110	<1	--	--
SEP												
06...	--	--	--	--	--	--	--	--	160	--	--	--
OCT												
18...	--	--	--	--	--	--	--	--	78	--	--	--
NOV												
30...	--	--	--	--	--	--	--	--	65	--	--	--
JAN 1996												
30...	--	--	--	--	--	--	--	--	53	--	--	--
SEP												
04...	--	--	--	--	--	--	--	--	100	--	--	--
SEP 1992												
23...	--	--	--	--	--	--	--	--	--	--	--	--

DISTRICT CODE 35 UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 6-11-97

374752105300801 - MEDANO CREEK NEAR MOSCA, CO

WATER-QUALITY DATA

DATE	MANGA-NESE, DIS-SOLVED (UG/L AS MN) (01056)	MOLYB-DENUM, DIS-SOLVED (UG/L AS MO) (01060)	MOLYB-DENUM, TOTAL RECOV-ERABLE (UG/L AS MO) (01062)	NICKEL, DIS-SOLVED (UG/L AS NI) (01065)	NICKEL, TOTAL RECOV-ERABLE (UG/L AS NI) (01067)	SILVER, DIS-SOLVED (UG/L AS AG) (01075)	SILVER, TOTAL RECOV-ERABLE (UG/L AS AG) (01077)	STRON-TIUM, DIS-SOLVED (UG/L AS SR) (01080)	STRON-TIUM, TOTAL RECOV-ERABLE (UG/L AS SR) (01082)	VANA-DIUM, DIS-SOLVED (UG/L AS V) (01085)	ZINC, DIS-SOLVED (UG/L AS ZN) (01090)	ZINC, TOTAL RECOV-ERABLE (UG/L AS ZN) (01092)
OCT 1994												
17...	12	--	--	--	--	--	--	--	--	--	--	--
NOV												
23...	13	--	--	--	--	--	--	--	--	--	--	--
DEC												
19...	13	--	--	--	--	--	--	--	--	--	--	--
JAN 1995												
11...	12	--	--	--	--	--	--	--	--	--	--	--
FEB												
08...	10	--	--	--	--	--	--	--	--	--	--	--
MAR												
22...	7	--	--	--	--	--	--	--	--	--	--	--
APR												
12...	7	--	--	--	--	--	--	--	--	--	--	--
MAY												
10...	8	--	2	--	<1	--	<1	--	40	--	--	20
JUN												
15...	11	--	--	--	--	--	--	--	--	--	--	--
JUL												
20...	7	--	--	--	--	--	--	--	--	--	--	--
AUG												
03...	--	--	--	--	--	--	--	--	--	--	--	--
16...	13	<1	--	<1	--	<1.0	--	43	--	<6	2	--
SEP												
06...	13	--	--	--	--	--	--	--	--	--	--	--
OCT												
18...	14	--	--	--	--	--	--	--	--	--	--	--
NOV												
30...	13	--	--	--	--	--	--	--	--	--	--	--
JAN 1996												
30...	12	--	--	--	--	--	--	--	--	--	--	--
SEP												
04...	12	--	--	--	--	--	--	--	--	--	--	--
SEP 1992												
23...	--	--	--	--	--	--	--	--	--	--	--	--

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374752105300801 - MEDANO CREEK NEAR MOSCA, CO

WATER-QUALITY DATA

DATE	ANTI-MONY, DIS-SOLVED (UG/L AS SB) (01095)	ANTI-MONY, TOTAL (UG/L AS SB) (01097)	ALUM-INUM, TOTAL RECOV-ERABLE (UG/L AS AL) (01105)	ALUM-INUM, DIS-SOLVED (UG/L AS AL) (01106)	LITHIUM DIS-SOLVED (UG/L AS LI) (01130)	LITHIUM TOTAL RECOV-ERABLE (UG/L AS LI) (01132)	SELE-NIUM, DIS-SOLVED (UG/L AS SE) (01145)	SELE-NIUM, TOTAL (UG/L AS SE) (01147)	PROP-CHLOR, WATER, DISS, REC (UG/L) (04024)	BUTYL-ATE, WATER, DISS, REC (UG/L) (04028)	SI-MAZINE, WATER, DISS, REC (UG/L) (04035)	PRO-METON, WATER, DISS, REC (UG/L) (04037)
OCT 1994												
17...	--	--	--	--	--	--	--	--	--	--	--	--
NOV												
23...	--	--	--	--	--	--	--	--	--	--	--	--
DEC												
19...	--	--	--	--	--	--	--	--	--	--	--	--
JAN 1995												
11...	--	--	--	--	--	--	--	--	--	--	--	--
FEB												
08...	--	--	--	--	--	--	--	--	--	--	--	--
MAR												
22...	--	--	--	--	--	--	--	--	--	--	--	--
APR												
12...	--	--	--	--	--	--	--	--	--	--	--	--
MAY												
10...	--	<1	1100	--	--	<10	--	<1	--	--	--	--
JUN												
15...	--	--	--	--	--	--	--	--	<0.007	<0.002	<0.005	<0.018
JUL												
20...	--	--	--	--	--	--	--	--	<0.007	<0.002	<0.005	<0.018
AUG												
03...	--	--	--	--	--	--	--	--	--	--	--	--
16...	<1	--	--	30	<4	--	<1	--	<0.007	<0.002	<0.005	<0.018
SEP												
06...	--	--	--	--	--	--	--	--	<0.007	<0.002	<0.005	<0.018
OCT												
18...	--	--	--	--	--	--	--	--	--	--	--	--
NOV												
30...	--	--	--	--	--	--	--	--	--	--	--	--
JAN 1996												
30...	--	--	--	--	--	--	--	--	--	--	--	--
SEP												
04...	--	--	--	--	--	--	--	--	<0.007	<0.002	<0.005	<0.018
SEP 1992												
23...	--	--	--	--	--	--	--	--	--	--	--	--

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374752105300801 - NEDANO CREEK NEAR MOSCA, CO

WATER-QUALITY DATA

DATE	DEETHYL ATRA-ZINE, WATER, DISS, REC (UG/L) (04040)	CYANA-ZINE, WATER, DISS, REC (UG/L) (04041)	FONOFOS WATER DISS REC (UG/L) (04095)	URANIUM NATURAL DIS-SOLVED (UG/L AS U) (22703)	ALKA-LINITY WAT.WH. GRAN T. FIELD CACO3 (MG/L) (29813)	ALPHA BHC DIS-SOLVED (UG/L) (34253)	P,P' DDE DISSOLV (UG/L) (34653)	ALUM-INUM BOT MAT <63U WS FIELD PERCENT (34790)	ANTI-MONY BOT MAT <63U WS FIELD (UG/G) (34795)	ARSENIC BOT MAT <63U WS FIELD (UG/G) (34800)	BARIUM BOT MAT <63U WS FIELD (UG/G) (34805)	BERYL-LIUM BOT MAT <63U WS FIELD (UG/G) (34810)
OCT 1994												
17...	--	--	--	--	--	--	--	--	--	--	--	--
NOV												
23...	--	--	--	--	--	--	--	--	--	--	--	--
DEC												
19...	--	--	--	--	--	--	--	--	--	--	--	--
JAN 1995												
11...	--	--	--	--	--	--	--	--	--	--	--	--
FEB												
08...	--	--	--	--	--	--	--	--	--	--	--	--
MAR												
22...	--	--	--	--	--	--	--	--	--	--	--	--
APR												
12...	--	--	--	--	--	--	--	--	--	--	--	--
MAY												
10...	--	--	--	--	--	--	--	--	--	--	--	--
JUN												
15...	<0.002	<0.004	<0.003	--	--	<0.002	<0.006	--	--	--	--	--
JUL												
20...	<0.002	<0.004	<0.003	--	--	<0.002	<0.006	--	--	--	--	--
AUG												
03...	--	--	--	--	26	--	--	--	--	--	--	--
16...	<0.002	<0.004	<0.003	<1.0	--	<0.002	<0.006	--	--	--	--	--
SEP												
06...	<0.002	<0.004	<0.003	--	--	<0.002	E0.001	--	--	--	--	--
OCT												
18...	--	--	--	--	--	--	--	--	--	--	--	--
NOV												
30...	--	--	--	--	--	--	--	--	--	--	--	--
JAN 1996												
30...	--	--	--	--	--	--	--	--	--	--	--	--
SEP												
04...	<0.002	<0.004	<0.003	--	--	<0.002	<0.006	--	--	--	--	--
SEP 1992												
23...	--	--	--	--	--	--	--	7.0	0.400	3	740	2

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374752105300801 - MEDANO CREEK NEAR MOSCA, CO

WATER-QUALITY DATA

DATE	BISMUTH BOT MAT <180UWS FIELD (UG/G) (34816)	CADMIUM BOT MAT <63U WS FIELD (UG/G) (34825)	CALCIUM BOT MAT <63U WS FIELD PERCENT (34830)	CERIUM BOT MAT <63U WS FIELD (UG/G) (34835)	CHRO-MIUM BOT MAT <63U WS FIELD (UG/G) (34840)	COBALT BOT MAT <63U WS FIELD (UG/G) (34845)	COPPER BOT MAT <63U WS FIELD (UG/G) (34850)	EURO-PIUM BOT MAT <63U WS FIELD (UG/G) (34855)	GALLIUM BOT MAT <63U WS FIELD (UG/G) (34860)	GOLD BOT MAT <63U WS FIELD (UG/G) (34870)	HOLMIUM BOT MAT <63U WS FIELD (UG/G) (34875)	IRON BOT MAT <63U WS FIELD PERCENT (34880)
OCT 1994												
17...	--	--	--	--	--	--	--	--	--	--	--	--
NOV												
23...	--	--	--	--	--	--	--	--	--	--	--	--
DEC												
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JAN 1995												
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FEB												
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MAR												
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APR												
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MAY												
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JUN												
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JUL												
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AUG												
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SEP												
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OCT												
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NOV												
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JAN 1996												
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SEP												
04...	--	--	--	--	--	--	--	--	--	--	--	--
SEP 1992												
23...	<10	0.200	2.1	100	59	18	40	2	19	<8	<4	5.4

DISTRICT CODE 35 UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 6-11-97

374752105300801 - MEDANO CREEK NEAR MOSCA, CO

WATER-QUALITY DATA

DATE	LANTHA-NUM BOT MAT <63U WS FIELD (UG/G) (34885)	LEAD BOT MAT <63U WS FIELD (UG/G) (34890)	LITHIUM BOT MAT <63U WS FIELD (UG/G) (34895)	MAGNE-SIUM BOT MAT <63U WS FIELD PERCENT (34900)	MANGA-NESE BOT MAT <63U WS FIELD (UG/G) (34905)	MERCURY BOT MAT <63U WS FIELD (UG/G) (34910)	MOLYB-DENUM BOT MAT <63U WS FIELD (UG/G) (34915)	NEODYM-IUM BOT MAT <63U WS FIELD (UG/G) (34920)	NICKEL BOT MAT <63U WS FIELD (UG/G) (34925)	NIOBIUM BOT MAT <63U WS FIELD (UG/G) (34930)	PHOS-PHORUS BOT MAT <63U WS FIELD PERCENT (34935)	POTAS-SIUM BOT MAT <63U WS FIELD PERCENT (34940)
OCT 1994												
17...	--	--	--	--	--	--	--	--	--	--	--	--
NOV												
23...	--	--	--	--	--	--	--	--	--	--	--	--
DEC												
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JAN 1995												
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FEB												
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MAR												
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APR												
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MAY												
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JUN												
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JUL												
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AUG												
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16...	--	--	--	--	--	--	--	--	--	--	--	--
SEP												
06...	--	--	--	--	--	--	--	--	--	--	--	--
OCT												
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NOV												
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JAN 1996												
30...	--	--	--	--	--	--	--	--	--	--	--	--
SEP												
04...	--	--	--	--	--	--	--	--	--	--	--	--
SEP 1992												
23...	61	21	30	1.1	1100	0.040	<2	59	20	14	0.19	1.8

181

DISTRICT CODE 35 UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 6-11-97

374752105300801 - MEDANO CREEK NEAR MOSCA, CO

WATER-QUALITY DATA

DATE	SCAN-DIUM BOT MAT <63U WS FIELD (UG/G) (34945)	SELE-NIUM BOT MAT <63U WS FIELD (UG/G) (34950)	SILVER BOT MAT <63U WS FIELD (UG/G) (34955)	SODIUM BOT MAT <63U WS FIELD PERCENT (34960)	STRON-TIUM BOT MAT <63U WS FIELD (UG/G) (34965)	SULFUR BOT MAT <63U WS FIELD (UG/G) (34970)	TANTA-LUM BOT MAT <63U WS FIELD (UG/G) (34975)	THORIUM BOT MAT <63U WS FIELD (UG/G) (34980)	TIN BOT MAT <63U WS FIELD (UG/G) (34985)	URANIUM BOT MAT <63U WS FIELD (UG/G) (35000)	VANA-DIUM BOT MAT <63U WS FIELD (UG/G) (35005)	YTTRIUM BOT MAT <63U WS FIELD (UG/G) (35010)
OCT 1994												
17...	--	--	--	--	--	--	--	--	--	--	--	--
NOV												
23...	--	--	--	--	--	--	--	--	--	--	--	--
DEC												
19...	--	--	--	--	--	--	--	--	--	--	--	--
JAN 1995												
11...	--	--	--	--	--	--	--	--	--	--	--	--
FEB												
08...	--	--	--	--	--	--	--	--	--	--	--	--
MAR												
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APR												
12...	--	--	--	--	--	--	--	--	--	--	--	--
MAY												
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JUN												
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JUL												
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AUG												
03...	--	--	--	--	--	--	--	--	--	--	--	--
16...	--	--	--	--	--	--	--	--	--	--	--	--
SEP												
06...	--	--	--	--	--	--	--	--	--	--	--	--
OCT												
18...	--	--	--	--	--	--	--	--	--	--	--	--
NOV												
30...	--	--	--	--	--	--	--	--	--	--	--	--
JAN 1996												
30...	--	--	--	--	--	--	--	--	--	--	--	--
SEP												
04...	--	--	--	--	--	--	--	--	--	--	--	--
SEP 1992												
23...	15	1	0.200	1.5	330	0.080	<40	19	<5	7.4	140	40

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DISTRICT CODE 35 UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 6-11-97

374752105300801 - MEDANO CREEK NEAR MOSCA, CO

WATER-QUALITY DATA

DATE	YTTER-BIUM BOT MAT <63U WS FIELD (UG/G) (35015)	ZINC BOT MAT <63U WS FIELD (UG/G) (35020)	CHLOR-PYRIFOS DIS-SOLVED (UG/L) (38933)	ALKA-LINITY WAT DIS TOT IT FIELD MG/L AS CACO3 (39086)	LINDANE DIS-SOLVED (UG/L) (39341)	DI-ELDRIN DIS-SOLVED (UG/L) (39381)	METO-LACHLOR WATER DISSOLV (UG/L) (39415)	MALA-THION, DIS-SOLVED (UG/L) (39532)	PARA-THION, DIS-SOLVED (UG/L) (39542)	DI-AZINON, DIS-SOLVED (UG/L) (39572)	ATRA-ZINE, WATER, DISS, REC (UG/L) (39632)	ALA-CHLOR, WATER, DISS, REC, (UG/L) (46342)
OCT 1994												
17...	--	--	--	39	--	--	--	--	--	--	--	--
NOV												
23...	--	--	--	44	--	--	--	--	--	--	--	--
DEC												
19...	--	--	--	45	--	--	--	--	--	--	--	--
JAN 1995												
11...	--	--	--	47	--	--	--	--	--	--	--	--
FEB												
08...	--	--	--	46	--	--	--	--	--	--	--	--
MAR												
22...	--	--	--	33	--	--	--	--	--	--	--	--
APR												
12...	--	--	--	29	--	--	--	--	--	--	--	--
MAY												
10...	--	--	--	30	--	--	--	--	--	--	--	--
JUN												
15...	--	--	<0.004	17	<0.004	<0.001	<0.002	<0.005	<0.004	<0.002	<0.001	<0.002
JUL												
20...	--	--	<0.004	24	<0.004	<0.001	<0.002	<0.005	<0.004	<0.002	<0.001	<0.002
AUG												
03...	--	--	--	--	--	--	--	--	--	--	--	--
16...	--	--	<0.004	32	<0.004	<0.001	<0.002	<0.005	<0.004	<0.002	<0.001	<0.002
SEP												
06...	--	--	<0.004	37	<0.004	<0.001	<0.002	<0.005	<0.004	<0.002	<0.001	<0.002
OCT												
18...	--	--	--	45	--	--	--	--	--	--	--	--
NOV												
30...	--	--	--	46	--	--	--	--	--	--	--	--
JAN 1996												
30...	--	--	--	46	--	--	--	--	--	--	--	--
SEP												
04...	--	--	<0.004	40	<0.004	<0.001	<0.002	<0.005	<0.004	<0.002	<0.001	<0.002
SEP 1992												
23...	4	130	--	46	--	--	--	--	--	--	--	--

DISTRICT CODE 35 UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 6-11-97

374752105300801 - NEDANO CREEK NEAR MOSCA, CO

WATER-QUALITY DATA

DATE	ACETO-CHLOR, WATER FLTRD REC (UG/L) (49260)	CARBON, ORGANIC SED, BM WS,<63U DW, REC (PER-CENT) (49266)	CARBON, ORG + INORG, SED, BM WS,<63U DW, REC PERCENT (49267)	CARBON, INORG, SED, BM WS,<63U DW, REC (PER-CENT) (49269)	CARBON, INORG, SED, BM WS,<2MM DW, REC (G/KG) (49270)	CARBON, ORGANIC SED, BM WS,<2MM DW, REC (G/KG) (49271)	CARBON, ORG + INORG SED, BM WS,<2MM DW, REC (G/KG) (49272)	TITA-NIUM, SED, BM WS,<63U DRY WGT REC PERCENT (49274)	ALPHA-BHC, D6 SURROGT SED, BM WS,<2MM DW, REC PERCENT (49275)	OCTCHLR BIPHENL SURROGT SED, BM WS,<2MM DW, REC PERCENT (49276)	BIPHENL 35DICHR SURROGT SED, BM WS,<2MM DW, REC PERCENT (49277)	TERPHEN YL D14-SURROGT SED, BM WS,<2MM DW, REC PERCENT (49278)
OCT 1994												
17...	--	--	--	--	--	--	--	--	--	--	--	--
NOV												
23...	--	--	--	--	--	--	--	--	--	--	--	--
DEC												
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JAN 1995												
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FEB												
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MAR												
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APR												
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MAY												
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JUN												
15...	<0.002	--	--	--	--	--	--	--	--	--	--	--
JUL												
20...	<0.002	--	--	--	--	--	--	--	--	--	--	--
AUG												
03...	--	--	--	--	--	--	--	--	--	--	--	--
16...	<0.002	--	--	--	--	--	--	--	--	--	--	--
SEP												
06...	<0.002	--	--	--	--	--	--	--	--	--	--	--
OCT												
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NOV												
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JAN 1996												
30...	--	--	--	--	--	--	--	--	--	--	--	--
SEP												
04...	<0.002	--	--	--	--	--	--	--	--	--	--	--
SEP 1992												
23...	--	4.7	4.7	<0.01	<0.1	3.5	3.5	0.640	72	40	50	80

DISTRICT CODE 35 UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 6-11-97

374752105300801 - MEDANO CREEK NEAR MOSCA, CO

WATER-QUALITY DATA

DATE	BIPHENL 2FLUORO SURROGT SED, BM WS,<2MM DW, REC PERCENT (49279)	BENZENE NITROD5 SURROGT SED, BM WS,<2MM DW, REC PERCENT (49280)	CIS-NONA-CHLOR, SED, BM WS,<2MM DW, REC (UG/KG) (49316)	TRANS-NONA-CHLOR, SED, BM WS,<2MM DW, REC (UG/KG) (49317)	OXY-CHLOR-DANE, SED, BM WS,<2MM DW, REC (UG/KG) (49318)	ALDRIN, SED, BM WS,<2MM DW, REC (UG/KG) (49319)	CIS-CHLOR-DANE, SED, BM WS,<2MM DW, REC (UG/KG) (49320)	TRANS-CHLOR-DANE, SED, BM WS,<2MM DW, REC (UG/KG) (49321)	CHLORO-NEB, SED, BM WS,<2MM DW, REC (UG/KG) (49322)	DCPA, SED, BM WS,<2MM DW, REC (UG/KG) (49324)	O, P'-DDD, SED, BM WS,<2MM DW, REC (UG/KG) (49325)	P, P'-DDD, SED, BM WS,<2MM DW, REC (UG/KG) (49326)
OCT 1994												
17...	--	--	--	--	--	--	--	--	--	--	--	--
NOV												
23...	--	--	--	--	--	--	--	--	--	--	--	--
DEC												
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JAN 1995												
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FEB												
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MAR												
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APR												
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MAY												
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JUN												
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JUL												
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AUG												
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SEP												
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OCT												
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NOV												
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JAN 1996												
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SEP												
04...	--	--	--	--	--	--	--	--	--	--	--	--
SEP 1992												
23...	58	64	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<5.0	<5.0	<1.0	<1.0

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DISTRICT CODE 35 UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 6-11-97

374752105300801 - MEDANO CREEK NEAR MOSCA, CO

WATER-QUALITY DATA

DATE	O, P'-DDE, SED, BM WS,<2MM DW, REC (UG/KG) (49327)	P, P'-DDE, SED, BM WS,<2MM DW, REC (UG/KG) (49328)	O, P'-DDT, SED, BM WS,<2MM DW, REC (UG/KG) (49329)	P, P'-DDT, SED, BM WS,<2MM DW, REC (UG/KG) (49330)	DIELDRIN, SED, BM WS,<2MM DW, REC (UG/KG) (49331)	ENDOSULFAN I, SED, BM WS,<2MM DW, REC (UG/KG) (49332)	ENDRIN, SED, BM WS,<2MM DW, REC (UG/KG) (49335)	ALPHA-BHC, SED, BM WS,<2MM DW, REC (UG/KG) (49338)	BETA-BHC, SED, BM WS,<2MM DW, REC (UG/KG) (49339)	HEPTACHLOR, SED, BM WS,<2MM DW, REC (UG/KG) (49341)	HEPTACHLOR EPOXIDE SED, BM WS,<2MM DW, REC (UG/KG) (49342)	BENZENE HEXACHLORO- SED, BM WS,<2MM DW, REC (UG/KG) (49343)
OCT 1994												
17...	--	--	--	--	--	--	--	--	--	--	--	--
NOV												
23...	--	--	--	--	--	--	--	--	--	--	--	--
DEC												
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JAN 1995												
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FEB												
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MAR												
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APR												
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MAY												
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JUN												
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JUL												
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AUG												
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SEP												
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OCT												
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NOV												
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JAN 1996												
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SEP												
04...	--	--	--	--	--	--	--	--	--	--	--	--
SEP 1992												
23...	<1.0	<1.0	<2.0	<2.0	<1.0	<1.0	<2.0	<1.0	<1.0	<1.0	<1.0	<1.0

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DISTRICT CODE 35 UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 6-11-97

374752105300801 - MEDANO CREEK NEAR MOSCA, CO

WATER-QUALITY DATA

DATE	ISODRIN SED, BM WS,<2MM DW, REC (UG/KG) (49344)	LINDANE SED, BM WS,<2MM DW, REC (UG/KG) (49345)	METHOXY CHLOR P,P'-, SED, BM WS,<2MM DW, REC (UG/KG) (49346)	METHOXY CHLOR, O,P'-, SED, BM WS,<2MM DW, REC (UG/KG) (49347)	MIREX, SED, BM WS,<2MM DW, REC (UG/KG) (49348)	CIS-PER-METHRIN SED, BM WS,<2MM DW, REC (UG/KG) (49349)	TRANS-PER-METHRIN SED, BM WS,<2MM DW, REC (UG/KG) (49350)	TOXA-PHENE SED, BM WS,<2MM DW, REC (UG/KG) (49351)	PHTHAL-ATE, DIBUTYL SED, BM WS,<2MM DW, REC (UG/KG) (49381)	PHTHAL ATE, D IOCTYL SED, BM WS,<2MM DW, REC (UG/KG) (49382)	PHTHAL-ATE, D IETHYL SED, BM WS,<2MM DW, REC (UG/KG) (49383)	PHTHAL-ATE,DI-METHYL SED, BM WS,<2MM DW, REC (UG/KG) (49384)
OCT 1994												
17...	--	--	--	--	--	--	--	--	--	--	--	--
NOV												
23...	--	--	--	--	--	--	--	--	--	--	--	--
DEC												
19...	--	--	--	--	--	--	--	--	--	--	--	--
JAN 1995												
11...	--	--	--	--	--	--	--	--	--	--	--	--
FEB												
08...	--	--	--	--	--	--	--	--	--	--	--	--
MAR												
22...	--	--	--	--	--	--	--	--	--	--	--	--
APR												
12...	--	--	--	--	--	--	--	--	--	--	--	--
MAY												
10...	--	--	--	--	--	--	--	--	--	--	--	--
JUN												
15...	--	--	--	--	--	--	--	--	--	--	--	--
JUL												
20...	--	--	--	--	--	--	--	--	--	--	--	--
AUG												
03...	--	--	--	--	--	--	--	--	--	--	--	--
16...	--	--	--	--	--	--	--	--	--	--	--	--
SEP												
06...	--	--	--	--	--	--	--	--	--	--	--	--
OCT												
18...	--	--	--	--	--	--	--	--	--	--	--	--
NOV												
30...	--	--	--	--	--	--	--	--	--	--	--	--
JAN 1996												
30...	--	--	--	--	--	--	--	--	--	--	--	--
SEP												
04...	--	--	--	--	--	--	--	--	--	--	--	--
SEP 1992												
23...	<1.0	<1.0	<5.0	<5.0	<1.0	<5.0	<5.0	<200	51	<50	16	<5

DISTRICT CODE 35

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY
374752105300801 - MEDANO CREEK NEAR MOSCA, CO

PROCESS DATE 6-11-97

WATER-QUALITY DATA

DATE	PYRENE, SED, BM WS,<2MM DW, REC (UG/KG) (49387)	PYRENE, 1-METHYL, SED, BM WS,<2MM DW, REC (UG/KG) (49388)	BENZO (A) PYRENE SED, BM WS,<2MM DW, REC (UG/KG) (49389)	INDENO 123-CD PYRENE SED, BM WS,<2MM DW, REC (UG/KG) (49390)	2,2'-BI QUINO-LINE, SED, BM WS,<2MM DW, REC (UG/KG) (49391)	QUINO-LINE, SED, BM WS,<2MM DW, REC (UG/KG) (49392)	PHENAN-THRI-DINE SED, BM WS,<2MM DW, REC (UG/KG) (49393)	ISO-QUINO-LINE, SED, BM WS,<2MM DW, REC (UG/KG) (49394)	TOLUENE 2,4-DI-NITRO-SED, BM WS,<2MM DW, REC (UG/KG) (49395)	TOLUENE 2,6-DI-NITRO-SED, BM WS,<2MM DW, REC (UG/KG) (49396)	BENZO K FLUOR-ANTHENE SED, BM WS,<2MM DW, REC (UG/KG) (49397)	9H-FLU-ORENE, 1METHYL SED, BM WS,<2MM DW, REC (UG/KG) (49398)
OCT 1994												
17...	--	--	--	--	--	--	--	--	--	--	--	--
NOV												
23...	--	--	--	--	--	--	--	--	--	--	--	--
DEC												
19...	--	--	--	--	--	--	--	--	--	--	--	--
JAN 1995												
11...	--	--	--	--	--	--	--	--	--	--	--	--
FEB												
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MAR												
22...	--	--	--	--	--	--	--	--	--	--	--	--
APR												
12...	--	--	--	--	--	--	--	--	--	--	--	--
MAY												
10...	--	--	--	--	--	--	--	--	--	--	--	--
JUN												
15...	--	--	--	--	--	--	--	--	--	--	--	--
JUL												
20...	--	--	--	--	--	--	--	--	--	--	--	--
AUG												
03...	--	--	--	--	--	--	--	--	--	--	--	--
16...	--	--	--	--	--	--	--	--	--	--	--	--
SEP												
06...	--	--	--	--	--	--	--	--	--	--	--	--
OCT												
18...	--	--	--	--	--	--	--	--	--	--	--	--
NOV												
30...	--	--	--	--	--	--	--	--	--	--	--	--
JAN 1996												
30...	--	--	--	--	--	--	--	--	--	--	--	--
SEP												
04...	--	--	--	--	--	--	--	--	--	--	--	--
SEP 1992												
23...	11	<50	<50	<50	<50	<50	19	<50	<50	<500	<50	<50

188

DISTRICT CODE 35 UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 6-11-97

374752105300801 - MEDANO CREEK NEAR MOSCA, CO

WATER-QUALITY DATA

DATE	9H-FLU-ORENE SED, BM WS,<2MM DW, REC (UG/KG) (49399)	ISOPHOR ONE SED, BM WS,<2MM DW, REC (UG/KG) (49400)	METHANE 2CHLORO ETHOXY SED, BM WS,<2MM DW, REC (UG/KG) (49401)	NAPHTH-ALENE, SED, BM WS,<2MM DW, REC (UG/KG) (49402)	NAPTHAL ENE, 12 DIMETHL SED, BM WS,<2MM DW, REC (UG/KG) (49403)	NAPTHAL ENE, 16 DIMETHL SED, BM WS,<2MM DW, REC (UG/KG) (49404)	NAPTHAL ENE,236 TRIMETH SED, BM WS,<2MM DW, REC (UG/KG) (49405)	NAPTHAL ENE, 26 DIMETHL SED, BM WS,<2MM DW, REC (UG/KG) (49406)	NAPTHAL ENE, 2-CHLORO- SED, BM WS,<2MM DW, REC (UG/KG) (49407)	BENZO(G HI)PERY LENE SED, BM WS,<2MM DW, REC (UG/KG) (49408)	PHENAN THRENE SED, BM WS,<2MM DW, REC (UG/KG) (49409)	PHENAN THRENE 1METHYL SED, BM WS,<2MM DW, REC (UG/KG) (49410)
OCT 1994												
17...	--	--	--	--	--	--	--	--	--	--	--	--
NOV												
23...	--	--	--	--	--	--	--	--	--	--	--	--
DEC												
19...	--	--	--	--	--	--	--	--	--	--	--	--
JAN 1995												
11...	--	--	--	--	--	--	--	--	--	--	--	--
FEB												
08...	--	--	--	--	--	--	--	--	--	--	--	--
MAR												
22...	--	--	--	--	--	--	--	--	--	--	--	--
APR												
12...	--	--	--	--	--	--	--	--	--	--	--	--
MAY												
10...	--	--	--	--	--	--	--	--	--	--	--	--
JUN												
15...	--	--	--	--	--	--	--	--	--	--	--	--
JUL												
20...	--	--	--	--	--	--	--	--	--	--	--	--
AUG												
03...	--	--	--	--	--	--	--	--	--	--	--	--
16...	--	--	--	--	--	--	--	--	--	--	--	--
SEP												
06...	--	--	--	--	--	--	--	--	--	--	--	--
OCT												
18...	--	--	--	--	--	--	--	--	--	--	--	--
NOV												
30...	--	--	--	--	--	--	--	--	--	--	--	--
JAN 1996												
30...	--	--	--	--	--	--	--	--	--	--	--	--
SEP												
04...	--	--	--	--	--	--	--	--	--	--	--	--
SEP 1992												
23...	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	7	<50

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DISTRICT CODE 35 UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 6-11-97

374752105300801 - MEDANO CREEK NEAR MOSCA, CO

WATER-QUALITY DATA

DATE	4HCYPEN PHENAN THRENE SED, BM WS,<2MM DW, REC (UG/KG) (49411)	PHENOL SED, BM WS,<2MM DW, REC (UG/KG) (49413)	3,5-XYLENOL SED, BM WS,<2MM DW, REC (UG/KG) (49421)	M-CRE-SOL, 4-CHLORO-SED, BM WS,<2MM DW, REC (UG/KG) (49422)	PHENOL C8-ALKYL-SED, BM WS,<2MM DW, REC (UG/KG) (49424)	PHTHALA TE,BIS2 ETHHEXL SED, BM WS,<2MM DW, REC (UG/KG) (49426)	PHTHALA TEBUTYL BENZYL-SED, BM WS,<2MM DW, REC (UG/KG) (49427)	ACENAPH THYLENE SED, BM WS,<2MM DW, REC (UG/KG) (49428)	ACENAPH THENE SED, BM WS,<2MM DW, REC (UG/KG) (49429)	ACRI-DINE SED, BM WS,<2MM DW, REC (UG/KG) (49430)	DPROPYL AMINE,N NITROSO SED, BM WS,<2MM DW, REC (UG/KG) (49431)
OCT 1994											
17...	--	--	--	--	--	--	--	--	--	--	--
NOV											
23...	--	--	--	--	--	--	--	--	--	--	--
DEC											
19...	--	--	--	--	--	--	--	--	--	--	--
JAN 1995											
11...	--	--	--	--	--	--	--	--	--	--	--
FEB											
08...	--	--	--	--	--	--	--	--	--	--	--
MAR											
22...	--	--	--	--	--	--	--	--	--	--	--
APR											
12...	--	--	--	--	--	--	--	--	--	--	--
MAY											
10...	--	--	--	--	--	--	--	--	--	--	--
JUN											
15...	--	--	--	--	--	--	--	--	--	--	--
JUL											
20...	--	--	--	--	--	--	--	--	--	--	--
AUG											
03...	--	--	--	--	--	--	--	--	--	--	--
16...	--	--	--	--	--	--	--	--	--	--	--
SEP											
06...	--	--	--	--	--	--	--	--	--	--	--
OCT											
18...	--	--	--	--	--	--	--	--	--	--	--
NOV											
30...	--	--	--	--	--	--	--	--	--	--	--
JAN 1996											
30...	--	--	--	--	--	--	--	--	--	--	--
SEP											
04...	--	--	--	--	--	--	--	--	--	--	--
SEP 1992											
23...	<50	7	<50	<50	<50	55	36	<50	<50	<50	<50

DISTRICT CODE 35 UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 6-11-97

374752105300801 - MEDANO CREEK NEAR MOSCA, CO

WATER-QUALITY DATA

DATE	DIPHNYL AMINE,N NITROSO SED, BM WS,<2MM DW, REC (UG/KG) (49433)	ANTHRA-CENE SED, BM WS,<2MM DW, REC (UG/KG) (49434)	ANTHRA-CENE,2-METHYL- SED, BM WS,<2MM DW, REC (UG/KG) (49435)	BENZ(A) ANTHRA-CENE SED, BM WS,<2MM DW, REC (UG/KG) (49436)	9,10-ANTHRA-QUINONE SED, BM WS,<2MM DW, REC (UG/KG) (49437)	BENZENE 124TRI-CHLORO- SED, BM WS,<2MM DW, REC (UG/KG) (49438)	BENZENE O-DI-CHLORO- SED, BM WS,<2MM DW, REC (UG/KG) (49439)	BENZENE M-DI-CHLORO- SED, BM WS,<2MM DW, REC (UG/KG) (49441)	BENZENE P-DI-CHLORO- SED, BM WS,<2MM DW, REC (UG/KG) (49442)	AZO-BENZENE SED, BM WS,<2MM DW, REC (UG/KG) (49443)	BENZENE NITRO- SED, BM WS,<2MM DW, REC (UG/KG) (49444)
OCT 1994											
17...	--	--	--	--	--	--	--	--	--	--	--
NOV											
23...	--	--	--	--	--	--	--	--	--	--	--
DEC											
19...	--	--	--	--	--	--	--	--	--	--	--
JAN 1995											
11...	--	--	--	--	--	--	--	--	--	--	--
FEB											
08...	--	--	--	--	--	--	--	--	--	--	--
MAR											
22...	--	--	--	--	--	--	--	--	--	--	--
APR											
12...	--	--	--	--	--	--	--	--	--	--	--
MAY											
10...	--	--	--	--	--	--	--	--	--	--	--
JUN											
15...	--	--	--	--	--	--	--	--	--	--	--
JUL											
20...	--	--	--	--	--	--	--	--	--	--	--
AUG											
03...	--	--	--	--	--	--	--	--	--	--	--
16...	--	--	--	--	--	--	--	--	--	--	--
SEP											
06...	--	--	--	--	--	--	--	--	--	--	--
OCT											
18...	--	--	--	--	--	--	--	--	--	--	--
NOV											
30...	--	--	--	--	--	--	--	--	--	--	--
JAN 1996											
30...	--	--	--	--	--	--	--	--	--	--	--
SEP											
04...	--	--	--	--	--	--	--	--	--	--	--
SEP 1992											
23...	<50	13	<50	<50	<50	<50	<50	<50	<50	<50	<50

DISTRICT CODE 35 UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 6-11-97

374752105300801 - MEDANO CREEK NEAR MOSCA, CO

WATER-QUALITY DATA

DATE	BENZENE PNTCHLR NITRO- SED, BM WS,<2MM DW, REC (UG/KG) (49446)	CARBA- ZOLE SED, BM WS,<2MM DW, REC (UG/KG) (49449)	CHRY- SENE SED, BM WS,<2MM DW, REC (UG/KG) (49450)	P- CRESOL SED, BM WS,<2MM DW, REC (UG/KG) (49451)	THIOPH ENE,DI- BENZO- SED, BM WS,<2MM DW, REC (UG/KG) (49452)	4-BROMO PHNPHNL ETHER SED, BM WS,<2MM DW, REC (UG/KG) (49454)	4CHLORO PHNPHN LETHER SED, BM WS,<2MM DW, REC (UG/KG) (49455)	BENZOB FLUOR- ANTHENE SED, BM WS,<2MM DW, REC (UG/KG) (49458)	PCB, SED, BM WS,<2MM DW, REC (UG/KG) (49459)	PENTA- CHLORO- ANISOLE SED, BM WS,<2MM DW, REC (UG/KG) (49460)	DIBENZ (AH),AN THRACEN SED, BM WS,<2MM DW, REC (UG/KG) (49461)
OCT 1994											
17...	--	--	--	--	--	--	--	--	--	--	--
NOV											
23...	--	--	--	--	--	--	--	--	--	--	--
DEC											
19...	--	--	--	--	--	--	--	--	--	--	--
JAN 1995											
11...	--	--	--	--	--	--	--	--	--	--	--
FEB											
08...	--	--	--	--	--	--	--	--	--	--	--
MAR											
22...	--	--	--	--	--	--	--	--	--	--	--
APR											
12...	--	--	--	--	--	--	--	--	--	--	--
MAY											
10...	--	--	--	--	--	--	--	--	--	--	--
JUN											
15...	--	--	--	--	--	--	--	--	--	--	--
JUL											
20...	--	--	--	--	--	--	--	--	--	--	--
AUG											
03...	--	--	--	--	--	--	--	--	--	--	--
16...	--	--	--	--	--	--	--	--	--	--	--
SEP											
06...	--	--	--	--	--	--	--	--	--	--	--
OCT											
18...	--	--	--	--	--	--	--	--	--	--	--
NOV											
30...	--	--	--	--	--	--	--	--	--	--	--
JAN 1996											
30...	--	--	--	--	--	--	--	--	--	--	--
SEP											
04...	--	--	--	--	--	--	--	--	--	--	--
SEP 1992											
23...	<50	<50	<50	<50	<50	<50	<50	<50	<100	<1.0	<50

DISTRICT CODE 35 UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 6-11-97

374752105300801 - NEDANO CREEK NEAR MOSCA, CO

WATER-QUALITY DATA

DATE	FLUOR-ANTHENE BED MAT WS <2MM DRY WGT REC (UG/KG) (49466)	PHENOL, 2CHLORO BED MAT WS <2MM DRY WGT REC (UG/KG) (49467)	BENZOCI NNOLINE BED MAT WS <2MM DRY WGT REC (UG/KG) (49468)	MOVE VALUES TO PCODE 49948 (49490)	SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (MG/L) (70300)	SOLIDS, SUM OF CONSTI-TUENTS, DIS-SOLVED (MG/L) (70301)	MERCURY DIS-SOLVED (UG/L AS HG) (71890)	MERCURY TOTAL RECOV-ERABLE (UG/L AS HG) (71900)	SAMPLE PURPOSE CODE (71999)	ELEV. OF LAND SURFACE DATUM (FT. ABOVE NGVD) (72000)	SEDI-MENT, SUS-PENDED (MG/L) (80154)
OCT 1994											
17...	--	--	--	--	47	55	--	--	15.0	8450	4
NOV											
23...	--	--	--	--	57	63	--	--	15.0	8450	15
DEC											
19...	--	--	--	--	65	61	--	--	15.0	8450	11
JAN 1995											
11...	--	--	--	--	64	62	--	--	15.0	8450	9
FEB											
08...	--	--	--	--	70	61	--	--	15.0	8450	8
MAR											
22...	--	--	--	--	56	50	--	--	15.0	8450	19
APR											
12...	--	--	--	--	53	47	--	--	15.0	8450	53
MAY											
10...	--	--	--	--	68	48	--	<0.10	15.0	8450	9
JUN											
15...	--	--	--	--	41	31	--	--	15.0	8450	618
JUL											
20...	--	--	--	--	44	37	--	--	15.0	8450	88
AUG											
03...	--	--	--	--	--	--	--	--	--	8450	--
16...	--	--	--	--	48	49	<0.1	--	15.0	8450	5
SEP											
06...	--	--	--	--	59	55	--	--	15.0	8450	17
OCT											
18...	--	--	--	--	55	61	--	--	15.0	8450	10
NOV											
30...	--	--	--	--	57	63	--	--	15.0	8450	9
JAN 1996											
30...	--	--	--	--	65	62	--	--	15.0	8450	14
SEP											
04...	--	--	--	--	55	55	--	--	15.0	8450	32
SEP 1992											
23...	14	<50	<50	<50	--	--	--	--	--	8450	--

193

DISTRICT CODE 35 UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 6-11-97

374752105300801 - MEDANO CREEK NEAR MOSCA, CO

WATER-QUALITY DATA

DATE	BED MAT. SIEVE DIAM. % FINER THAN .062 MM (80164)	BED MAT. SIEVE DIAM. % FINER THAN .125 MM (80165)	DRAIN-AGE AREA (SQ. MI.) (81024)	SAM-PLING METHOD. CODES (82398)	METRI-BUZIN SENCOR WATER DISSOLV (UG/L) (82630)	2,6-DI-ETHYL ANILINE WAT FLT 0.7 U GF, REC (UG/L) (82660)	TRI-FLUR-ALIN WAT FLT 0.7 U GF, REC (UG/L) (82661)	ETHAL-FLUR-ALIN WAT FLT 0.7 U GF, REC (UG/L) (82663)	PHORATE WATER FLTRD 0.7 U GF, REC (UG/L) (82664)	TER-BACIL WATER FLTRD 0.7 U GF, REC (UG/L) (82665)	LIN-URON WATER FLTRD 0.7 U GF, REC (UG/L) (82666)
OCT 1994											
17...	--	--	15.0	10	--	--	--	--	--	--	--
NOV											
23...	--	--	15.0	70	--	--	--	--	--	--	--
DEC											
19...	--	--	15.0	70	--	--	--	--	--	--	--
JAN 1995											
11...	--	--	15.0	70	--	--	--	--	--	--	--
FEB											
08...	--	--	15.0	70	--	--	--	--	--	--	--
MAR											
22...	--	--	15.0	10	--	--	--	--	--	--	--
APR											
12...	--	--	15.0	10	--	--	--	--	--	--	--
MAY											
10...	--	--	15.0	10	--	--	--	--	--	--	--
JUN											
15...	--	--	15.0	10	<0.004	<0.003	<0.002	<0.004	<0.002	<0.007	<0.002
JUL											
20...	--	--	15.0	10	<0.004	<0.003	<0.002	<0.004	<0.002	<0.007	<0.002
AUG											
03...	--	--	15.0	--	--	--	--	--	--	--	--
16...	--	--	15.0	70	<0.004	<0.003	<0.002	<0.004	<0.002	<0.007	<0.002
SEP											
06...	--	--	15.0	10	<0.004	<0.003	<0.002	<0.004	<0.002	<0.007	<0.002
OCT											
18...	--	--	15.0	70	--	--	--	--	--	--	--
NOV											
30...	--	--	15.0	10	--	--	--	--	--	--	--
JAN 1996											
30...	--	--	15.0	70	--	--	--	--	--	--	--
SEP											
04...	--	--	15.0	70	<0.004	<0.003	<0.002	<0.004	<0.002	<0.007	<0.002
SEP 1992											
23...	3	100	15.0	--	--	--	--	--	--	--	--

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DISTRICT CODE 35 UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 6-11-97

374752105380801 - MEDANO CREEK NEAR MOSCA, CO

WATER-QUALITY DATA

DATE	METHYL PARA-THION WAT FLT 0.7 U GF, REC (UG/L) (82667)	EPTC WATER FLTRD 0.7 U GF, REC (UG/L) (82668)	PEB-ULATE WATER FILTRD 0.7 U GF, REC (UG/L) (82669)	TEBU-THIURON WATER FLTRD 0.7 U GF, REC (UG/L) (82670)	MOL-INATE WATER FLTRD 0.7 U GF, REC (UG/L) (82671)	ETHO-PROP WATER FLTRD 0.7 U GF, REC (UG/L) (82672)	BEN-FLUR-ALIN WAT FLD 0.7 U GF, REC (UG/L) (82673)	CARBO-FURAN WATER FLTRD 0.7 U GF, REC (UG/L) (82674)	TER-BUFOS WATER FLTRD 0.7 U GF, REC (UG/L) (82675)	PRON-AMIDE WATER FLTRD 0.7 U GF, REC (UG/L) (82676)	DISUL-FOTON WATER FLTRD 0.7 U GF, REC (UG/L) (82677)
OCT 1994											
17...	--	--	--	--	--	--	--	--	--	--	--
NOV											
23...	--	--	--	--	--	--	--	--	--	--	--
DEC											
19...	--	--	--	--	--	--	--	--	--	--	--
JAN 1995											
11...	--	--	--	--	--	--	--	--	--	--	--
FEB											
08...	--	--	--	--	--	--	--	--	--	--	--
MAR											
22...	--	--	--	--	--	--	--	--	--	--	--
APR											
12...	--	--	--	--	--	--	--	--	--	--	--
MAY											
10...	--	--	--	--	--	--	--	--	--	--	--
JUN											
15...	<0.006	<0.002	<0.004	<0.010	<0.004	<0.003	<0.002	<0.003	<0.013	<0.003	<0.017
JUL											
20...	<0.006	<0.002	<0.004	<0.010	<0.004	<0.003	<0.002	<0.003	<0.013	<0.003	<0.017
AUG											
03...	--	--	--	--	--	--	--	--	--	--	--
16...	<0.006	<0.002	<0.004	<0.010	<0.004	<0.003	<0.002	<0.003	<0.013	<0.003	<0.017
SEP											
06...	<0.006	<0.002	<0.004	<0.010	<0.004	<0.003	<0.002	<0.003	<0.013	<0.003	<0.017
OCT											
18...	--	--	--	--	--	--	--	--	--	--	--
NOV											
30...	--	--	--	--	--	--	--	--	--	--	--
JAN 1996											
30...	--	--	--	--	--	--	--	--	--	--	--
SEP											
04...	<0.006	<0.002	<0.004	<0.010	<0.004	<0.003	<0.002	<0.003	<0.013	<0.003	<0.017
SEP 1992											
23...	--	--	--	--	--	--	--	--	--	--	--

DISTRICT CODE 35 UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 6-11-97

374752105300801 - MEDANO CREEK NEAR MOSCA, CO

WATER-QUALITY DATA

DATE	TRIAL-LATE WATER FLTRD 0.7 U GF, REC (UG/L) (82678)	PRO-PANIL WATER FLTRD 0.7 U GF, REC (UG/L) (82679)	CAR-BARYL WATER FLTRD 0.7 U GF, REC (UG/L) (82680)	THIO-BENCARB WATER FLTRD 0.7 U GF, REC (UG/L) (82681)	DCPA WATER FLTRD 0.7 U GF, REC (UG/L) (82682)	PENDI-METH-ALIN WAT FLT 0.7 U GF, REC (UG/L) (82683)	NAPROP-AMIDE WATER FLTRD 0.7 U GF, REC (UG/L) (82684)	PRO-PARGITE WATER FLTRD 0.7 U GF, REC (UG/L) (82685)	METHYL AZIN-PHOS WAT FLT 0.7 U GF, REC (UG/L) (82686)	PER-METHRIN CIS WAT FLT 0.7 U GF, REC (UG/L) (82687)	SAMPLER TYPE (CODE) (84164)
OCT 1994											
17...	--	--	--	--	--	--	--	--	--	--	3050
NOV											
23...	--	--	--	--	--	--	--	--	--	--	8010
DEC											
19...	--	--	--	--	--	--	--	--	--	--	3050
JAN 1995											
11...	--	--	--	--	--	--	--	--	--	--	8010
FEB											
08...	--	--	--	--	--	--	--	--	--	--	8010
MAR											
22...	--	--	--	--	--	--	--	--	--	--	3050
APR											
12...	--	--	--	--	--	--	--	--	--	--	3050
MAY											
10...	--	--	--	--	--	--	--	--	--	--	3050
JUN											
15...	<0.001	<0.004	<0.003	<0.002	<0.002	<0.004	<0.003	<0.013	<0.001	<0.005	3050
JUL											
20...	<0.001	<0.004	<0.003	<0.002	<0.002	<0.004	<0.003	<0.013	<0.001	<0.005	3050
AUG											
03...	--	--	--	--	--	--	--	--	--	--	--
16...	<0.001	<0.004	<0.003	<0.002	<0.002	<0.004	<0.003	<0.013	<0.001	<0.005	8010
SEP											
06...	<0.001	<0.004	<0.003	<0.002	<0.002	<0.004	<0.003	<0.013	<0.001	<0.005	3050
OCT											
18...	--	--	--	--	--	--	--	--	--	--	3070
NOV											
30...	--	--	--	--	--	--	--	--	--	--	3070
JAN 1996											
30...	--	--	--	--	--	--	--	--	--	--	3070
SEP											
04...	<0.001	<0.004	<0.003	<0.002	<0.002	<0.004	<0.003	<0.013	<0.001	<0.005	3070
SEP 1992											
23...	--	--	--	--	--	--	--	--	--	--	--

374752105300801 - NEDANO CREEK NEAR MOSCA, CO

WATER-QUALITY DATA

DATE	SPE-CIFIC CON-DUCT-ANCE LAB (US/CM) (90095)	ALKA-LINITY LAB (MG/L AS CACO3) (90410)	DIAZ-INON D10 SRG WAT FLT 0.7 U GF, REC PERCENT (91063)	TERBUTH YLAZINE SURROGT WAT FLT 0.7 U GF, REC PERCENT (91064)	HCH ALPHA D6 SRG WAT FLT 0.7 U GF, REC PERCENT (91065)	SET NUMBER SCHED-ULE 2001 (NO.) (99818)	SET NUMBER SCHED-ULE 2502 (NO.) (99825)	ANALYT REFRNCE NUMBER SCHED-ULE 2501 (NO.) (99850)	SAMPLE WEIGHT SCHED-ULE 2501 (GRAMS) (99853)	SAMPLE VOLUME SCHED-ULE 2001 (ML) (99856)	CALL USGS LAB FOR EXPLA-NATION OF CODE 99870 (99870)
OCT 1994											
17...	98	41	--	--	--	--	--	--	--	--	--
NOV											
23...	103	47	--	--	--	--	--	--	--	--	--
DEC											
19...	101	46	--	--	--	--	--	--	--	--	--
JAN 1995											
11...	103	47	--	--	--	--	--	--	--	--	--
FEB											
08...	106	48	--	--	--	--	--	--	--	--	--
MAR											
22...	79	35	--	--	--	--	--	--	--	--	--
APR											
12...	77	34	--	--	--	--	--	--	--	--	--
MAY											
10...	74	32	--	--	--	--	--	--	--	--	140
JUN											
15...	47	19	110	100	82	2130	--	--	--	847	--
JUL											
20...	56	25	130	100	130	2300	--	--	--	917	--
AUG											
03...	--	--	--	--	--	--	--	--	--	--	--
16...	75	34	77	98	78	2471	--	--	--	<950	--
SEP											
06...	84	39	130	120	110	2568	--	--	--	917	--
OCT											
18...	101	46	--	--	--	--	--	--	--	--	--
NOV											
30...	105	48	--	--	--	--	--	--	--	--	--
JAN 1996											
30...	110	49	--	--	--	--	--	--	--	--	--
SEP											
04...	93	44	88.5	111	83.5	3562	--	--	--	707	--
SEP 1992											
23...	--	--	--	--	--	--	<0.00	<0.00	<0.00	--	--