

VIII. WIND CAVE NATIONAL PARK

A. DESCRIPTION

Wind Cave National Park (WICA) is located in the Black Hills region in southwestern South Dakota. The park was established in 1903 to protect and manage a nationally significant cave resource. In 1912, Wind Cave National Game Preserve was superimposed on the surface of the park to provide permanent range for bison and other native animals. Management of the national park and game preserve was consolidated under the National Park Service in 1935.

WICA is 11,454 ha in area, of which 3.5% is developed. Lands south and east of the park are mainly used for dry-land ranching. Custer State Park comprises the northern boundary of the park while Black Hills National Forest lies to the west.

The remarkable cave systems located in WICA include the third longest limestone cave in the United States. The first recorded discovery of the cave was in 1881. The name "Wind Cave" refers to the strong winds which frequently blow through the entrance of the cave. The caves contain a diversity of geological formations which are valuable for both their rarity and beauty. The protection and interpretation of cave resources is the primary management objective of the park. In contrast, the surface resources include a diversity of flora and fauna that are mostly distinct from the caves. Aboveground ecosystems are managed primarily for maintenance of conditions that approximate those of pre-European settlement. The relatively small size of the park, boundary fences, and proximity to lands with contrasting management objectives provide a challenging situation for management of park resources. In 1991 annual park visitation totaled 100,000 for the cave and 1.1 million for the surface (WICA 1994).

1. Geology and Soils

The Black Hills, which constitute the easternmost extension of the Rocky Mountains, are an isolated and unglaciated group of mountains that rise above the surrounding Plains. WICA is located in the southeastern portion of the Black Hills and contains a diversity of geological materials. The oldest geological formation is a small portion of the core of the central Black Hills, consisting of Precambrian metamorphic (schists, slates, and quartzites) and igneous (granite and pegmatite) rocks (Darton 1951). All other materials are of sedimentary origin, including Mesozoic sandstones and shales of the Sundance and Spearfish formations; Paleozoic limestones, sandstones, and shales of the Minnekahta limestone/Opeche, Minnelusa sandstone, Pahasapa limestone/Englewood limestone, and Deadwood formations; and Cenozoic clays and gravels of the White River group.

WICA contains a diversity of soils associated with different topographic features and vegetation. Nearly all the soils are well-drained and many are skeletal with intermittent rock outcrops. Entisols dominate the shallowest soil profiles, Inceptisols and Alfisols dominate the forested sites, and Inceptisols and Mollisols dominate the mixed-grass prairies. The red hues of most of the well-drained soils in the region indicate that the soils of this region are highly weathered.

2. Climate

The park ranges from 1,110 to 1,528 m elevation. Climate is typical of the northern Plains region with generally moderate average temperatures, but with extreme summer and winter temperatures (>35°C and <-15°C) common in most years. Most precipitation occurs during late spring and during frequent summer thunderstorms. Winter precipitation commonly falls as snow but contributes only a small fraction of the annual precipitation of 40 cm.

Wind rose data from WICA during the period 1989 through 1992 show that the predominant wind direction is from the northwest. These winds tend to predominate between November and April (Weber 1982). A second frequent wind direction is from the east, which tends to occur between May and October.

3. Biota

The vegetation of WICA can be roughly divided into three components: (1) mixed-grass prairies (approx. 75%), (2) ponderosa pine woodlands (approx. 20%), and (3) deciduous forest complex (including "woody draws") (approx. 5%) that dominates riparian areas. Forested and

grassland areas are indicated in a general map of the park (Figure VIII-1).

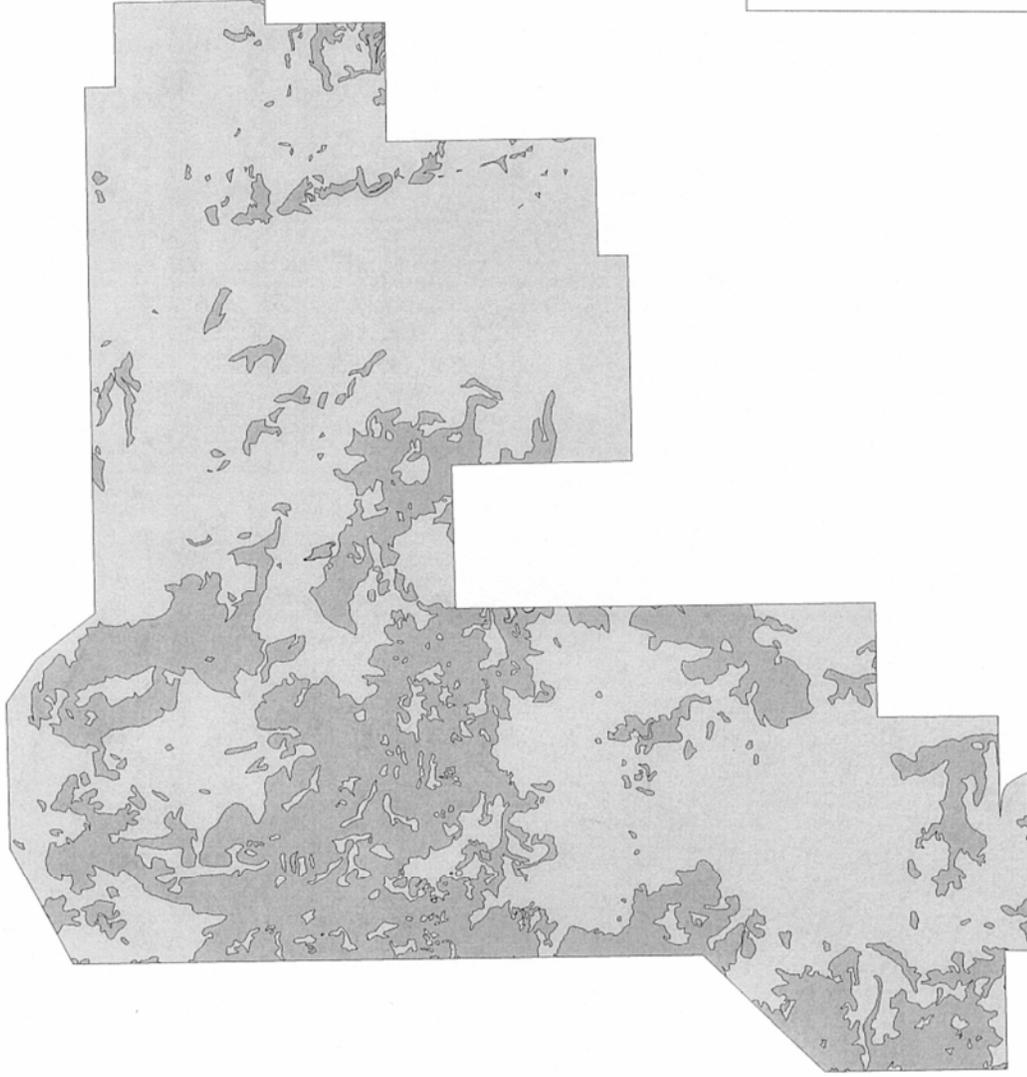
A diversity of grass species, often mixed with forbs, dominate areas with low soil moisture, especially south-facing sites and thin, rocky, soils (Froiland and Weedon 1990). Some of the representative species include little bluestem (*Andropogon scoparius*), blue grama (*Bouteloua gracilis*), buffalo grass (*Buchloe dactyloides*), Japanese cress (*Bromus japonicus*), Western wheatgrass (*Agropyron smithii*), prairie junegrass (*Koeleria pyramidata*), pasture sage (*Artemisia frigida*), and prickly pear (*Opuntia* spp.). The presence of grasslands is facilitated by fire which kills encroaching woody vegetation. Grasslands in WICA provide critical forage for native ungulates and many other animals.

Ponderosa pine woodlands (*Pinus ponderosa*) contain a mix of subdominant shrubs, forbs, and grasses depending on local soil moisture and stand density. Ponderosa pine in WICA is generally found on north and east slopes, ridges and higher elevations, and sites with more soil moisture than those dominated by grasslands. Age, stem density, and basal area of the pines vary widely as a function of site history, including human disturbance and fire occurrence. Most of the pines are in younger age classes (<100 years) because of extensive cutting prior to creation of the park, although there are a few trees up to about 300 years old.

The deciduous woodland complex occurs primarily along and adjacent to riparian areas of the park (Magruder 1985). These areas maintain higher soil moisture in drainages which have surface

Wind Caves National Park Land Cover

Forests
Forest- Ponderosa Pine
Grassland



Locational Map

South Dakota
Park



water (often transient). Referred to locally as woody draws, they intersect drier adjacent sites dominated by grasses. Dominant species of deciduous woodland include plains cottonwood (*Populus deltoides*), bur oak (*Quercus marocarpa*), paper birch (*Betula papyrifera*), box elder (*Acer negundo*), American elm (*Ulmus americanus*), green ash (*Fraxinus pennsylvanica*), Bebb willow (*Salix bebbiana*) chokecherry (*Prunus virginiana*), western snowberry (*Symphoricarpos mollis*), and skunkbush sumac (*Rhus trilobata*).

The primary natural disturbance in WICA is fire, which can spread rapidly during the summer when fuel moistures are low, winds are high, and a lightning ignition source is available. Fire frequency was higher prior to the 20th century due to both natural and human ignitions in the area; grasslands may have burned every 6-7 years and forests every 15-25 years (Weaver 1967). While current policy is to suppress all unplanned ignitions, prescribed fire is being successfully used at WICA to reduce hazard fuels and stem densities in ponderosa pine stands.

By the time of the creation of WICA, both bison (*Bison bison*) and elk (*Cervus elaphus*) had been extirpated from the Black Hills region. Bison, elk, and pronghorn (*Antilocapra americana*) were subsequently introduced from other locations. Bison are managed essentially as an island population because a fence prevents their movement from the park to adjacent lands. There are many smaller mammal species in the park, including black-tailed prairie dogs (*Cynomys ludovicianus*). Although the NPFauna database records the presence of many bird species and several reptile and amphibian species, there is little ecological information on them.

4. Aquatic Resources

Although there is little information on the hydrology of WICA, historical accounts indicate that surface water was more prevalent during the early part of the 20th century. Streams in and around the park have been impacted by water withdrawals and stream modification. Subsurface water movement in WICA is poorly understood. It is likely that the main parking lot and administrative developments in the park are having impacts on subsurface hydrology and potential water transport into the caves.

The magnificent geological formations contained in the caves of WICA have been created primarily through groundwater hydrological processes. In other words, they are affected by "bottom-up" water movement rather than "top-down" flow from the surface. As a result, air pollution sources such as acidic deposition have no real impact on cave resources. Despite their importance to overall park management, the caves are not relevant to this discussion of air quality.

B. EMISSIONS

The human population of South Dakota is small, and there are no major metropolitan areas. Ranching and farming are major industries (Weber 1982). South Dakota generally has lower emissions of SO₂, NO_x and VOCs than other Rocky Mountain and northern Great Plains states and emissions of criteria pollutants in the immediate vicinity of WICA are relatively low. The closest urban area to WICA is Rapid City, where there is light industry. The city lies in a valley where pollution can remain trapped for several days during inversions. Rapid City is the only urban area in South Dakota that does not meet EPA standards for particulates. Coal-fired power plants in southeastern Wyoming, upwind of WICA, may pose a potential threat to air quality in the Black Hills Area.

Local pollution comes from a variety of sources: (1) the sawmills in the Pringle and Custer areas, (2) a rock crushing mill and quarry at Hot Springs, (3) a feldspar mill in Custer, and (4) vehicles and home wood stoves in the Hot Springs area (WICA 1993). While small quantities of emissions from these sources and from Rapid City may reach WICA, of greater importance are regional-scale sources located to the west of WICA. Annual emissions of NO_x in Wyoming are particularly high, and although VOCs are relatively low, they may influence the airshed of WICA as well. Prevailing westerly winds transport NO_x, SO₂, and VOCs eastward over the Black Hills region and WICA, providing precursors for ozone formation during the summer when it is sunny and warm. The development of additional coal-fired power plants in eastern Wyoming would increase emissions

transported to WICA.

A summary of statewide emissions of NO_x, SO₂, and VOC for 1994 is listed in Tables II-2, II-3 and II-4. Coal-burning power plants are major emission sources of SO₂ and NO_x in South Dakota. However, they are mostly located downwind and remote from WICA in the far eastern portion of the state. The one exception is Black Hills Power & Light located approximately 90 km north of WICA.

Historically, fires, and therefore smoke, have been a part of the Great Plains ecosystem. Fires are generally not considered to be a significant long term source of pollutants but they can result in episodic degraded visibility and high particulate matter concentrations.

C. MONITORING AND RESEARCH ACTIVITIES

1. Air Quality

a. Wet Deposition

WICA has no NADP site, so the NADP/NTN site at Cottonwood, SD (130 km northeast of WICA) is used to represent wet deposition at WICA. Wetfall chemistry data are available for this location since 1983. The data indicate no particular trends during this period of time (Table VIII-1). Hydrogen ion (acidic) inputs are relatively low, which suggests that the acidity of wet deposition is not a concern in this area. Ionic deposition of N and S are considerably higher than that of other elements.

Table VIII-1. Wetfall chemistry at the NADP/NTN site near WICA. Units are in $\mu\text{eq/L}$, except precipitation (cm) and H^+ (pH).

Year	Precip	H^+	SO_4^{2-}	NH_4^+	NO_3^-	Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-
1995	47.6	5.6	12.2	16.8	15.9	8.2	1.4	2.1	0.5	1.7
1994	38.2	6.3	16.9	23.6	18.7	11.1	2.0	2.1	0.7	2.0
1993	58.9	3.0	16.1	22.1	16.5	8.8	1.8	2.6	0.8	2.0
1992	53.3	6.3	18.2	20.6	15.1	6.6	1.1	1.7	0.5	1.6
1991	62.7	2.7	13.7	19.1	14.5	11.1	1.8	2.1	0.6	2.7
1990	29.1	4.4	16.0	22.5	18.8	8.7	1.8	2.8	0.5	3.0
1989	29.4	3.7	16.3	18.7	16.8	10.4	2.0	2.7	0.6	2.5
1988	36.1	4.6	12.9	5.5	11.1	8.6	1.4	2.5	0.5	1.4
1987	31.7	4.6	17.6	23.6	17.7	7.4	1.8	2.7	0.7	2.2
1986	56.4	5.9	17.9	12.6	15.7	12.5	2.2	2.3	0.9	1.9
1985	26.3	3.5	18.4	17.5	17.2	14.2	3.5	2.6	1.4	3.2
1984	41.7	1.9	20.5	22.6	17.7	14.4	4.2	3.7	1.0	3.0
Average	42.6	4.4	16.4	18.8	16.3	10.2	2.1	2.5	0.7	2.3

Sulfate deposition is moderately high due to geological sources of this ion. Despite these relatively high ionic concentrations of sulfate, wet deposition of S averages only 1.1 kg/ha/yr, which is quite low (Table VIII-2). This is because precipitation volumes are low. Total inorganic nitrogen deposition is only 2.0 kg/ha/yr, with approximately equal contributions from nitrate and ammonium. The values for S and N deposition, in combination with wetfall input of hydrogen and other ions, indicate that WICA is a relatively clean site and that there is no apparent threat from acidic deposition at the present time.

Table VIII-2. Wet deposition (kg/ha/yr) of sulfur and nitrogen at the NADP/NTN site near WICA.

Date	Sulfur	$\text{NO}_3\text{-N}$	$\text{NH}_4\text{-N}$	Total Inorganic N
1995	0.9	1.1	1.1	2.2
1994	1.0	1.0	1.3	2.3
1993	1.5	1.4	1.8	3.2
1992	1.6	1.1	1.5	2.7
1991	1.4	1.3	1.7	3.0
1990	0.8	0.8	0.9	1.7
1989	0.8	0.7	0.8	1.5
1988	0.8	0.6	0.3	0.8
1987	0.9	0.8	1.1	1.8
1986	1.6	1.2	1.0	2.2
1985	0.8	0.6	0.6	1.3
1984	1.4	1.0	1.3	2.4
Average	1.1	1.0	1.1	2.1

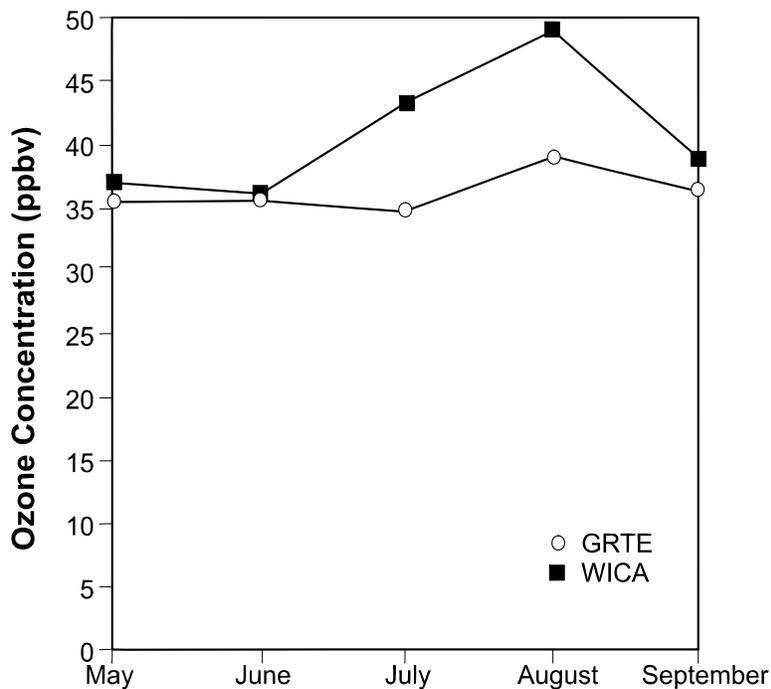
b. Occult/Dry Deposition

There are no dry deposition data available in the vicinity of WICA. Dry deposition is not expected to have a major impact on natural resources in the park.

c. Gaseous Monitoring

Air quality monitoring has been, and continues to be, limited in WICA (Table II-5). Most historical monitoring done in the park was short term or seasonal. The state of South Dakota also does not currently monitor gaseous pollutants. The South Dakota Department of Environment and Natural Resources currently monitors only PM-10. Since 1975, gaseous monitoring had been conducted using SO₂/NO₂ bubblers sampling every sixth day (because levels did not warrant continuous operation). Measured levels of SO₂ rarely exceeded the threshold limit of the instruments. The network was reduced in 1985, with all sites being eliminated as of December 1986. The data are on file with the South Dakota Air Monitoring Program.

Gaseous monitoring in the park has been limited to the use of passive ozone samplers. The samplers were deployed during the summer of 1995, 1996 and 1997 by NPS-ARD. Results of this study are summarized in Figure VIII-2. Weekly average values ranged between 36 and 50 ppbv.



Passive samplers were also deployed in GRTE at the same time, and concentrations in GRTE were

Figure VIII-2. Weekly average ozone concentration, based on passive ozone sampler data from WICA. Data from GRTE is provided for comparison.

found to be slightly lower or equal to those found in WICA during the summer of 1995. These relatively low values suggest that WICA will have minimal impacts on vegetation from ozone, although it is possible that the park could be subjected to regionally elevated ozone concentrations during warm weather and atmospheric inversions.

2. Water Quality

Surface waters are expected to be well-buffered against acid inputs. EPA's STORET data base contains 1,971 pH measurements for southwestern South Dakota, in an area that includes WICA. Only one measurement showed pH less than 6.1, having a reported pH of 1.5, and it was either due to an error or to direct acid discharge (e.g., acid mine drainage). The first pH percentile was 6.6. In other words, 99% of the measured values were higher than pH 6.6. Similarly, 99% of the calcium measurements (n=236) were higher than 10 mg/L (500 µeq/L). Surface water SO₄²⁻ concentrations tended to be very high due to geological sources of SO₄²⁻. The median SO₄²⁻ concentration (n=77) in the data set was 88 mg/L (1,800 µeq/L). There is no evidence to suggest that surface waters in WICA would be responsive to acidic deposition impacts or that aquatic biota would be affected.

3. Terrestrial

No studies have been performed to date on the effects of air pollutants on the terrestrial resources of WICA. There have been no surveys for endangered, threatened or rare plants. There are also no vegetation status records or maps available for determining what changes may have occurred in species composition (WICA 1994). Much of the focus on resource management in the park relates to wildlife and cave resources. Park management acknowledges that there is a need for periodic monitoring and a need to remain apprised of any new industrial activities in the area.

D. AIR QUALITY RELATED VALUES

1. Vegetation

Current emissions of SO₂, NO_x and VOC may not pose an immediate threat to resources in WICA, but increased industrial activities will possibly bring changes in air quality. Vegetation is the resource which is most sensitive to ozone and SO₂ (based on current knowledge of ozone- and SO₂-sensitive organisms) and several tree species have been identified as potential bioindicators (see below). Additional studies would be needed to further evaluate the potential impact of SO₂ and ozone on terrestrial ecosystems in WICA. Furthermore, baseline data on the condition of sensitive species in the absence of injurious pollutants will be helpful for comparison if pollutant levels increase. Monitoring bioindicators by using detailed descriptions and classifications of sensitive indicators (characteristics of leaf or plant injury) will be necessary for long-term evaluation of ecosystem health.

Ponderosa pine is common in WICA. It is the dominant tree throughout the park and

encroaches into grasslands and riparian areas. Ponderosa pine is one of the most ozone-sensitive Western tree species (especially var. *ponderosa*), for which extensive data are available on field (Miller and Millecan 1971, Pronos and Vogler 1981, Peterson and Arbaugh 1988) and experimental (Temple et al. 1992) exposures. The evidence for ozone impacts on ponderosa pine is based on observable symptoms of foliar chlorosis and reduced growth (Peterson et al. 1991, Peterson and Arbaugh 1992) as well as physiological (Darrall 1989, Bytnerowicz and Grulke 1992) data. The cause-and-effect relationship, especially for trees growing in forests of southern California and the southern Sierra Nevada, is clear and quantifiable. The Rocky Mountain variety of ponderosa pine (var. *scopulorum*) is known to be somewhat more tolerant to ozone and has a higher threshold for symptoms of injury under experimental exposures than var. *ponderosa* (Aitken et al. 1984).

Of the hardwood species present at WICA, quaking aspen (*Populus tremuloides*) is the most sensitive to ozone and is a potential secondary sensitive receptor after ponderosa pine. Aspen grows in isolated pockets in riparian areas and other high soil-moisture areas in the park. Numerous studies have documented the sensitivity of this species to ozone under field and experimental conditions (Wang et al. 1986, Karnosky et al. 1992, Coleman et al. 1996), although there is considerable variability in sensitivity among different genotypes (Berrang et al. 1986). Diagnostic ozone symptomatology for aspen includes chlorosis, stippling, necrotic spotting, and leaf margin burn. Symptoms generally vary seasonally, with stippling being most prominent in the spring and black, bifacial (both leaf surfaces) necrosis appearing in late summer (J.P. Bennett, pers. comm.). Great care must be taken in distinguishing ozone symptoms from various pathogens and insect herbivores commonly found on this species.

Aspen is also considered to be sensitive to SO₂ and may be the best bioindicator for this gaseous pollutant. Injury is similar to that normally found for ozone (stippling, followed by bifacial necrosis), although SO₂-induced injury rapidly bleaches to a light tan color (ozone injury remains dark) (Karnosky 1976). There could be some confusion of ozone injury and SO₂ injury.

Chokecherry, which is common in WICA and highly sensitive to ozone, is another potential bioindicator for ozone. Paper birch, which is common in WICA and highly sensitive to SO₂, is another potential bioindicator for SO₂.

An inventory of vascular plants found in WICA is available in the NPFlora database. Table VIII-3 summarizes vascular plant species of WICA with known sensitivity to ozone, SO₂, and NO_x. This table is based on a variety of sources from the published literature and other information. It should be noted that the various sources used a wide range of field and experimental approaches to determine pollutant pathology, and that sensitivity ratings are general estimates based on published

Table VIII-3. Plant species of WICA with known sensitivities to SO₂, ozone, and NO_x. L = low, M = medium, H = high, none = unknown. (Sources: Esserlieu and Olson 1986, Bunin 1990, Peterson et al. 1993, National Park Service 1994, Electric Power Research Institute 1995, Binkley et al. 1996)

Species Name	SO ₂ Sensitivity	O ₃ Sensitivity	NO _x Sensitivity
<i>Acer negundo</i>	M	M	
<i>Achillea millefolium</i>		L	
<i>Agoseris glauca</i>	M		
<i>Agropyron smithii</i>	M		
<i>Ambrosia psilostachya</i>		L	
<i>Amelanchier alnifolia</i>	H	M	
<i>Arctostaphylos uva-ursi</i>	L	L	
<i>Artemisia ludoviciana</i>	M		
<i>Betula papyrifera</i>	H		
<i>Bouteloua gracilis</i>	L		
<i>Bromus tectorum</i>	L	M	
<i>Cercocarpus montanus</i>	M		
<i>Cirsium arvense</i>		L	
<i>Cirsium undulatum</i>	M		
<i>Collomia linearis</i>		L	
<i>Convolvulus arvensis</i>	H		
<i>Crataegus chrysoarpa</i>	L		
<i>Fragaria virginiana</i>		H	
<i>Fraxinus pennsylvanica</i>	M	H	
<i>Geranium richardsonii</i>	M	M	
<i>Helianthus annuus</i>	H	L	
<i>Helianthus maximiliana</i>	H		
<i>Juniperus scopulorum</i>	L		
<i>Koeleria nitida</i>	H		
<i>Oryzopsis hymenoides</i>	M		
<i>Pinus ponderosa</i>	M	H	H
<i>Poa pratensis</i>	H	M	
<i>Populus angustifolia</i>	M		
<i>Populus deltoides</i>	M	L	
<i>Populus tremuloides</i>	H	H	
<i>Prunus virginiana</i>	M	H	
<i>Quercus macrocarpa</i>		L	
<i>Rosa woodsii</i>	M	L	
<i>Rubus idaeus</i>	H		
<i>Rumex crispus</i>		L	
<i>Shepherdia canadensis</i>	L		
<i>Solidago canadensis</i>	H	L	
<i>Solidago rigida</i>	H		
<i>Stipa comata</i>	L		
<i>Taraxacum officinale</i>		L	
<i>Tragopogon dubius</i>	M		
<i>Ulmus americana</i>	M		
<i>Urtica gracilis</i>		L	
<i>Vicia americana</i>		L	
<i>Yucca glauca</i>	L		

Table VIII-4. Lichen species of WICA with known sensitivities to SO ₂ and ozone. L = low, M = medium, H = high, none = unknown. (Sources: Peterson et al. 1993, Electric Power Research Institute 1995, Binkley et al. 1996)		
Species	SO ₂ sensitivity	Ozone sensitivity
<i>Candelaria concolor</i>	M-H	
<i>Candelariella vitellina</i>	M	
<i>Cladonia chlorophaea</i>	M	
<i>Cladonia coniocraea</i>	M	
<i>Parmelia sulcata</i>	L-H	M-H
<i>Peltigera canina</i>	L	H
<i>Physcia aipolia</i>	M	
<i>Physcia caesia</i>	M	
<i>Physcia dubia</i>	L	
<i>Physcia stellaris</i>	M	
<i>Platismatia glauca</i>	M	H
<i>Usnea hirta</i>	M-H	

information and our expert opinion. While it will not be possible for park staff to collect data on all the species indicated in Table VIII-3, the list can be used by park managers to indicate potentially sensitive species. Of the many plant species in WICA, it is likely that there are many species other than those in the table which have high sensitivity to air pollution, but we currently have no information about them.

Table VIII-4 summarizes lichen and bryophyte species of WICA with known sensitivity to ozone and SO₂. As in Table VIII-3, this table is based on a variety of sources from the published literature and other information. It should be noted that diagnostic symptoms of air pollutant injury to lichens are difficult to identify, and that some species have reduced productivity or even mortality without exhibiting visible symptoms (Nash and Wirth 1988). One of the best sources of background information and guidelines for addressing the use of lichens as sensitive receptors of air pollution is Stolte et al. (1993).

E. RESEARCH AND MONITORING NEEDS

Air quality at WICA generally has been considered to be excellent. Visibility has been a valued feature of park resources, with topographic features visible 60 to 90 km to the east. There is the potential for degradation of air quality if mineral and energy exploration increases and if coal-fired power plants are built to the west of the park in Wyoming.

1. Deposition and Gases

Deposition of pollutants could be better quantified at WICA. Although NADP data are available from the Cottonwood, SD site, 130 km to the northeast, it would be desirable to have better quantification of wet and dry deposition at WICA. Short-term collection of wet deposition data could be used to calibrate with the Cottonwood site and establish a reference for deposition of S and N. Short term collection of dry deposition data using NDDN-type collectors would further establish this reference for deposition, but is probably not warranted at the present time.

A better spatial characterization of ozone distribution at WICA would be useful, although levels are currently below those believed to adversely affect sensitive plant species. A continuous ozone analyzer at the Visitor Center should be operated for two summers in order to better establish a reference point in time. In addition, a small network of passive ozone samplers could be established to compare ozone measurements from different locations in the park. Three samplers should be sufficient to spatially characterize the ozone distribution, with collection of weekly samples for two months during the summer. Two years of monitoring would be sufficient to establish spatial patterns and a reference point in time. One of the samplers should be colocated with a continuous ozone analyzer (if possible) to facilitate comparisons and as a check on the accuracy of the samplers. Other samplers could be situated along the Rankin Ridge Trail and the Boland Ridge Trail. Samplers should be situated where they are reasonably accessible but not within 50 meters of a road or trail where they may be subject to excessive dust or vandalism.

Operation of an SO₂ analyzer at the Visitor Center would provide a better characterization of SO₂ deposition at WICA. Two years of monitoring should be sufficient to establish a reference point for SO₂. Because the State of South Dakota does not have an active SO₂ monitoring program, WICA should participate in any future efforts to documenting changes in air quality.

2. Terrestrial

A basic inventory of many natural resources is still in its infancy at WICA. Monitoring schemes, short and long term, are similarly lacking, making it impossible to compare data over time to predict or assess changes. There are no current air pollution threats to WICA vegetation, although ozone, SO₂ and possibly NO₂ could be sources of concern in the future if there are new point sources that significantly increase ambient pollutant levels.

If air pollutants increases in the future, monitoring of terrestrial resources should be considered. If monitoring is implemented, we recommend ponderosa pine and quaking aspen be used as bioindicators for ozone and quaking aspen for SO₂ at WICA. One plot of each species should be sufficient for initial monitoring. Three levels of monitoring associated with increasing amounts of effort and expense are detailed in Appendix A. These plots should be colocated with the passive ozone samplers wherever possible. Monitoring should follow the methodology developed by Forest Service and National Park Service scientists for evaluating pollutant injury (Stolte and Miller 1991,

Stolte et al. 1992). If herbaceous species and lichens are included in a future monitoring effort, they should be monitored at locations adjacent to the tree plots if possible.

3. Visibility Recommendations

WICA is located approximately 100 km southwest of the visibility monitoring site at BADL. Due to the close proximity of the Badlands monitoring site and limited intervening terrain between WICA and BADL, visibility data collected at BADL can also be used to represent conditions at WICA.