# Lakes of the **Nebraska Sandhills**

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The Nebraska Sandhills is one of only two regions in the Great Plains where natural lakes have formed in great numbers. The Sandhills are located in north central Nebraska and span 49,000 km² of grass-stabilized sand dunes (Figure 1). This distinct and homogeneous ecoregion is the largest sand dune area in the western hemisphere and one of the largest grass-stabilized dune regions in the world. Relatively low precipitation, temperature extremes, and wind create semi-arid grasslands in the western part of the region, which was once called the "Great American Desert" by early European and American settlers. Despite the relative aridity of the landscape, the region contains over 1500 shallow lakes and over 400,000 hectares of wetlands, which makes it unique amongst dune systems around the world. Also, the Sandhills region is diverse in animal and plant species, making it one of the best functioning mixed grass prairie ecosystems remaining in North America.

Dune formation began 10,000 years ago with the largest dunes forming between 8,000 and 5,000 years ago when winds blew alluvial sands during a warm, dry climate. The climate has been dry enough over the past 1,000 years for the sands to blow again several times, reshaping the dunes. Periods of active dune formation have been interspersed with periods of increased precipitation and lower temperature when mixed grass prairie plants grew and kept the sand in place. The prairies now support the dominant land use in the Sandhills, cattle grazing. Other land use includes center pivot farming along stream valleys and the eastern and southern margins of the region and a few confinement animal feeding operations are found in the eastern and central Sandhills. While human population density is low and towns are few and small, large cattle ranches are common (average ranch size is about 2,000 hectares). The first humans in the region were nomads who crossed the Sandhills about 10,000 years ago. Evidence of permanent settlements of plains tribes along the streams have been dated to 1,000-2,000 years ago. At least eight tribes have lived in the region, hunting mostly and growing beans, corns, and squash. Bison roamed in large herds and buffalo wallows can still be found in many parts of the Sandhills. The early European settlers found farming in the Sandhills very difficult due to the sand underlying the thin topsoil, but permanent sources of standing water and perennial streams allowed settlers to raise domesticated herd animals. Today, 95 percent of the land is maintained as native prairie for grazing of cattle.

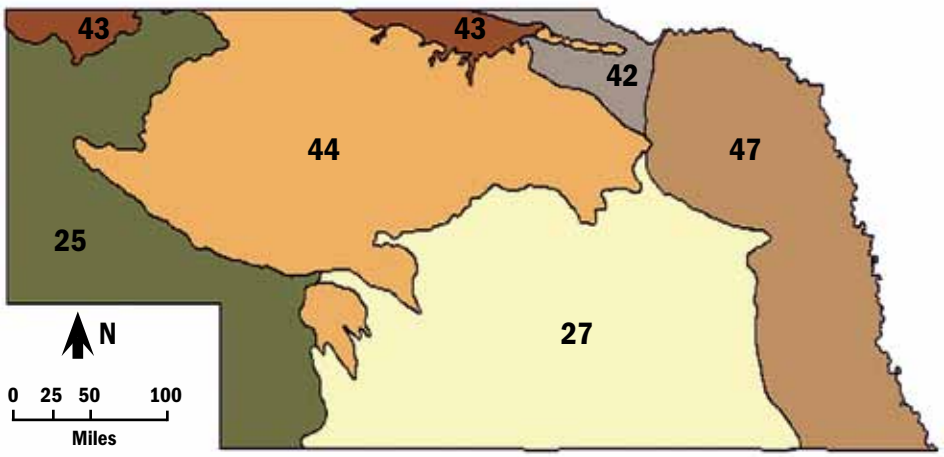


*Figure 1. U.S. Environmental Protection Agency Level III Ecoregions of Nebraska: Ecoregion 44 - Nebraska Sandhills; Ecoregion 25 - Western High Plains; Ecoregion 27 - Central Great Plains; Ecoregion 42 - Northwest Glaciated Plains; Ecoregion 43 - Northwest Great Plains; and Ecoregion 47 - Western Cornbelt Plains.*

The aquatic resources in the Sandhills provide a study in contrasts. The streams have few tributaries, are perennial, vary little in water chemistry, and rarely flood, contrary to typical streams in the Great Plains. On the other hand, lakes of the Sandhills are dynamic, varying in water level, lake area, and water chemistry. Two regions of the Sandhills are densely covered by lakes of all sizes and have been designated National Wildlife Refuges. The Valentine National Wildlife Refuge located in the north-central part of the Sandhills, covers about 29,000 hectares with 5,260 hectares of lakes. The Crescent Lake National Wildlife Refuge, located in the southwest part of the Sandhills, covers 19,000 hectares and includes 21 lakes and hundreds of ponds and wetlands (Figure 2). The large number and variable nature of the lakes support a healthy fishery, unique and endemic species of macroinvertebrates and plants, and large numbers of migratory water birds.

The Nebraska Natural Legacy Project has designated two regions of lakes and wetlands in the Sandhills as biologically

*Figure 2. Aerial view of lakes in the Crescent Lake National Wildlife Refuge; note the crescent-shaped, rounded edges of the lakes and the sandy shorelines.* Photo by D. Baker.

unique landscapes. These two landscapes are managed in cooperation and collaboration with landowners and other stakeholders to conserve rare species in the region while maintaining overall biodiversity.

### Characteristics of Sandhills Lakes

The Sandhills are characterized by a thin layer of soil atop thick dunes of sand that act as a filter through which water flows to form vast aquifers. The region is the recharge zone for the High Plains Aquifer (also known as the Ogallala Aquifer). An estimated 65 percent of the aquifer is located under the Sandhills. The saturated sands mean that the water table is close to the surface, thus ground water upwelling occurs in low-lying areas such as dune valleys and streams. These low-lying depressions hold water and determine lake shape, increasing the heterogeneity of Sandhills lakes because lake shape varies based on the shape of the surrounding dunes. At least seven distinct types of dunes have been classified and are spatially grouped in distinct regions of the Sandhills. Some dunes, such as the Barhanoid-ridge type found in the Valentine National Wildlife Refuge, are long and thin, creating linear lakes. Other dunes, such as the parabolic type found in the Crescent National Wildlife refuge, are crescent-shaped creating circular or crescent-shaped lakes. Some lakes are nestled at the base of dunes reaching 120 m in height (Figure 3).

The number of observed lakes in the Nebraska Sandhills varies between 1,500 to nearly 2,500, due to variation in precipitation and groundwater discharge. Precipitation ranges from19-20 inches per year in the east to 15-17 inches per year in the west. Although precipitation in the form of rain and snow melt constitute the dominant source of water for Sandhills lakes, precipitation in the west is not enough to maintain the large number of permanent lakes. The rate of water loss due to evaporation is greater than the amount of water gain through precipitation, thus groundwater discharge is an important source of water maintaining the lakes in the region. Sandhills lakes are shallow, with maximum depths less than 2 m on average, although some lakes have a maximum depth of 4 m. As groundwater input varies in these shallow lakes, lake levels change. Decreasing groundwater input decreases lake level, increasing the proportion of the lake covered by wetland vegetation. Increasing groundwater input increases lake level, decreasing the proportion of the lake covered by wetland vegetation. Lakes grade into wetlands and vice versa. This change is so rapid and dramatic that the lakes can grade into wetlands within a season during a dry year (Figure 4).

The climate of the region is characterized by high winds. The combination of shallow lakes and high

*Figure 3. School Lake in the Valentine National Wildlife Refuge; note the tall dunes along the lakeshore with regions of exposed sand.* Photo by B. Hayford.

*Figure 4. Swan Lake in the eastern Sandhills; note the shoreline vegetation. This proportion of lake covered by emergent macrophytes increases as water levels drop.* Photo by A. Caires.

winds causes many Sandhills lakes to mix constantly and most do not stratify during summer. Most of the lakes have large photic zones, with light penetrating the entire basin. The lakes are also characterized by elevated concentrations of total phosphorus and total nitrogen relative to lakes in nearby ecoregions (Table 1). The combination of high concentrations of nutrients and large photic zones result in productive lake ecosystems; the lakes are naturally eutrophic. Typical of shallow lakes in the Great Plains, some Sandhills lakes are so productive that phytoplankton shade out the underlying portions of the lake, increasing turbidity and decreasing production. Wave action can also release shoreline nutrients and sediments into the lakes increasing turbidity. However, despite the high concentrations of nutrients and high productivity, Sandhills lakes are less turbid than lakes in nearby ecoregions (Table 1).

Sandhills lakes show extreme variation in ion concentration. For example, lakes range in alkalinity from 0.0 mg/L to over 90,000 mg/L. Hyperalkaline and hypersaline lakes are found in the closed basin watersheds in the west where drainage is poor and subsequently ions are concentrated as a result of evaporation over the summer months. Lakes around the towns of Atioch and Lakeside in western Nebraska have salinity in excess of 19 percent, much higher than the 4 percent salinity of seawater (Figure 5). These salts, particularly potassium chloride, form the basis of potash, which can be used as a fertilizer, to produce munitions, or to make soap. Potash in the Sandhills was used as fertilizer and was mined and shipped to other regions of the country during World War I when potash from Germany was unavailable. This swift growth created boom towns in the region until cheaper German potash became available again after the end of the War. The industry failed and the boomtowns became ghost towns.

The extreme variation in lakes of the Sandhills drives variation in the biological communities. For example, fish vary predictably along a gradient in alkalinity between the lakes. Lakes with high alkalinity support few to no species

**Table 1.** Median Total Phosphorus, Total Nitrogen, Chlorophyll-*a*, and Secchi Disc Values for Lakes* of the Nebraska Sandhills and Surrounding Ecoregions.

| **Variable** | **Level III Ecoregion** | **n** | **Median** |
|---|---|---|---|
| TP (µg/L) | Central Great Plains | 61 | 90.00 |
| TP (µg/L) | Central Irregular Plains | 136 | 61.00 |
| TP (µg/L) | Flint Hills | 30 | 50.00 |
| TP (µg/L) | Nebraska Sandhills | 51 | 253.00 |
| TP (µg/L) | Western Cornbelt Plains | 129 | 108.00 |
| **Variable** | **Level III Ecoregion** | **n** | **Median** |
| TN (µg/L) | Central Great Plains | 30 | 865.00 |
| TN (µg/L) | Central Irregular Plains | 94 | 838.33 |
| TN (µg/L) | Flint Hills | 18 | 723.75 |
| TN (µg/L) | Nebraska Sandhills | 48 | 2862.26 |
| TN (µg/L) | Western Cornbelt Plains | 79 | 1900.00 |
| **Variable** | **Level III Ecoregion** | **n** | **Median** |
| Chl-*a* (µg/L) | Central Great Plains | 26 | 11.73 |
| Chl-*a* (µg/L) | Central Irregular Plains | 105 | 14.60 |
| Chl-*a* (µg/L) | Flint Hills | 24 | 9.55 |
| Chl-*a* (µg/L) | Nebraska Sandhills | 43 | 28.00 |
| Chl-*a* (µg/L) | Western Cornbelt Plains | 70 | 29.53 |
| **Variable** | **Level III Ecoregion** | **n** | **Median** |
| Secchi Disc (m) | Central Great Plains | 40 | 0.69 |
| Secchi Disc (m) | Central Irregular Plains | 112 | 0.89 |
| Secchi Disc (m) | Flint Hills | 24 | 0.94 |
| Secchi Disc (m) | Nebraska Sandhills | 51 | 0.60 |
| Secchi Disc (m) | Western Cornbelt Plains | 84 | 0.90 |

* Data produced by the U.S. Environmental Protection Agency Region 7, Regional Technical Advisory Group for lakes < than 10 acres.

*Figure 5. Saline lake at the town of Lakeside, Nebraska.* Photo by B. Hayford.

of fish, whereas fish become more diverse and abundant with decreased alkalinity. Most species of fish in the Sandhills are found in the streams, but some of the larger, freshwater lakes support healthy fisheries important to the local recreation economy. Highly productive lakes, particularly the alkaline lakes with few fish, support large populations of aquatic invertebrates such as beetles, midges, brine flies, and freshwater shrimp. Wetland soils containing high concentrations of salts and carbonates support locally rare saline tolerant plants and high alkalinity and salinity in the lakes supports locally rare and endemic species such as the fairy shrimp *Branchinecta potassa*. The presence of highly productive natural lakes in the middle of the Great Plains supports large populations of migratory birds, many of which come to feed on macroinvertebrates within the lakes and/or emerging and aerial aquatic insects. Although natural resource managers in the region have studied much of the biodiversity of these lakes, some lakes are difficult to access or are not under state or federal management and so have not been studied. It is possible that new endemic species or distribution records may be found by studying the lakes and wetlands of the Sandhills more extensively. Documenting biodiversity and searching for rare and endemic species in the Biologically Unique Landscapes designated by the Nebraska Natural Legacy Project will assist the stakeholders in implementing the NNLP conservation plans.

The Nebraska Sandhills is one of the best conserved mixed grass prairie regions in North America; however, a few human activities pose threats to Sandhills lakes. One threat is the combination of warming climate and an increase in center pivot agriculture along the river valleys and southern and eastern margins of the region. Climate projections forecast increased drought and significant warming in the Great Plains. As the climate becomes warmer, dryer lakes will receive less precipitation and will rely more on ground water inputs to maintain lake levels. Less precipitation also will mean that row crops will require more irrigation. Increased center pivot irrigation will draw down water levels in the aquifers resulting in less ground water available to maintain lakes. It is possible that future drought and warming will reduce the number of lakes in the Sandhills.

Another threat is over-grazing. Ranchers in the Sandhills have a tradition of best management practices for their rangeland. The fragile soil is easily destroyed, leading to erosion and open areas of sand. Consequently, ranchers are able to quickly see when grazing is destroying the soil and can take corrective actions. However, the water/land interface is a region in grasslands that may easily degrade before corrective action is taken. Cattle that are allowed to graze along the shorelines of lakes and streams destabilize banks and shorelines and increase ammonia and organic waste into these waters (Figure 6). In addition, there is economic pressure to increase cattle production and, consequentially, over-grazing is a persistent threat. Some natural resource managers are also concerned that an increase in absentee land ownership may lead to increased grazing because it breaks the tradition of best management practices passed down through generations in ranching families in the Sandhills.

## Conclusions

In summary, Nebraska Sandhills is the largest sand dune area in the western hemisphere and one of the largest grass-stabilized dune areas in the world. The proximity of the High Plains Aquifer to the surface of the Sandhills allows for a dynamic exchange of groundwater and surface water in the interdune areas that maintains over 1,500 lakes in a semi-arid climate. The lakes vary significantly in surface area and water chemistry and their dynamic nature supports diverse communities of plants, fish, macroinvertebrates, and birds. Two National Wildlife Refuges and two Biologically Unique Landscapes have been designated in the Sandhills for conservation of this region's biological diversity. Overall, the Sandhills region is characterized by one of the best conserved mixed-grass prairies in North America, but a warming climate combined with increased drawdown of ground water sources and a possible switch in range management threaten the condition of the Sandhills lakes.

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