



Niobrara National Scenic River

Geologic and Soil Resources Inventory Summary



On this page: The scenic view from Fort Falls Overlook within Fort Niobrara National Wildlife Refuge. The fluvial landscape of the Niobrara River is a diverse biological zone shaped by the climate and geology of the Great Plains. Steep river bluffs expose the resistant late Oligocene Rosebud Formation that forms the base of the regional Ogallala or High Plains groundwater aquifer. Numerous waterfalls, springs, and seeps emerge from the upper contact of the formation, which sustain the quality and quantity of flow along the Niobrara River—and support its ecosystems. NPS photograph.

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Abstract

This document summarizes the status of National Park Service (NPS) Geologic Resources Inventory (GRI) and Soil Resources Inventory (SRI) deliverables for Niobrara National Scenic River. It also provides information on current geology and soil resources management concerns, with a focus on identified inventory needs related to geologic heritage, geohazards, and related soil features and processes. This document is intended to assist park staff with prioritizing technical assistance or new inventory and assessment funding requests in the near term (roughly 1–5 years).

The GRI hosted a baseline scoping meeting for Niobrara National Scenic River in August 2008. Baseline bedrock and surficial geologic maps were delivered to the scenic river in 2024. SRI delivered a legacy soil database, map, and “enhanced report” in 2013. Additional soil survey reports have been published by the US Natural Resource Conservation Service (NRCS) that include Brown, Cherry, Keya Paha, and Rock counties, Nebraska. The most up-to-date soil data for the scenic river is available through [Web Soil Survey](#).

Niobrara National Scenic River’s geologic heritage is ingrained in its paleontological records, Indigenous connections, stratotypes, and its geologic connections to ecological diversity. The geologic and soil resources inventory needs for the park include various data and/or GIS information related to the inventory and monitoring of cultural and paleontological resources, geohazards, geomorphology, and visual resources, in addition to geologic mapping, interpretation, and management needs. Geologic hazards identified in the park include cave and karst, climate change, disturbed lands (e.g., land use changes), flooding, mass wasting, radon, seismicity, swelling clays, and toxicological soil.

Additional guidance for park staff regarding proposal processes and timeframes for the new Inventories and Assessment (I&A) program is available on the [GSRI](#) and [I&A](#) SharePoint sites.

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Background of the GSRI

The Geologic and Soil Resources Inventory (GSRI) facilitates the collection of new data, or derives new information from existing data, regarding the presence, absence, abundance, distribution, and significance of geologic or soil features or processes to inform park management decisions and planning.

In the 1990s, the NPS Geologic Resources Inventory (GRI) and Soil Resource Inventory (SRI) programs were established as two of the original 12 baseline inventories in the Inventory and Monitoring (I&M) program. These baseline inventories compiled existing information, acquired new information, and helped establish a minimum level of data across more than 270 parks, which served as a common starting point for natural resource monitoring. For both the GRI and SRI, the primary deliverable was a digital (GIS) map. Between the 1990s and early 2020s, GRI scoping summaries, geologic map posters, and GRI reports were also produced for most of the 270 parks. As of 2024, the I&M program is transitioning from a baseline inventory strategy to a park-proposed inventory strategy.

The GRI and SRI are now unified as one inventory program, the Geologic and Soil Resources Inventory (GSRI), and will be integrated into the new Inventories & Assessment (I&A) program, in which parks will submit geology- and soil-related project requests in PMIS during the Servicewide Comprehensive Call (SCC). This transition will begin in FY25, with new guidance enacted for GSRI. During this transition period, 13 “priority” parks, including Niobrara National Scenic River (“NIOB,” also referred to as the “scenic river” herein), were identified as missing a baseline GRI report.

This GSRI summary serves as a substitute for a baseline GRI report and is intended to support the national park’s participation in the new inventories program. As such, it summarizes the status of GRI and SRI deliverables for NIOB and provides information on current geology and soil resources management concerns with a focus on identified inventory needs. Information in this summary was compiled from existing reports, meetings with park staff, and the best professional judgment from GRI and WASO Geologic Resources Division (GRD) geoscientists.

Baseline GSRI Products

Geology

The digital geologic and surficial map for NIOB is available on the NPS DataStore accessed through the Integrated Resource Management Applications (IRMA) portal (see <https://irma.nps.gov/DataStore/Reference/Profile/2303662>). This product is adapted from a source map created by the US Geological Survey (USGS). Additional GSRI documents include the NPS Scoping Report (Graham 2008).

GSRI source maps:

- Lundstrom, S. C., J. L. McBeth, J. Alexander, P. Hanson, and S. A. Mahan. 2024. Geologic map of
- the valley corridor of the Niobrara National Scenic River, Nebraska. US Geological Survey,
- unpublished data release, scale 1:100,000. <https://www.usgs.gov/data/geologic-map-valley-corridor-niobrara-national-scenic-river-nebraska>

GSRI scoping report:

- Graham, J. 2008. Geologic Resources Inventory scoping summary: Niobrara National Scenic River. <https://irma.nps.gov/DataStore/Reference/Profile/2250384>

Soils

Soil maps provide information on soil types, including scores of different characteristics and management considerations, including linear extensibility (“shrink-swell”) potential, erosion potential, soil stability, suitability for site development, suitability for recreation development (e.g., trails), and many other topics. Perrone (2023) provides an overview of the use of soil data at the NPS WASO level and lists soil data currently available in the Natural Resources Conservation Service (NRCS) [Web Soil Survey](#) website along with NPS-specific uses for the data. The NRCS plans to complete all soil survey areas in the US by 2026 (Thompson et al. 2020).

The most up-to-date soils data for NIOB is available via Web Soil Survey, which is updated and maintained regularly. Management-focused maps for the park or potential project areas can be developed on demand on the website. The Web Soil Survey homepage gives instructions for how to view and download soil data, which are typically broken down into county-level soil survey areas. Each survey area is assigned a code and a name. NIOB includes five soil survey areas that are complete (Table 1). To view the soil data for NIOB on the Web Soil Survey website, use the navigation pane on the left side of the homepage to select the soil survey “Area of Interest (‘AOI’)” tab. Under the “National Park Service” dropdown menu, select NIOB to view the soil data. The AOI icons along the top of the screen allow users to select specific areas of the map and generate detailed soil data (e.g., soil suitability and limitations, soil properties, soil qualities, and ecological sites). Use the “Soil Map” tab at the top to view the soil map and the “Soil Data Explorer” tab to view the detailed soil data. See additional Web Soil Survey guidance and FAQs or contact the NRCS state soil scientist for technical assistance.

In 2013, the SRI delivered a legacy soil database, map, and “enhanced report” to the scenic river (<https://irma.nps.gov/DataStore/Reference/Profile/1048941>). Additional soil survey reports have been published by the NRCS that include Brown, Cherry, Keya Paha, and Rock counties ([USDA - Nebraska Soil Surveys](#); accessed April 2025).

Table 1. Web Soil Survey areas related to the scenic river.

Web Soil Survey Area Code	Web Soil Survey Area Name	Status
NE017	Brown County, Nebraska	Complete
NE031	Cherry County, Nebraska	Complete
NE103	Keya Paha County, Nebraska	Complete
NE149	Rock County, Nebraska	Complete

Possible Future GSRI Products

As the GSRI becomes integrated into the I&A program, future GSRI products will be determined by the project proposals submitted by the parks. Moving forward, the GSRI program will fund inventory projects that include the following:

- Collect new data or derive new information from existing data regarding the presence, absence, abundance, distribution, and significance of geologic heritage, soil features or processes, or geohazards.
- Include features or processes on an individual feature- or landscape-scale.
- Include groups of features or maps of multiple features in a defined area of management needs.
- Are a snapshot in time and may set a baseline for monitoring or assessment.
- Typically include a geospatial (GIS) component.

GSRI project examples:

- Features and processes eligible for funding through the GSRI program include cave/karst, geothermal, paleontological (fossils), landslides and rockfall, other geohazards (e.g., avalanches, permafrost, volcanoes, earthquakes, tsunamis, sinkholes), eolian, erosion, soil suitability and limitations for use, soil properties and qualities, ecological site descriptions, and other geologic or soil features or processes of management interest.
- Features and processes covered by other sources of funding and **not** eligible for GSRI funding are abandoned mineral lands (AML), orphaned oil and gas wells, coastal processes, coastal storm response, sea level change projections or mitigation, coastal engineering structures, or shoreline sediment movement.
- The GSRI will accept proposals for new baseline map products, such as funding a traditional geologic (bedrock or surficial) or soil mapping effort, especially at new or expanded parks outside the original 270 I&M parks. Parks requesting these products will need to indicate a management need, which the baseline data will support.

Geologic Setting and History

Park Establishment and Setting

Niobrara National Scenic River (“NIOB,” also referred to as the “scenic river” herein) preserves a 122 km (76 mi) stretch of the Niobrara River in portions of Brown, Cherry, Keya Paha, and Rock counties in north-central Nebraska. Established on 24 May 1991, NIOB protects the free-flowing river—including its significant scenic, geologic, biologic, historic, and paleontological (fossil) resources—and provides recreational opportunities compatible with its resource protection goals (National Park Service 2016). The scenic river encompasses approximately 11,776 ha (29,101 ac) that are cooperatively managed by the NPS, US Fish and Wildlife Service, and private landowners. The Niobrara River is considered a “mountain stream in a prairie state” and contains a unique collection of scenic vistas, rocky cliffs, and waterfalls that are rare on the Great Plains; the river is also the only bedrock river in the state of Nebraska (National Park Service 2006b, 2016). Originating in the tablelands of east-central Wyoming, the Niobrara River flows east across Nebraska (the longest river in the state) and supports a variety of diverse ecosystems, including the Sandhills, tallgrass and mixed-grass prairies, and northern boreal, eastern deciduous, and western coniferous forests (Narumalani et al. 2010). The upper portion of NIOB is confined to a single bedrock river channel that is surrounded by steep valley slopes, terraces, and incised tributary canyons. Downstream of the Norden Bridge (river mile 35.2), the scenic river widens into a broad floodplain with multiple meandering river channels, sandy shorelines, unvegetated sandbars, and wetlands that support several threatened or endangered species.

The scenic river is located within the Great Plains physiographic province, an extensive, relatively flat region covering roughly 725,000 km² (450,000 mi²). In north-central Nebraska, NIOB traverses several subregions of the Great Plains, including the Sandhills, Dakota–Nebraska Eroded Tablelands, and the unglaciated Missouri Plateau (Figure 1). The Sandhills feature some of the largest sand dunes in the Western Hemisphere and are responsible for groundwater discharge that supports the flow of the Niobrara River (National Park Service 1995; Johnsgard 2009; Mosier 2019). A large portion of the scenic river passes through the Dakota–Nebraska Eroded Tablelands, an area of flat to rolling sandy plains that have been highly dissected by the Niobrara River (Chapman et al. 2001; Alexander et al. 2010). The easternmost portion of NIOB flows through the unglaciated Missouri Plateau, a region characterized by flat, gently sloping terrain that features occasional buttes and badlands shaped by the erosive action of the Missouri River and its tributaries—including the lower Niobrara River (Manske 2022).

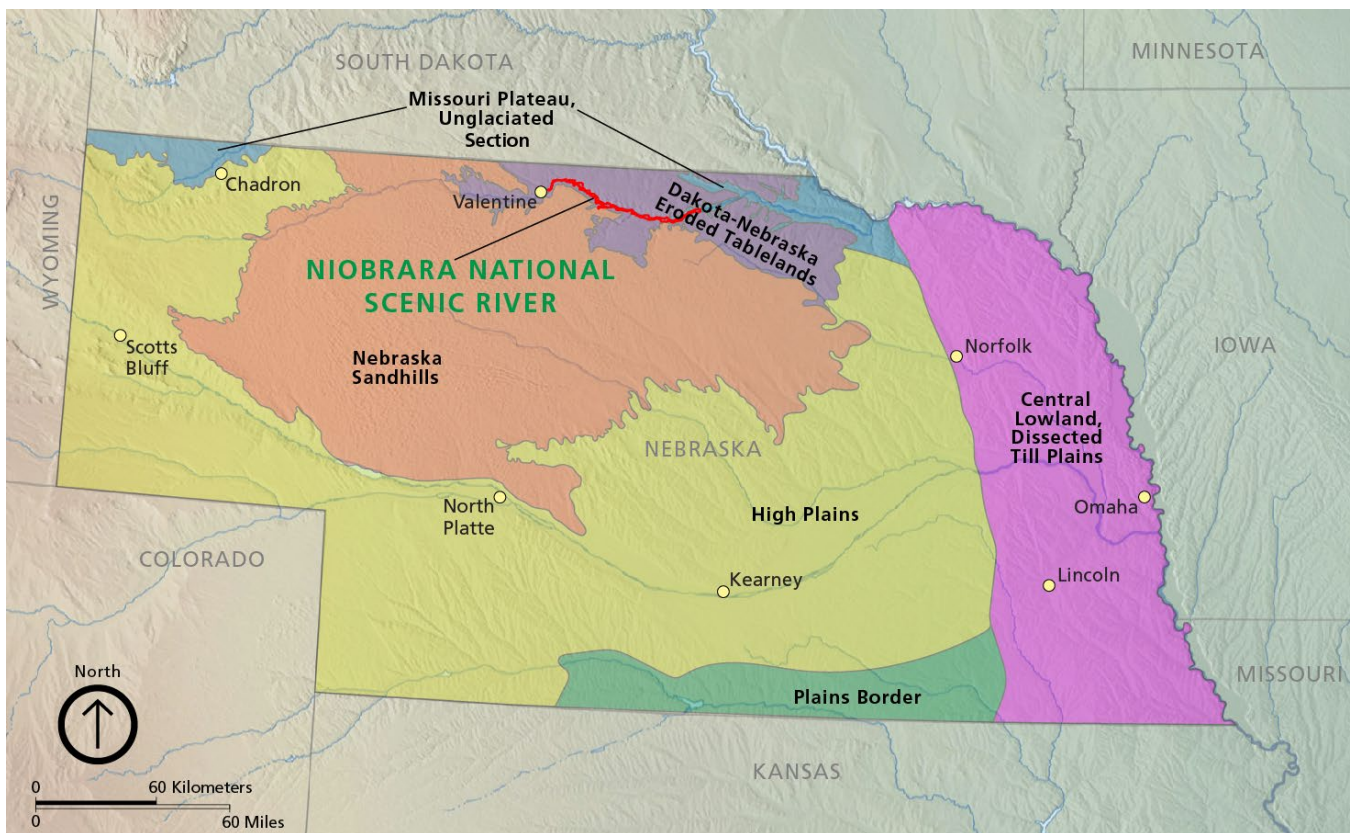


Figure 1. Physiographic subregions of Nebraska. The scenic river is in the Great Plains physiographic province, an extensive, relatively flat region of the central United States. In north-central Nebraska, the Niobrara River flows through portions of the Sandhills, the Dakota–Nebraska Eroded Tablelands, and the unglaciaded Missouri Plateau. Collectively, these subregions are characterized by flat to rolling hills dissected by the Niobrara River that feature some of the largest stabilized sand dunes in the Western Hemisphere. Figure created by Trista L. Thornberry-Ehrlich (Colorado State University).

Geologic History

Mesozoic Era (251.9 million to 66.0 million years ago): The Western Interior Seaway

The oldest bedrock exposed along the scenic river is the Cretaceous Pierre Shale, a sequence of dark shales, siltstones, and sandstones originally deposited in the Western Interior Seaway, an ancient shallow sea that inundated the interior of North America approximately 100 million to 70 million years ago (Table 2; Tweet et al. 2011; National Park Service 2016). The Pierre Shale contains scattered beds of bentonite, a clay mineral formed by the alteration of volcanic ash. Approximately 80 million years ago, extensive volcanism occurred throughout western North America that was driven by the subduction of the oceanic crust beneath the western margin of the continent (Bertog et al. 2007). In eastern South Dakota and Nebraska, portions of the Pierre Shale also contain shocked quartz and feldspar, metamorphic minerals that form under extreme pressure and temperature conditions associated with meteorite impacts. Radiometric $^{40}\text{Ar}/^{39}\text{Ar}$ dating performed by Izett et al. (1998) provided mineral ages that align with the 74.1-million-year-old Manson impact structure (impact crater) that occurred in northwestern Iowa. Outcrops of the Pierre Shale form the dark gray bluffs along the southern riverbank in the downstream (eastern) segment of NIOB (Figure 2). Several exposures mapped by the USGS include the following (in downstream order with river miles

measured from Borman Bridge): (1) the Meadville Bridge, near river mile 46.0; (2) upstream of Lucky Creek; (3) upstream of Wentworth Creek; (4) the Nebraska State Highway 7 Landing, near river mile 60.3; and (5) upstream of Rock Creek.

Table 2. Geologic units mapped within or immediately adjacent to the scenic river.

GSRI map abbreviations for each time division and GSRI map unit symbols are in parentheses. Only geologic units mapped immediately adjacent to or within NIOB are included. Boundary ages follow the International Commission on Stratigraphy (2023).

Geologic Time Unit	Age	Geologic Units (GSRI map symbol)	Geologic Events
Cenozoic Era: Quaternary Period (Q) – Holocene Epoch (H) and Pleistocene Epoch (PE)	2.58 million years ago to the present	Engineered fill (Qef) Historic low terrace alluvium of Niobrara River (Qnly) Low terrace alluvium of Niobrara River (Qnl) Dune sand (Qd) Dune sand over high terrace of Niobrara River (Qd/Qnh) Intermediate terrace alluvium of Niobrara River (Qnit) Tributary alluvium (Qtal) High terrace alluvium of Niobrara River (Qnh) Slope colluvium over Tertiary bedrock (QNPgc)	The modern Niobrara River and the Sandhills region started to develop approximately 15,000 years ago following the end of the previous Ice Age. The Quaternary history of the scenic river is dominated by river incision, terrace development, and large-scale dune formation and stabilization.
Cenozoic Era: Tertiary (T) – Neogene Period (N) and Paleogene Period (PG)	66.0 million to 2.58 million years ago	Ash Hollow Formation (Ogallala Group) Cap Rock Member (Noac) Valentine Formation (Ogallala Group; Nv) Burge Member Devils Gulch Member Crookston Bridge Member Cornell Dam Member Rosebud Formation (Arikaree Group; PGr) Chamberlain Pass Formation (White River Group; Pgc)	The Laramide orogeny (approximately 80 million to 45 million years ago) resulted in the uplift and erosion of the modern Rocky Mountains. Massive amounts of sediment were sourced from the mountains and carried eastward by river systems. Deposition within these fluvial environments was accompanied by pulses of volcanic activity, notably in the Ash Hollow Formation.
Mesozoic Era: Cretaceous Period (K)	145.0 million to 66.0 million years ago	Pierre Shale (Kp)	Deposition within the Western Interior Seaway, a shallow marine sea that flooded the interior of North America approximately 100 million to 70 million years ago.



Figure 2. Steep river bluffs of the Cretaceous Pierre Shale. These dark shales are commonly exposed along the lower (eastern) reach of the Niobrara River. These particular exposures form the southern bank of the Niobrara River immediately downstream of the mouths of Long Pine and Beeman creeks (west of the Highway 7 Landing bridge). Kayakers provide scale for the bluffs. NPS photograph.

Tertiary Period (66.0 million to 2.58 million years ago): Erosion and Volcanism

The Mesozoic–Cenozoic transition marks the withdrawal of the Western Interior Seaway and coincides with the Laramide orogeny (approximately 80 million to 45 million years ago), a major mountain-building event responsible for the uplift of the Rocky Mountains (Joeckel et al. 2018). Following the deposition of the Pierre Shale, there was a significant unconformity (a gap in the geologic record) from approximately 70 million to 37 million years ago that represents the uplift and erosion of the Rockies (Diffendal 1995; Terry et al. 1995; Joeckel et al. 2015). Although rocks of this age are missing or scarce at NIOB, they are well-preserved in western Nebraska (Agate Fossil Beds National Monument and Scotts Bluff National Monument), southwestern South Dakota (Badlands National Park), and western North Dakota (Theodore Roosevelt National Park). Tertiary sediments found along the scenic river were sourced from the mountains and transported eastward by several river systems into the Kennedy basin, an ancient, regional-scale depression that formed during the Paleozoic or Mesozoic eras in north-central Nebraska (Joeckel et al. 2015, 2017). Today, these sedimentary deposits form a thick alluvial fan comprised of the Eocene–Oligocene (37.8

million to 33.9 million years ago) White River Group (Chamberlain Pass Formation), Oligocene–Miocene (25 million to 23 million years ago) Arikaree Group (Rosebud Formation), and Miocene–Pliocene (14 million to 9.5 million years ago) Ogallala Group (Valentine Formation and Ash Hollow Formation; see Table 2). Along the scenic river, each of these groups is separated by unconformities representing nearly 10 million years of missing time (see figure 3 of Joeckel et al. 2015).

The late Eocene Chamberlain Pass Formation (approximately 37.8 million to 33.9 million years ago) of the White River Group is the oldest Tertiary unit in NIOB and is restricted to a single, easily accessible exposure along US Highway 183 about 2.0–2.5 km (1.2–1.6 mi) north of the Niobrara River. At the site, the formation consists of tuffaceous (rocks containing a high amount of volcanic ash) fluvial sandstone, siltstone, and unconsolidated sand and clay approximately 23 m (75 ft) thick; previous interpretations considered these deposits to be the Eocene–Oligocene Chadron Formation of the White River Group (Skinner et al. 1972; Skinner and Johnson 1984; Joeckel et al. 2015; Lundstrom et al. 2024). The Chamberlain Pass Formation is unconformably overlain by the late Oligocene Rosebud Formation of the Arikaree Group, a pinkish-tan siltstone and sandstone interpreted as floodplain deposits, loess (windblown sediment), or a combination of both (Lundstrom et al. 2024). The Rosebud Formation not only accounts for many of the Niobrara River rapids between the Brewer and Norden bridges but also forms the resistant bedrock underlying the scenic river’s bluffs, waterfalls, springs, seeps, spring-branch canyons, and chutes (steep-sided, erosional passages through which water flows rapidly; Figures 3–4; see “Geology and Ecology”; National Park Service 2006b). Additionally, the formation represents the impervious base underlying the regional High Plains or Ogallala groundwater aquifer, a vital source of water that supports the flow of the Niobrara River. A disconformity (an unconformity or erosional surface between two sedimentary layers) separates the Rosebud Formation from the overlying Ogallala Group (Tweet et al. 2011).



Figure 3. Eroded bluffs of the Oligocene Rosebud Formation. The formation is defined by pinkish-tan siltstone and sandstone that form the resistant base underlying the regional High Plains or Ogallala aquifer. These steep cliffs form the southern bank of a riverbend located upstream of Allen Bridge. The lack of vegetation and fallen tree indicate these exposures have been subjected to recent erosion or mass wasting. Canoers provide scale for the bluff. NPS photograph.



Figure 4. Norden Chute. Located downstream of Rocky Ford Rapids, the chute is a dynamic fluvial feature incised by the Niobrara River that contains pronounced bedrock shelves consisting of the Rosebud Formation. NPS photograph.

The Middle Miocene Valentine Formation (approximately 14 million to 12 million years ago) of the Ogallala Group was originally named by Barbour and Cook (1917) to describe a fossiliferous sequence of sand, semi-consolidated sandstone, siltstone, and volcanic ash exposed near the city of Valentine, Nebraska; the type section (reference exposure; see “Stratotypes”) of the formation is located about 1.6 km (1 mi) south of the Borman Bridge (Figure 5). According to Lundstrom et al. (2024), the formation represents various fluvial and eolian depositional settings. The Valentine Formation is a permeable sedimentary sequence, providing an efficient groundwater recharge zone and aquifer. As precipitation and runoff percolate downward through the formation, the water emerges as springs, seeps, and waterfalls along its lower contact with the Rosebud Formation (Graham 2008; National Park Service 2016). Within the scenic river corridor, the Valentine Formation is subdivided into several members that include (in ascending order) the Cornell Dam, Crookston Bridge, Devil’s Gulch, and Burge members (Voorhies 1990; Lundstrom et al. 2024). Several valuable reference exposures or stratotypes for the Cornell Dam Member are located within NIOB (see “Stratotypes”). The Valentine Formation is disconformably overlain by the Late Miocene Cap Rock Member (approximately 12.0 million to 9.5 million years ago) of the Ash Hollow Formation of the Ogallala Group, a gray carbonate-rich sandstone that is interbedded with clay, silt, and volcanic ash. The Cap Rock Member was deposited by fluvial and eolian processes similar to the Valentine Formation but also contains relatively abundant lacustrine (lake or pond) deposits (Tweet et al. 2011). As the name implies, the Cap Rock Member forms a highly resistant cap of tuffaceous sandstone along the northern rim of the Niobrara River valley (Figure 6; Voorhies 1990; Alexander et al. 2009, 2010; Narumalani et al. 2010). As the name implies, the rocks associated with the Ogallala Group comprise the regional High Plains or Ogallala aquifer but are also responsible for preserving NIOB’s exceptional paleontological (fossil) resources (see “Paleontology”).



Figure 5. The Middle Miocene Valentine Formation. The formation consists of sand, semi-consolidated sandstone, siltstone, and volcanic ash that preserve a diverse array of fossils. These exposures form the northern bank of the river downstream of Berry Bridge. The Valentine Formation is highly permeable and is a valuable source of groundwater that contributes to the Niobrara River. Many of the springs, seeps, and waterfalls along NIOB issue from the base of the formation, where it is underlain by the Rosebud Formation. NPS photograph.



Figure 6. The Late Miocene Cap Rock Member of the Ash Hollow Formation. The member consists of gray, carbonate-rich sandstone interbedded with clay, silt, and volcanic ash that form a resistant cap along the northern rim of the Niobrara River valley. These exposures cap the rolling hills surrounding Coon Creek. NPS photograph.

Quaternary Period (2.58 million years ago to the present): River Incision and the Sandhills

Some of the youngest geologic units within NIOB are unconsolidated Quaternary surficial deposits associated with the Niobrara River and the Sandhills. During the Pleistocene Epoch, approximately 1.6 million to 100,000 years ago, a proto-Niobrara River likely existed in north-central Nebraska, at a time when massive ice sheets advanced south from Canada. Although glaciers never occupied the area of NIOB, there were at least four separate glacial events that crossed into the eastern portion of Nebraska (Mosier 2019). Although the mouth of the modern Niobrara River marks the western limit of these glacial pulses, it is possible that glacial meltwater modified drainage networks and helped incise some of the steeper canyons now on display along the scenic river (Mosier 2019). According to Johnsgard (2007), the modern Niobrara River valley and the Sandhills region are likely less than 15,000 years old and developed following the Ice Age at the end of the Pleistocene Epoch. As the climate warmed and the ice retreated north, massive deposits of alluvial sand were reworked by intermittent wind erosion to form the Sandhills. Over several millennia, periodic cycles of aridity and humidity allowed the massive dunes of the Sandhills to form, migrate, and develop stabilizing vegetation, respectively (Mosier 2019). The transition to the Holocene Epoch

(approximately 11,700 years ago) marks a significant environmental shift associated with the conversion of cooler tundra flora to modern grasslands. Some plant species considered relics of the Ice Age still survive within NIOB along the spring-branch canyons bordering the river to the south (see “Geology and Ecology”; National Park Service 1995, 2006b; Narumalani et al. 2010). Since the Pleistocene, the Niobrara River has incised multiple river terraces that form a stair-like pattern, with progressively younger terraces located at lower elevations. The modern river system—including its tributaries—continues to incise and redistribute sediment as it redefines the ever-changing landscape of the scenic river.

Geologic Heritage

Geologic heritage (also called “geoheritage”) evokes the idea that the geology of a place is an integral part of its history and cultural identity. In 2015, the NPS GRD, in cooperation with the American Geosciences Institute, published a booklet introducing the American experience of geoheritage, geodiversity, and geoconservation: *America's Geologic Heritage: An Invitation to Leadership*. This publication introduces key principles and concepts of America's geoheritage, which are the focus of ongoing collaboration and cooperation on geologic conservation in the United States. The booklet includes the following five big ideas:

- America’s geologic landscape is an integral part of its history and cultural identity, and Americans have a proud tradition of exploring and preserving geologic heritage.
- America’s geologic heritage, as shaped by geologic processes over billions of years, is diverse and extensive.
- America’s geologic heritage holds abundant values—aesthetic, artistic, cultural, ecological, economic, educational, recreational, and scientific—for all Americans.
- America’s geologic heritage benefits from established conservation methods developed around the world and within the United States.
- America’s geologic heritage engages many communities, and involvement by individuals will ensure its conservation for future generations.

Additional information about the geology of Nebraska, including its geoheritage connections, can be found at the University of Nebraska-Lincoln School of Natural Resources Conservation and Survey Division website: <https://snr.unl.edu/csd/geology/> (accessed May 2025).

Geology and Ecology

The scenic river occupies a climatic transition zone and has often been regarded as a “biological crossroads” due to its significant ecological and paleontological diversity (National Park Service 2006b, 2016; Narumalani et al. 2010; Joeckel et al. 2015). Situated within the dry rain shadow of the Rocky Mountains, the Niobrara River supports a wide range of biological communities that include northern boreal forest, eastern deciduous forest, Rocky Mountain coniferous forest, tallgrass prairie, Sandhills prairie, and mixed-grass prairie. The existence of these communities is dependent upon the complex interactions between the Niobrara River and its underlying geology; a unique feature of the Niobrara is that it is the only river in Nebraska that is immediately underlain by bedrock (Graham 2008; Schaepe et al. 2016). The river and its tributaries are primarily sustained by groundwater flow that is sourced from the High Plains or Ogallala aquifer of the Sandhills region (National Park Service 2006b, 2016; Johnsgard 2009; Schaepe et al. 2016). As the Niobrara River emerges from southeastern Wyoming, it incises into the water table of the Sandhills, which provides a source of high-quality water that supports river flow, springs, seeps, and waterfalls, as well as a rich assortment of flora and fauna (National Park Service 2016).

In addition to groundwater sustenance and flow regulation, the geology of NIOB controls several other variables of the Niobrara River, including channel morphology (e.g., width, depth, sinuosity, gradient), water quality, suspended sediment load, and channel feature development. A downstream traverse of the scenic

river is a tale of two landscapes, each with its own unique geology, geologic features, and ecosystems. The upstream (western) segment of NIOB is a clear, narrow, single-channel river surrounded by scenic forested cliffs, incised grassland canyons, and spring-channel tributary canyons (Joeckel et al. 2015; Mosier 2019). This entrenched upstream segment of the scenic river is a popular destination for river-goers and is underlain by the more resistant bedrock of the Oligocene Rosebud Formation (Alexander et al. 2010; Narumalani et al. 2010; Lundstrom et al. 2024). The impervious nature of the Rosebud Formation prevents groundwater penetration and is responsible for the hundreds of waterfalls (including Smith Falls, Nebraska's highest waterfall at 20 m [66 ft]) and springs distributed along the river and its tributaries (Figure 7). These spring-fed tributary canyons, often referred to as "spring-branch canyons," provide cooler microclimates and critical habitats for rare plant species (e.g., paper birch, quaking and bigtooth aspen, ferns, and several species of club-mosses) considered to be relicts of the previous Ice Age (National Park Service 1995, 2006b, 2016; Narumalani et al. 2010). In eastern Cherry County, the geomorphology and landscape expression of the Niobrara River transition in response to a change in bedrock substrate to the less resistant Cretaceous Pierre Shale (Alexander et al. 2010; Schaepe et al. 2016). The lower portion of NIOB is characterized by a broadened floodplain featuring multiple, meandering river channels in addition to sandy shorelines, unvegetated sandbars, and wetlands. Many of these channel features, including the open water, are critical habitats that support several endangered or threatened species such as the piping plover (*Charadrius melodus*), interior least tern (*Sternula antillarum athalassos*), and whooping crane (*Grus americana*; Figure 8; Narumalani et al. 2010; Schaepe et al. 2016).



Figure 7. Smith Falls. The scenic waterfall is the tallest waterfall in Nebraska, at approximately 20 m (66 ft). Groundwater that sustains the falls is sourced along the contact between the Miocene Valentine Formation and the underlying Oligocene Rosebud Formation. During the winter season, Smith Falls and many other waterfalls along NIOB freeze, which facilitates frost wedging, erosion, and mass wasting; note the massive boulders at the base of the waterfall. NPS photograph / G. Warrick.



Figure 8. The endangered piping plover nesting on bare sandbars. The lower stretch of NIOB is characterized by a broad floodplain that features sandy shorelines, unvegetated sandbars, and wetlands that are critical habitats to many threatened or endangered species. Flooding and human activity can negatively impact the nesting grounds of these vital species. NPS photograph.

Paleontology

Paleontological resources (fossils) are any evidence of life preserved in a geologic context (Santucci et al. 2009). They may be body fossils (any remains of the actual organism such as bones, teeth, shells, or leaves) or trace fossils (evidence of an organism’s activity such as nests, burrows, tracks, or feces). Fossils may occur in rocks or unconsolidated deposits, in museum collections, or in cultural contexts, such as building stone.

Often referred to as the “Bone Hunter’s River,” the paleontological resources of the Niobrara River valley are internationally and nationally significant and chronicle millions of years of mammal evolution in North America (see [Flowing Through Time](#) [accessed April 2025]; Voorhies 1990; Voorhies and Corner 1993; National Park Service 2006b; Joeckel et al. 2015). A rich collection of fossil sites has been reported within and surrounding NIOB that are preserved in the Middle Miocene Valentine Formation, Upper Miocene Ash Hollow Formation, and Quaternary sediments. Fossil discoveries within the scenic river include extinct horses, camels, rhinos, saber-toothed cats, bison, and proboscideans (mammoth and mastodons), as well as a

diverse non-mammalian assemblage including fish, amphibians, reptiles, birds, and petrified wood (Figures 9–10; Voorhies 1990; Voorhies and Corner 1993; Tweet et al. 2011; National Park Service 2016; Mead et al. 2020). Some of the earliest documented paleontological resources from along the Niobrara River date back to the 1850s and include specimens collected during the 1857 Lt. G. K. Warren Military Expedition that first explored the Nebraska Territory—a vast expanse of the Great Plains that included parts of Nebraska, Colorado, Montana, Wyoming, and the Dakotas (Voorhies 1990; National Park Service 2006b; Tweet et al. 2011; Joeckel et al. 2015). Multiple fossil localities within NIOB illustrate an astounding diversity of ancient life and are sites where previously unknown species were first described and named; these fossils are referred to as type specimens (akin to stratotypes; see “Stratotypes”). At least 28 fossil species are based on remains discovered within what is now NIOB, and another 38 are based on remains that may have been discovered there (early paleontological reports often have vague locality descriptions) (Justin Tweet, NPS GRD, personal communication July 2025). The Norden Bridge Quarry of the Valentine Formation, one of the most impressive fossil sites within NIOB, contains almost 150 vertebrate species, surpassing any other site in North America (National Park Service 1995, 2006b, 2016).

The rich collection of fossils preserved within the Miocene Ash Hollow Formation is also notably on display at [Ashfall Fossil Beds State Historical Park](#), located approximately 40 km (25 mi) south of the Niobrara-Missouri River confluence. Like the famous preservation of Pompeii, mammals were encased or blanketed by a layer of volcanic ash (Late Miocene Cap Rock Member) that is roughly 2–3 m (8–10 ft) thick at the site (Tweet et al. 2011). In recognition of its incredible paleontological resources, Ashfall Fossil Beds has been designated a National Natural Landmark.



Figure 9. Photograph of a fossilized rhinoceros vertebra recovered in NIOB. Rhino fossils such as this are preserved in Tertiary deposits of the Miocene Valentine Formation and Ash Hollow Formation. The scenic river contains a diverse collection of fossil resources that are internationally and nationally recognized. NPS photograph.



Figure 10. Bison fossils of NIOB. The long-horned bison (left; *Bison latifrons*) and ancient bison (right; *Bison antiquus*) occupied the Niobrara River valley during the Pleistocene Epoch. For comparison, modern bison (*Bison bison*) are about 20% smaller than their Pleistocene ancestors. Scale bar is about 15 cm (6.0 in). NPS photograph.

Indigenous Connections

The Niobrara River valley has a rich history of human occupation spanning at least 9,000 years and includes the ancestral lands of the Pawnee, Arikara, Omaha, Ponca, and Sioux peoples (see [Flowing Through Generations](#) [accessed April 2025]; Ritter et al. 1995; National Park Service 1995, 2006b). The name “Niobrara” is of Indigenous origin and has several meanings, including “running waters” or “wide flowing waters” in the Ponca language—a testament to the steady, continuous flow of the river (Franklin et al. 1994). For thousands of years, Indigenous hunter-gatherers used the river corridor for sustenance, trade, and as a means of travel. Evidence of seasonal hunting and gathering camps is scattered throughout the river valley and the adjacent Sandhills (National Park Service 1995, 2006b). Archeological remains identified within NIOB date back to the Paleo-Indian period roughly 7,500 to 11,500 years ago and include projectile points, stone tools, animal bone fragments, charcoal, pottery sherds, and scattered lithic debris (National Park Service 1995, 2006b). According to Franklin et al. (1994) and National Park Service (1995), the Niobrara River valley offered the only source of rock (green, silica-cemented orthoquartzite) suitable for the manufacture of stone tools in the Sandhills region. Green orthoquartzite is associated with lenticular bodies (elongate, lens-shaped beds of rock) that occur within the lower part of the Miocene Valentine Formation (Voorhies 1990; Graham 2008; Joeckel et al. 2015). One of the most extensive outcrops of the orthoquartzite occurs at Rocky Ford, approximately 3.2 km (2 mi) east of the Cherry–Keya Paha County line (Voorhies 1990).

Stratotypes

Stratotypes are important geologic reference exposures that help identify, define, and correlate geologic units from one location to another. When geologists propose or describe a new layer or body of rock, a stratotype is assigned to exposures containing all (or most) of the unique diagnostic criteria. Stratotypes have significant scientific value and are often easily accessible, world-class locations to study outcrops of rock. Akin to natural libraries of Earth history, stratotypes preserve meaningful clues to the past and serve as geologic classrooms (Henderson et al. 2023, 2025). The stratotype concept is ingrained in the modern system of geologic nomenclature, as many formal geologic unit names are derived from geologic or geographic features found near stratotype locations. Some particularly recognizable examples from within the National Park System (and their stratotype assignments) include the Permian De Chelly Sandstone (Canyon de Chelly National Monument, Arizona), the Cretaceous Mesaverde Group (Mesa Verde National Park, Colorado), and the Pleistocene Valles Rhyolite (Valles Caldera National Preserve, New Mexico). More information about the various kinds of stratotypes (i.e., lithostratigraphic versus chronostratigraphic) and how to propose or modify them can be found in the North American Stratigraphic Code (North American Commission on Stratigraphic Nomenclature 2021) as well as Stamm (2023).

The scenic river contains four stratotypes that represent the Miocene Cornell Dam Member of the Valentine Formation as well as the Pliocene “Fort Niobrara Formation” (Henderson et al. 2022). The Cornell Dam Member was first named and described by Skinner and Johnson (1984) after geologic exposures near Cornell Dam; additional reference sections are located at Rocky Ford and Norden Bridge. Although the Fort Niobrara Formation has been superseded by the Valentine Formation, its designation was associated with river exposures located near historic Fort Niobrara (Osborn 1918). In addition to stratotypes found within the scenic river corridor, the type section of the Valentine Formation is located about 1.6 km (1.0 mi) south of the Borman Bridge near upstream NIOB.

Geologic Resource Management Issues and Inventory Needs

This section briefly summarizes the geologic resource management issues, inventory needs, and geologic hazards that have been identified by discussions with NIOB staff. Geologic resource management issues refer to problems related to geologic resources. Inventory needs are highlighted to summarize what is currently known and what is needed to ensure good management of NIOB. Geologic hazards refer to notable hazards stemming from geologic features or processes that may require active management. Refer to the [Guidance for Geologic Resource Management SharePoint](#) for more information regarding geologic resource management.

Summary of Geologic and Soil Hazards

Park resources are not only visitor attractions but may also be potentially hazardous. The landscape of NIOB presents a variety of geologic hazards, or “geohazards”—naturally occurring, dynamic geologic processes that have the potential to cause damage, loss of property, and/or injury and loss of life. The Addressing Climate Change and Natural Hazards Handbook (National Park Service 2015, 2023), grounded in NPS Policy Memorandum 15-01 (Jarvis 2015), provides a process and information to help teams and decision-makers identify, avoid, and mitigate risks associated with environmental change hazards and effects on proposed and planned facility investments. The handbook supports NPS planning guidance, policy directives, and executive orders and does not supersede existing mandated compliance processes and policies. Additional guidance for facility management (e.g., [Climate-Smart Planning Principles](#) and [Recommended Practices](#)) has been developed to support effective decision-making.

According to PM 15-01, managers should apply the handbook guidance to identify options to manage natural hazard and climate change risks throughout all levels of facility planning and design. Project teams are required to submit the completed Natural Hazards Checklist (Table 3) as part of Regional and Bureau Investment Review Board submissions. This information can also be used as part of the updated (2024) Automated Investment Review Board (AIRB) submittal process at the Investment Concept (IC) stage. Table 3 includes selected geologic and soil hazards listed in Part 1 of NPS (2023). The GSRI team has added additional hazards where appropriate for the park. If needed, Part 2 of the handbook could inform the completion of the checklist, such as whether a hazard is applicable. Contact the NPS GRD with any questions.

Table 3. Geologic hazards checklist.

This summary table is a synthesis of existing GSRI-compiled map data and information, as well as published US Geological Survey and other government agency information. It is suitable for use at park-scale discussions and assessments. It is not a substitute for site-specific investigations or NEPA analysis. Ground-disturbing activities should neither be approved nor denied based on the information here. This table is modeled after the Natural Hazard Checklist (see National Park Service 2015, 2023, and Jarvis 2015). It is meant to provide general information to identify the full range of natural hazard-based risks for the scenic river.

Hazard	Examples of Risk or Secondary Hazard	Best Professional Judgment	Sources of Geohazard Information
Slope movements (also called “mass wasting”)	Landslides (e.g., debris slides, soil creep, and debris flows) Shoreline erosion, particularly along sharp river bends on the southern side of the Niobrara River Damage to or loss of park infrastructure Damage to or loss of natural or cultural resource sites or features Human injury or casualty	Known hazard (very high; DOI SHIRA)	Alexander et al. (2010) DOI SHIRA Risk Mapper Report GSRI GIS hazard layers or slope movement deposits (e.g., “slope colluvium over Tertiary bedrock”) Hearty (1978) National Park Service (1995)
Riverine Flood	Flooding (driven by storms, prolonged rainfall, or ice jams) capable of generating mass wasting events Enhanced surface runoff and stream flow capable of carrying sediment, rock, and woody debris Stream channel migration Stream bank erosion Destruction of infrastructure (e.g., roads, trails) Destruction of cultural or paleontological sites Human injury or casualty	Potential hazard (extreme; DOI SHIRA)	Alexander et al. (2009, 2010) DOI SHIRA Risk Mapper Report Federal Emergency Management Agency (FEMA) Map Service Center Franklin et al. (1994) Graham (2008) Narumalani et al. (2010) National Park Service (1995, 2006b)
Flash Flood	Rapid flooding along tributaries Enhanced mass wasting susceptibility Enhanced surface runoff and stream flow capable of carrying sediment, rock, and woody debris Stream channel migration Stream bank erosion Destruction of infrastructure (e.g., roads, trails) Destruction of cultural or paleontological sites Human injury or casualty	Potential hazard	National Park Service (1995, 2006b)

Hazard	Examples of Risk or Secondary Hazard	Best Professional Judgment	Sources of Geohazard Information
Shrink/swell soils	Zones of very high shrink/swell potential are mapped along both sides of the Niobrara River downstream (east) of the Meadville Bridge Sinking or lateral shifting of the ground beneath roads, trails, or structures Damage to infrastructure (e.g., buildings, utility systems) Increased susceptibility to slope movements Human injury or casualty	Potential hazard (low to very high; USDA Web Soil Survey)	Hearty (1978) USDA Web Soil Survey
Toxicological soil (arsenic ¹ , asbestos or erionite ² , <i>Bacillus anthracis</i> [causes anthrax] ³ , cadmium ¹ , lead ³ , and selenium ¹)	Health hazard	¹ Potential hazard (moderate) ² Potential hazard (high) ³ Potential hazard (low)	DOI SHIRA Risk Mapper Report
Radon	Health hazard	Potential hazard (low to moderate; US EPA).	DOI SHIRA Risk Mapper Report Otton (1992) US Environmental Protection Agency (EPA) Map of Radon Zones
Earthquake	Falling objects Collapsing structures Inoperability of major building systems (e.g., power, sewer, water) Trigger to other hazards (e.g., landslides) Human injury or casualty	Potential hazard (low; DOI SHIRA)	Filina et al. (2018) Joeckel et al. (2015) Nebraska Seismicity US Geological Survey Reagor et al. (1981) US Department of Interior (DOI) Strategic Hazard Identification and Risk Assessment (SHIRA) Risk Mapper Report United States Geological Survey (USGS) Earthquake Hazard Probability Map (Petersen et al. 2023)
Cave/karst	Pseudokarst development Enhanced erosion or mass wasting susceptibility Human injury or casualty	Potential hazard (very low; DOI SHIRA)	DOI SHIRA Risk Mapper Report Graham (2008)
Permafrost	Not applicable	Not applicable	Not applicable
Coastal storm surge/sea or lake level change/shoreline erosion	Not applicable	Not applicable	Not applicable

Hazard	Examples of Risk or Secondary Hazard	Best Professional Judgment	Sources of Geohazard Information
Tsunami	Not applicable	Not applicable	Not applicable
Volcanic eruption	Not applicable	Not applicable	Not applicable
Hydrothermal activity	Not applicable	Not applicable	Not applicable

Cave and Karst

Karst topography develops in limestone, dolostone, gypsum, and other rocks by dissolution, as the rock is chemically and physically eroded by rainwater containing dissolved carbonic acid. Over time, dissolution can create open spaces or voids in the bedrock that develop into larger interconnected cavities or passages. Karst topography presents several hazards (e.g., surface collapse, ceiling collapse, rockfall), as the dissolution of bedrock often weakens its structural integrity. According to the NPS scoping summary for NIOB (Graham 2008), there have been known cases of pseudokarst (subsurface voids or spaces created by non-dissolution) development in the Rosebud Formation. Pseudokarst topography resembles true karst but is formed through non-dissolution mechanisms such as jointing (the development of cracks or fractures that lack displacement), lava emplacement, or piping. The process of piping is a form of subsurface erosion caused by percolating groundwater that creates natural tubes or tunnels in the rock. The impervious nature of the formation is likely responsible for any piping, as the Rosebud Formation redirects groundwater flow, which is responsible for many of the scenic river's springs, seeps, and waterfalls.

Climate Change

Although climate change planning is beyond the scope of this GSRI summary, a discussion of climate change is included because of the potential disruption it may cause to the scenic river's resources, including geologic resources. The climate at NIOB is already changing; all future climate model projections include temperatures above the recent historical average (1979–2012), and average annual precipitation is anticipated to be highly variable (Climate Change Response Program 2024). Projected increases in several variables (e.g., air temperatures, evaporation rates, droughts, and precipitation) may negatively impact groundwater aquifer recharge, which will have a detrimental effect on the watershed quality and flow of the Niobrara River system. As a groundwater-fed river, the Niobrara River is particularly susceptible to periods of drought that may jeopardize aquifer recharge and increase the relative rate of groundwater withdrawal for agricultural or residential use. These modifications to water availability are likely to impact additional geologic processes (e.g., floods, landslides, shoreline erosion), in addition to ecological processes (e.g., invasive species, phenology), wildfire occurrence, visitation, and park management procedures (Climate Change Response Program 2024).

Climate change manifestations that may intensify geologic hazards include the following:

- Increased average temperatures
- Increased frequency and intensity of storms
- Increased frequency and magnitude of fires
- Increased susceptibility to mass wasting events
- Increased extreme weather scenarios, including drought and flooding
- Decreased water availability as groundwater aquifers are stressed or jeopardized

Disturbed Lands

Disturbed lands are those areas where natural conditions and processes have been directly impacted by development, including facilities, mining, roads, dams, and campgrounds; agricultural activities such as farming, timber harvest, and irrigation ditches; and overuse or inappropriate use. Restoration aims to restore

a site, watershed, or landscape to a previous condition, typically a desirable historic baseline. Human activity often disturbs lands, leading to unintended and long-lasting issues that affect other resources. Many of these disturbances obliterate soil profiles, exacerbate the invasion of exotic plants, result in contamination of water and soil, and/or cause erosion and sedimentation. These damages, in turn, frequently impair the quality of habitats, disrupt ecosystem functions, and cause problems for parks managing areas as wildlands. Usually, lands disturbed by natural phenomena such as landslides, earthquakes, floods, and fires are not considered for restoration unless influenced by human activities.

Land Use Changes

As a river park, one of the main management goals of the scenic river is to preserve the free-flowing nature of the Niobrara River. However, the long, linear nature of NIOB makes it susceptible to land use changes adjacent to or upstream from its administrative boundary. According to Mosier (2019), human activities, including dam construction and groundwater diversions for agricultural or residential use, can have a detrimental and possibly long-lasting impact on the flow regime of groundwater-fed rivers such as the Niobrara River. These activities are likely to have an enhanced effect during periods of drought, which can further stress or threaten regional groundwater aquifers (see “Climate Change”). Over the last century, the annual discharge of the Niobrara River has remained relatively stable due to the low number of dams along its length combined with minor agricultural development impacts in the Sandhills region (Mosier 2019). However, as surrounding cities continue to grow, there is a concern that groundwater development may limit water availability and impede the flow of the Niobrara River (National Park Service 2016). In the Niobrara River watershed, there are over 3,000 groundwater wells that have been installed for agricultural, livestock, residential, and other uses (Mosier 2019). Continued pressures or stressors will likely exacerbate issues related to water availability or quality and may threaten the biological, recreational, and scenic integrity of NIOB.

Flooding

The Niobrara River is primarily sustained through groundwater seepage sourced from the High Plains or Ogallala aquifer of the Sandhills region (Alexander et al. 2010; Narumalani et al. 2010). The high infiltration capacity of the Sandhills helps eliminate direct surface runoff from precipitation and provides a steady supply of filtered, clean water for the river and its tributaries. According to Alexander et al. (2009, 2010), groundwater is the primary source of flow regulating the Niobrara River west of Valentine, Nebraska, and overbank flooding is uncommon except during winter ice jams (Figure 11). During the winter season, ice jams form erratically and can cause the Niobrara River to back up and spill over onto the floodplain—including roads, bridges, fields, and private property (National Park Service 1995, 2006b; Alexander et al. 2010). Historic floods and ice jams that occurred during the late 19th and early 20th centuries resulted in multiple bridges being swept away along the river (Franklin et al. 1994). Downstream (east) of Valentine, the typical flow of the Niobrara River is less apparent because of increased precipitation, increased storm runoff supplied from tributaries, and changes in soil infiltration rates along the eastern margin of the Sandhills (Alexander et al. 2009; 2010). On average, the upstream (western) part of the Niobrara River watershed receives approximately 40 cm (16 in) of rain compared to about 60 cm (24 in) in its downstream (eastern) reach (Alexander et al. 2009). In the downstream portion of NIOB, flooding impacts sandbars and islands, which represent important nesting grounds for endangered or threatened species such as the piping plover and interior least tern. Although flooding of the river’s main stem is rare, several tributaries, such as

Muleshoe Creek, may flood annually and have been known to wash out county roads (Figures 12–13; Graham 2008). Additionally, several private campgrounds are situated in flood-prone areas along the river corridor and are susceptible to major storm- or ice jam-related flooding. Several tributaries, especially those on the north bank of the river, have a history of flash flooding due to summer thunderstorms (National Park Service 1995; 2006b). These flashy events result in rapid inundation and present a considerable hazard to infrastructure, resources, and public safety (Figure 14).



Figure 11. Photograph of an ice jam along the Niobrara River in January 2018. The view is facing southwest from Cornell Bridge. Ice jams are a common cause of flooding along the scenic river and allow water to erratically back up and spill over onto the adjacent floodplain. NPS photograph.



Figure 12. Photograph of a washed-out segment of River Road in June 2013. The washout occurred approximately 1.6 km (1 mi) east of the Norden Bridge and exposes the lower terrace alluvium of the Niobrara River. Enhanced runoff and flooding undercut and washed out a sizeable section of the roadway, making it impassable. NPS employee for scale. NPS photograph.



Figure 13. Photograph of a partial washout between Sharp's and Stan's landings in July 2013. Enhanced runoff undercut and washed away a portion of the roadway, leaving behind unconsolidated rocky and vegetative debris. NPS photograph.



Figure 14. Photograph of a bridge washout following July 2013 flooding. The bridge is located immediately east of Sunny Brook Camp along River Road. An unnamed tributary damaged the bridge and deposited mud, silt, rock, and vegetative debris along the roadway surface. NPS photograph.

Mass Wasting

The term “mass wasting” is used to describe downhill movements of rock, soil, or ice and includes several types of landslide phenomena, such as debris (or snow) avalanches, debris flows (mobile water-laden masses of loose rock or soil), slumping or slope creep (downslope movement of soil), and rockfalls. The scenic river is susceptible to mass wasting events that are driven by river incision, groundwater seepage, freeze-thaw processes, and possibly piping. As the Niobrara River continues to incise vertically and laterally into its underlying bedrock, it weakens the riverbank and its slopes, which can lead to instability or failure.

Landslides are a predominant process altering the landscape of NIOB and often involve several mechanisms, including debris slides, soil creep, debris flows, and rockfalls (Figure 15). Many landslides in NIOB are restricted to the steep southern banks of the Niobrara River, especially along incised meanders or sharp bends in the river (Hearty 1978; National Park Service 1995; Alexander et al. 2010). Debris slides are typically composed of colluvium (unconsolidated deposits at the base of a slope or cliff), bedrock, and soil but can include dense woody material (e.g., trees, roots) that binds the mass together as it moves downslope (Hearty 1978; Alexander et al. 2010). According to Hearty (1978), some slides can evolve or enlarge themselves by additional sliding, gullyng, and creep that accumulates additional debris and steepens the slope; larger slides have left unvegetated scars along the riverbank roughly 50 m (160 ft) in height (Figure

16). Along the scenic river, groundwater seepage along the upper surface of the Oligocene Rosebud Formation creates scenic waterfalls and seeps that are known to freeze in the winter. The expansion of ice within cracks in the rock can lead to instability and rockfalls; many waterfalls contain boulders at their bases (see Figure 7). In addition to waterfalls and seeps, the subsurface flow of water can cause pseudokarst development, as groundwater percolation causes piping, which slowly destabilizes the bedrock (see “Cave and Karst”; Graham 2008). In addition to piping and pseudokarst, the Rosebud Formation crumbles easily in areas where it is subjected to alternating wet and dry conditions—a phenomenon that may be due to the presence of swelling clays (see “Swelling Clays”; Hearty 1978). Overlying the Rosebud Formation are the Miocene Valentine Formation and younger colluvium deposits that are both susceptible to groundwater seepage and hillslope instability. Excessive amounts of rainfall or snowfall contribute to the threat of mass wasting events, as additional water increases ground mass and subsurface pore-water pressures, leading to slope destabilization and failure (Hearty 1978). Soil creep is common along the steepened riverbanks of NIOB and exacerbates debris slides by steepening hillsides that have additional colluvium and vegetative debris. A common indicator of creep includes arched or toppled trees that no longer appear to be in their original upright (vertical) growth positions. Another form of mass wasting along the scenic river are “sandruns,” sourced from the unconsolidated sands of the Valentine Formation. As the name implies, sandruns constitute debris flows of sand that migrate downslope under both wet and dry conditions (Hearty 1978).



Figure 15. Photograph of a rockfall upstream of Berry Bridge near Connot Cliff. View is facing upstream to the west. A portion of the cliff face has slumped and collapsed into the river, narrowing the channel with boulders and downed trees. NPS photograph.



Figure 16. Landslide scars along the scenic river at Eagle Bend, downstream of Buffalo Bridge. Landslides commonly occur along the steep bluffs flanking the southern banks of the Niobrara River, especially along incised meanders. In this photo, fresh landslide exposures of the Rosebud Formation lack vegetation, contain downed trees, and have small aprons of colluvium along their lower slopes. NPS photograph / Gordon Warrick.

Radon

Radon is a naturally occurring gas created by the decay of radioactive elements present in many rocks. Although radon is almost always present in small amounts in soil and rocks, some types of rock (e.g., volcanic rocks, granites, dark shales, phosphate-rich rocks, and metamorphic rocks) have the potential to produce above-average amounts of radon gas that can pose a known health risk (Otton 1992). According to the EPA map of radon zones, Brown, Cherry, and Rock counties are identified as zones of lowest potential (zone 3) for indoor radon levels that do not exceed 2 pCi/L; Keya Paha County is a zone of moderate potential (zone 2) between 2 and 4 pCi/L (see [US EPA Map of Radon Zones by State](#); accessed February 2025). The EPA has [guidance](#) for radon mitigation.

Seismicity

The state of Nebraska is traditionally considered an aseismic region, meaning it lacks significant earthquake activity. The USGS utilizes historic seismicity data to prepare seismic hazard probability maps, the latest of which (Petersen et al. 2023) indicates that NIOB occupies an area of low hazard compared to the rest of the country. The closest seismic monitoring station to NIOB is located approximately 6 km (4 mi) southwest of the Highway 7 Landing bridge in Bassett, Nebraska ([EarthScope Seismic Station Map](#)). Although Nebraska

lacks powerful, recurring seismicity, low-magnitude earthquakes still occur throughout north-central Nebraska as deeply buried geologic structures such as faults continue to accommodate stress within the interior of the Earth's crust (see figure 1 of Filina et al. 2018). At least one minor earthquake event has taken place along the scenic river within the Fort Niobrara Wildlife Refuge. This magnitude 2.9 earthquake occurred in December 2005; its epicenter was located along the Niobrara River immediately upstream from the confluence with Big Beaver Creek (see [Nebraska Seismicity | US Geological Survey](#)). Historically (1867 AD to present), there have been at least 20 recorded earthquakes in portions of Brown, Cherry, Keya Paha, and Rock counties (Reagor et al. 1981; Joeckel et al. 2015; Filina et al. 2018). The largest of these was a magnitude 5.1 earthquake that occurred in March 1964 approximately 11 km (7 mi) northwest of Merriman, Nebraska.

Swelling Clays

Swelling clays, or shrink-swell clays, include minerals such as smectites that are physically altered by the presence of water and tend to swell when wet and shrink when dry. As swelling clays expand or contract, the change in volume can undermine the integrity of the substrate, increase the susceptibility of slope failure, and cause infrastructural problems along roadways or trails. According to the USDA NRCS Web Soil Survey, several soils mapped adjacent to the scenic river are rated “low” to “very high” in linear extensibility (a determination of shrink-swell potential; see “Soils”). Linear extensibility ratings are based on the percentage of volume change as soil dries and include four assessment categories: (1) low, <3%; (2) medium, 3–6%; (3) high, 6–9%; and (4) very high, >9%. The ratings for NIOB indicate that swelling clays can cause large volume changes capable of damaging buildings, roads, and other structures. The upstream (western) segment of NIOB in Cherry County and westernmost Keya Paha County is bordered by soils with low swelling potential. However, downstream (east) of the Meadville Bridge, there is a continuous zone of clay-rich soils rated as moderate to very high swelling potential. These soils exist along the floodplain and upper slopes flanking both sides of the river. According to Hearty (1978), swelling clays may be responsible for the disintegration of the Oligocene Rosebud Formation in areas where it is exposed to alternating wet and dry conditions. As a relatively impervious barrier to groundwater flow, the formation is susceptible to seepage that may induce shrink-swell behavior.

Toxicological Soil

According to the DOI SHIRA Risk Mapper report, soils within NIOB have potentially high amounts of arsenic, asbestos or erionite (fibrous silicate minerals), cadmium, lead, selenium, and *Bacillus anthracis*—a naturally occurring soil pathogen known to cause anthrax. Naturally occurring asbestos or erionite occurs in certain geologic settings (e.g., those containing ultramafic or mafic rocks [rocks with low silica content] and fibrous minerals) and can introduce health issues if disturbed by natural erosion or human activities. Inhalation of fine airborne particles of asbestos or erionite can cause various respiratory illnesses, including mesothelioma and other types of cancer. Soil maps show that potentially hazardous concentrations of arsenic, cadmium, lead, and selenium occur within the top 5 cm (2 in) of soil based on 2010 sampling (DOI SHIRA). For more information on naturally occurring arsenic, cadmium, lead, selenium, and their potential health impacts, visit the US Department of Health and Human Services Agency for Toxic Substances and Disease Registry (see <https://www.atsdr.cdc.gov/>; accessed February 2025).

The bacteria *Bacillus anthracis* causes the rare, naturally occurring disease anthrax, which can cause severe illness in both humans and livestock exposed to spores. For more information on the public health risks

associated with anthrax, visit the US Centers for Disease Control and Prevention's anthrax website (see <https://www.cdc.gov/anthrax/about/index.html>; accessed February 2025).

Geologic Resource Protection

Legislatively Required Geologic Inventories

The NPS GRD has developed an article series (<https://www.nps.gov/articles/series.htm?id=FA0A8F89-CD67-1CCE-5A6608B444E8A7C0>; accessed February 2025) that summarizes the laws, regulations, and policies that specifically apply to geologic and soil resources or processes. These protection measures were established to maintain the integrity of these resources or processes while minimizing the impacts of natural or human activity.

The core responsibility of the NPS is to preserve and protect park resources, processes, systems, and values unimpaired for present and future generations. According to National Park Service (2006a), the NPS will preserve and protect geologic resources, features, and processes as integral components of park natural systems. The goals of the NPS are to assess the impacts of natural processes and human activities on geologic resources; maintain and restore the integrity of existing geologic resources; integrate geologic resources management into NPS operations and planning; and interpret geologic resources for the benefit and enjoyment of park visitors (National Park Service 2006a). Various management protection policies applicable to geologic resources, features, and processes are included in National Park Service (2006a) and are also organized at the following website: <https://home.nps.gov/subjects/geology/geoheritage-nps-management-policies.htm> (accessed February 2025).

Paleontological Resources

The paleontological resources of NIOB are invaluable and provide a unique glimpse into the geologic past. Fossils along the scenic river are associated with internationally and nationally recognized sites or “quarries,” some of which are protected and presented for public use by other land managing agencies such as the US Fish and Wildlife Service, the Nebraska Game and Parks Commission, and The Nature Conservancy (National Park Service 1995). However, several known fossil sites along or adjacent to the scenic river corridor are afforded a limited or uncertain degree of protection and interpretation due to their location on private property. According to National Park Service (2016), there has been an increase in illegal fossil looting in quarries within NIOB. Pressures from real estate development and recreational use pose the main threat to these sensitive resources and may directly or indirectly lead to their degradation and destruction (National Park Service 1995).

All paleontological resources are nonrenewable and subject to science-informed inventory, monitoring, protection, and interpretation. Protection measures for fossils are outlined by the 2009 Paleontological Resources Preservation Act (PRPA). For additional information regarding paleontological resource laws, regulations, and policies, the NPS GRD developed the following summary article: <https://www.nps.gov/articles/paleontology-legal-instruments.htm> (accessed February 2025).

Hydrological Resources

As a hydrological park, one of the main management concerns for NIOB is the water quality and quantity of the Niobrara River system, including its numerous tributaries. In 2008 and 2013, the Niobrara River was

designated one of “America’s most endangered rivers” due to water usage disputes to ensure adequate channel flow for recreation and wildlife (American Rivers 2008, 2013). Management of the river system is a complex and critical resource issue impacted by a myriad of variables such as climate change, land usage, erosion, landslides, groundwater sustenance, and water diversions. The Niobrara River and its tributaries are hydrologically connected to and sustained by the regional High Plains aquifer, which provides steady, dependable flow supporting NIOB’s ecological diversity, recreational opportunities, and landscape evolution. However, increased land usage and development—including agricultural irrigation, dam construction, and groundwater well installation—have diverted significant amounts of surface water and groundwater from the Niobrara watershed (see “Disturbed Lands”; Narumalani et al. 2010; Mosier 2019). In its 2025 annual report, the Nebraska Department of Natural Resources designated the groundwater resources of the upper Niobrara River basin as “fully appropriated,” a determination meaning that the balance between water supply and demand has been reached (Nebraska Department of Natural Resources 2024). According to Alexander et al. (2009), there is an inherent conflict regarding further groundwater development in the Niobrara River basin, as annual and peak flows have been persistently below average since 2002. Projected climate change scenarios for NIOB include an increased likelihood of extreme temperature and weather events that may impact aquifer recharge rates and the integrity of the river system (see “Climate Change”). For the purposes of sustainable management, there is an emphasized importance of understanding the complex hydrology of the Niobrara River basin, including its geology, hydrologic disturbances (e.g., floods, droughts, ice jams), and projected groundwater needs (Alexander et al. 2009, 2010).

Inventory Needs

The following table (Table 4) presents geologic and soil resources inventory needs that were identified in NPS planning documents or through literature review.

Table 4. List of identified geologic and soil resources inventory needs for the scenic river.

Subject	Inventory Need(s)	Reference(s)
Climate change	Develop a climate change adaptation plan. A regional planning effort would be particularly useful and could assess the impacts of major hydrological disturbances (e.g., floods, droughts, ice jams, groundwater diversions).	National Park Service (2016)
Cultural resources	Perform a detailed inventory and assessment of NIOB’s Indigenous cultural sites. The majority of recorded sites within NIOB have yet to be evaluated. There is potential for discovery of archeological resources, but additional work would be required for a thorough assessment.	National Park Service (1995, 2006b)
Geohazards	Perform a floodplain survey or floodplain mapping of the scenic river. Floods along the mainstem of the Niobrara River occur mainly as a result of winter ice jams, which form erratically and spill water onto the floodplain, inundating roads and fields along the river. Spring and summer floods are rare on the mainstem. Flash flooding and mud deposits have occurred along tributary creeks on the north bank due to summer thunderstorms. No floodplain survey or mapping has been performed.	National Park Service (2006b)

Subject	Inventory Need(s)	Reference(s)
Geomorphology	Determine the nature of Niobrara National Scenic River fluvial-geologic features using a sediment budget. The object of this proposal is to understand the relationship between sediment transport capacity and sediment supply at Niobrara National Scenic River and how this relationship has changed over time. These data will provide a baseline crucial to assessing potential effects of additional water diversions while simultaneously providing an interpretive context for the geologic processes active in the river today.	National Park Service (2016)
Geomorphology	Investigate the effects of the possible removal of Cornell Dam on river hydrology and sediment transport.	Narumalani et al. (2010)
Geomorphology	Conduct research to assess the effects of groundwater diversions and withdrawals on Niobrara River flow, including physical and ecological processes.	Narumalani et al. (2010)
Interpretation	Development of a geologic resources interpretive plan. According to National Park Service (2006b), there has been no cohesive effort to orient the public about NIOB's services, opportunities, and responsibilities, and no concerted effort has been made to develop greater public understanding and appreciation of the scenic river's stellar natural and cultural resources. Some visitors do not understand that the riverbanks are mostly private property.	National Park Service (2006b)
Inventory and assessment	Develop a visual resource inventory. The inventory should identify vantage points and replicate surveys to establish baselines and document changes to the landscape of NIOB. The inventory would identify significant viewpoints along the river, as well as look down upon it using aerial photography and video. The use of video would be a qualitative assessment to document the general character of the river.	National Park Service (2016)
Management	Develop a river management plan. Needs associated with the management plan include river access, visitor use, and the establishment of a long-term framework for cooperative management of land use and development.	National Park Service (2016)
Management	Develop a cultural or natural resource stewardship plan. Particularly, the plan could develop action agendas that achieve desired future conditions for NIOB's natural and cultural resources, establish standards for managing the scenic river's resources consistent with the policies of the National Park System, and prioritize a broad array of inventorying, monitoring, and resource management actions to be undertaken by the NPS in cooperation with public and private partners. A fully developed resource stewardship plan is essential to gaining specialized federal funding for selected management initiatives and undertakings.	National Park Service (2006b)
Paleontological resources	Organize NIOB's paleontological collections. The scenic river's collections include a handful of fossil specimens, but they have little documentation and have not been formally organized.	Tweet et al. (2011), Justin Tweet (NPS GRD, written communication, April 2025)
Visitor use	Develop a recreational use impact assessment. There are roughly a dozen locations along the scenic river impacted by high visitor use. The assessment would monitor river access landings and trailheads over time to determine impacts from visitor use.	National Park Service (2016)

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