National Park Service
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Natural Resource Stewardship and Science

Obed Wild & Scenic River

Geologic and Soil Resources Inventory Summary

Sandstone cliffs cap the nearly vertical slopes above the Obed River. The river and its tributaries carved deep, V-shaped gorges through the sandstone and shale layers of the Cumberland Plateau. Blocks of sandstone have broken away, tumbling downslope to litter the valley floor below, adding interest to the watercourse. NPS photograph.

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Geologic and Soil Resources Inventory Summary

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Abstract

This document summarizes the status of National Park Service (NPS) Geologic and Soil Resources Inventory (GSRI) deliverables for Obed Wild & Scenic River (OBRI). 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 (1–5 years).

GRI hosted a baseline scoping meeting for OBRI in 2007. Baseline bedrock and surficial geologic maps were delivered to the park in 2015 and updated in 2024. SRI delivered a legacy soil database and map to the park in 2006 and delivered updated data and an "enhanced report" in 2013.

Geologic heritage resources of particular interest include the Obed River, its tributaries and gorge; stratotypes; rock shelters and first inhabitants; homesteading; oil, gas, and coal; unique, geologically controlled habitats and ecological relationships; and river rapids and recreation. Soils at OBRI are generally thin and rocky on upper slopes with limited fertility. In the river floodplains and valley bottoms, the soils are thicker and more fertile but of limited spatial extent.

Geologic and soil resource management issues include fluvial issues, abandoned mineral lands (oil, gas, and coal), land use, visitor overuse, slope movements, and seismicity. Geohazards include flooding, extreme precipitation events, landslides, earthquakes, and toxicological soils.

Inventory needs for geologic heritage include cliff use surveys, trail use studies, field inventories, ecological flow studies, and streambed mapping. For soils, inventory needs include detailed correlations of soil type and vegetation communities. Geologic and soil resource management inventory needs include cave and karst mapping (talus caves), landscape evolution mapping, slope movement potential mapping, identifying gaps in cliff lines and gorge access points, studying effects from urban and exurban sprawl, hydrogeologic modeling, slope analyses, digitizing mine maps, spoil area mapping, and abandoned mineral land site identification.

Additional guidance for OBRI 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) aids in the collection of new data and 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. The GSRI also includes the legacy Geologic Resources Inventory (GRI) and Soil Resources Inventory (SRI) programs.

In the late 1990s, the GRI and SRI programs were established as two of the 12 original 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 the more than 270 parks that are part of the I&M networks. For both GRI and SRI, the primary deliverable was a digital geospatial information system (GIS) map. Between the 1990s and early 2020s, in addition to a digital map, GRI scoping summaries, geologic map posters, and GRI reports were produced for most of the 270 parks. GRI and SRI baseline inventory products are available through the NPS Geodiversity Atlas and the NPS DataStore. These products are designed to enhance stewardship of park resources by providing valuable information about soils, geologic formations, hazards, and links between geology, history, and other natural resources.

The GRI and SRI are now unified as one inventory, the GSRI, under the Inventories & Assessment (I&A) Program. The I&A Program, and henceforth the GSRI, operates under a park-proposed inventory strategy in which parks submit natural resource inventory and assessment project proposals to the Project Management Information System (PMIS) during the Servicewide Comprehensive Call (SCC). Park staff should refer to the GSRI SharePoint and I&A Program SharePoint for instructions on how to submit a project proposal including basic eligibility requirements, evaluation criteria, and the approval and implementation process.

As of 2025, the GSRI is in the process of completing baseline inventories for I&M parks and transitioning to the I&A model of accepting park-proposed projects from all NPS units. During this transition period, 13 parks, including Obed Wild & Scenic River (herein referred to by its four-letter code: OBRI, or as “the park”) were identified as not having a baseline GRI report. This GSRI summary serves as a substitute for a baseline GRI report and is intended to support the park’s participation in the I&A Program. As such, it summarizes the status of GRI and SRI deliverables for OBRI and provides information on current geology and soils resource management concerns with a focus on identifying inventory needs. Information in this summary was compiled from existing reports, meetings with park staff, and the best professional judgment from GSRI and Washington Support Office (WASO) Geologic Resources Division (GRD) geoscientists.

Baseline GSRI Products

Geology

The digital geologic map of OBRI is available on the NPS DataStore, accessed through the Integrated Resource Management Applications (IRMA) portal (see https://irma.nps.gov/DataStore/Reference/Profile/2194459) and is compiled and adapted from the following six source geologic maps, reports, and databases:

- Coker, A. E. 1965. Geologic map and mineral resources summary of the Jones Knob quadrangle, Tennessee (scale 1:24,000). Geologic Quadrangle Map GM 116-NW. Tennessee Division of Geology, Nashville, Tennessee.
- Coker, A. E. 1965. Geologic map and mineral resources summary of the Twin Bridges quadrangle, Tennessee (scale 1:24,000). Geologic Quadrangle Map GM 116-NE. Tennessee Division of Geology, Nashville, Tennessee.
- Finlayson, C. P., R. L. Powell, G. E. Kronman, and J. L. Moore. 1985. Geologic map and mineral resources summary of the Pilot Mountain quadrangle, Tennessee (scale 1:24,000). Geologic Quadrangle Map GM 122-NW. Tennessee Division of Geology, Nashville, Tennessee.
- Scruggs, P. L., G. Stearns, B. R. Hansen, A. L. Wunderlich, and R. D. Hatcher, Jr. 2015. Geologic map of the Hebbertsburg 7.5-minute quadrangle, Tennessee (scale 1:24,000). University of Tennessee, Knoxville, Tennessee.
- Scruggs, P. L., J. L. Moore, D. F. Gilmore, B. R. Hansen, A. L. Wunderlich, and R. D. Hatcher, Jr. 2015. Geologic map of the Lancing 7.5-minute quadrangle, Tennessee (scale 1:24,000). University of Tennessee, Knoxville, Tennessee.
- Scruggs, P. L., B. Rascoe, B., R. G. Stearns, B. R. Hansen, A. L. Wunderlich, and R. D. Hatcher, Jr. 2015. Geologic map of the Fox Creek 7.5-minute quadrangle, Tennessee (scale 1:24,000). University of Tennessee, Knoxville, Tennessee.

Additional GSRI documents include the GRI scoping report from the 2007 GRI scoping meeting (Thornberry-Ehrlich 2009).

- Thornberry-Ehrlich, T. L. 2009. Geologic Resources Inventory Scoping Summary Big South Fork National River and Recreation Area & Obed Wild and Scenic River. Geologic Resources Inventory Report. National Park Service, Fort Collins, Colorado. https://irma.nps.gov/DataStore/Reference/Profile/2250200

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 Web Soil Survey along with NPS-specific uses for the data. The Natural Resources Conservation Service (NRCS) plans to complete all soil survey areas in the United States by 2026 (Thompson et al. 2020).

SRI delivered a legacy soil database and map to the park in 2006 and delivered updated data and an "enhanced report" in 2013. This is available on the NPS DataStore accessed through IRMA (https://irma.nps.gov/DataStore/Reference/Profile/1048945). This map is part of a static dataset that will not be updated in the future as revisions or new data become available.

The most up-to-date soils data for OBRI is available via Web Soil Survey, which is updated and maintained regularly by the NRCS. Management-focused maps for OBRI 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.

The soil survey data are broken down into county-level soil survey areas. Each soil survey area is assigned a code and a name (Table 1). OBRI includes three soil survey areas. The soil survey status is complete for OBRI. Table 1 lists the soil survey areas and their completion status. To view the soil data for OBRI on the Web Soil Survey website, use the navigation pane on the left side of the main webpage to select the soil survey area of interest or the NPS unit and set it as the "area of interest" using the "AOI" icon along the top of the map. Use the "Soil Map" tab at the top to view the soil map and the "Soil Data Explorer" tab to view additional soil data, including linear extensibility and suitability for development. See additional Web Soil Survey guidance and FAQs or contact the NRCS state soil scientist for technical assistance.

Table 1. Soil Survey areas.

Soil Survey Area Code	Soil Survey Area Name	Status
TN035	Cumberland County, Tennessee	Complete
TN701	Fentress and Pickett Counties Area, Tennessee	Complete
TN629	Morgan County Area, Tennessee	Complete

Geologic Setting and History

The Obed River and its main tributaries (Clear Creek, Daddy's Creek, and Emory River) flow unimpeded more than 72 km (45 mi) within OBRI in north-central Tennessee. These waters have cut 150 m (500 ft) deep, V-shaped gorges in a dendritic (tree-like) pattern into the rolling hills of the Cumberland Plateau—a northeast–southwest trending tableland area stretching from northeast Kentucky to central Alabama (Figure 1; Fenneman 1938; National Park Service 2015a, 2017). As the Obed River flows northeastward toward its confluence with the Clinch River and ultimately the Tennessee River system, the river passes myriad geologic formations, including sedimentary rock layers and landforms created by weathering and erosion of these layers.

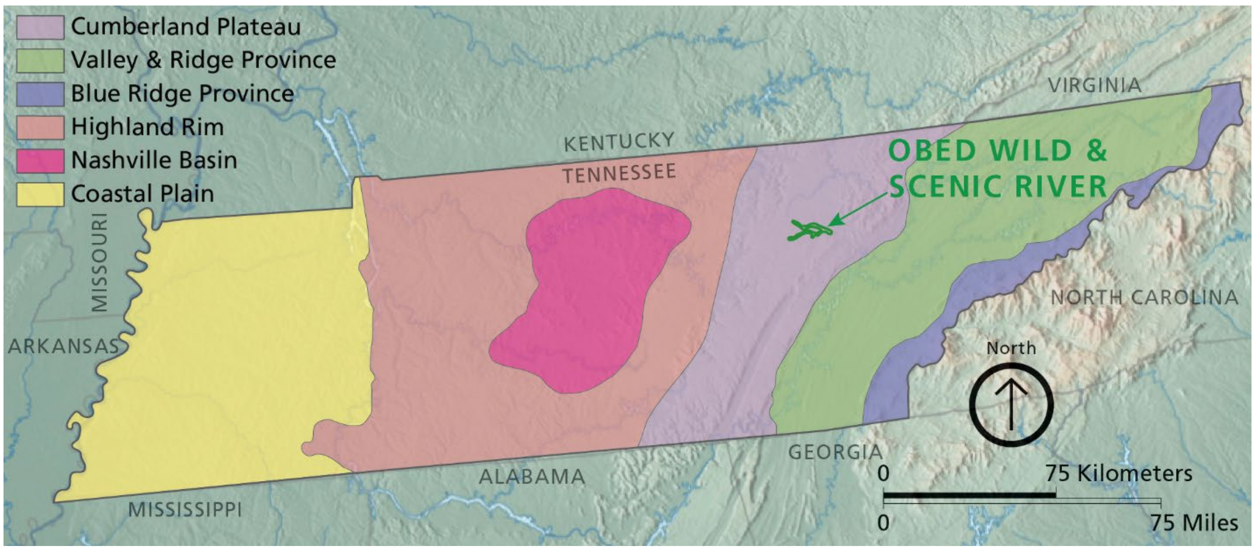

Figure 1. Map showing the Cumberland Plateau between the Highland Rim and Valley and Ridge physiographic province. Physiographic provinces are geographic regions characterized by distinct landforms, often shaped by specific geologic and climatic factors. Provinces are distinguished by their unique relief, subsurface rock types, and structural elements. The green outline indicates the approximate location of OBRI. Graphic by Trista L. Thornberry-Ehrlich (Colorado State University), with information from the US Geological Survey and Middle Tennessee State University. Basemap by Tom Patterson (National Park Service), available online: http://www.shadedrelief.com/physical/index.html (accessed 2 February 2025).

OBRI's present-day landscape, encompassing about 2,094 ha (5,173 ac), is a function of its geologic history (Anderson 2017). The following are notable geologic events that shaped the landscape of OBRI:

- More than 323 million years ago, during the Mississippian Period (358.9 million–323.2 million years ago), a warm, shallow marine basin covered the OBRI area (Figure 2A). Regional uplift during the Allegheny Orogeny (mountain-building event) caused the marine waters to recede and rivers to flow across the landscape (Figure 2B; Milici et al. 1979). Following a period of erosion or non-deposition, the oldest sedimentary rocks at OBRI were formed in river systems that flowed across the landscape (Coker 1965a, b; Scruggs et al. 2015a, b). These rivers carried sediments shed from the rising heights of the Appalachian Mountains to the east, depositing them as thick sandstones and conglomerates of the Pennsylvanian Period (323.2 million–298.9 million years ago) atop the Mississippian marine rocks, including the following: Sewanee Conglomerate, Newton Sandstone, Rockcastle Conglomerate, Crossville Sandstone, Coalfield Sandstone, Wartburg Sandstone, Slatestone Formation, and Indian Bluff Formation.

Compared to shales and limestones, sandstones and conglomerates are more resistant to erosion. In addition to "holding up" the tableland of the Cumberland Plateau, they also form the steep cliff walls lining the gorges. Erosion, regional dip (tilt of the rock layers), and fractures influence the formation of many stone overhangs, mesas, chimneys, ledges, waterfalls, cracks, and shelters in the Pennsylvanian rocks at OBRI (Scruggs et al. 2015c).

- Throughout the Pennsylvanian, while rivers were flowing across the landscape, sea level rose periodically, causing incursions of marine or estuarine water across the landscape (Coker 1965a, b; Scruggs et al. 2015a, b). These low-energy environments accumulated fine-grained shales, including the following: Gizzard Group, Whitwell Shale, Vandever Formation, Dorton Shale, Burnt Mill Shale, and Glenmary Shale.

  These settings also harbored extensive forests, vast swamps, and marshes. The organic material in these environments collected in thick layers that, with time, heat, and pressure upon burial, became coal seams (see Figure 2B). Coal seams include the Jellico, Poplar Creek, Hooper, Potters Falls, Rex, Nemo, Morgan Springs, Richland, and Sewanee coal beds (Finlayson et al. 1985; Scruggs et al. 2015).

- The geologic record after the Pennsylvanian is missing at OBRI. It either never accumulated, or more likely, accumulated and has since eroded away. Throughout the Mesozoic (251.9 million–66.0 million years ago) and Cenozoic (66.0 million years ago–present) Eras, Earth-surface processes of weathering and erosion removed vast amounts of rock (Figure 2C), transporting them with wind and water downslope to ultimately become part of the coastal plain. These events are recorded today in the Tertiary (66.0 million–2.58 million years ago) and Quaternary (2.58 million years ago–present) surficial deposits.

- During the Pleistocene Epoch (2.58 million–10,000 years ago), climate fluctuations caused a series of ice ages or continental-scale glacial advances. Although the ice sheets did not reach as far south as Tennessee, the colder climates in proximity to the glaciers accelerated erosion and weathering. At OBRI, colluvium blocks (a type of slope deposit) of sandstone are widespread and record intense erosional forces—some of the blocks are car-sized or larger. Other surficial deposits include colluvium of boulders, cobbles, and pebbles.

- Today, the Obed River and its tributaries continue to cut through the geologic layers and transport sediment along their lengths. They deposit unconsolidated alluvium, gravel, sand, silt, and clay along their channels and narrow floodplains. Weathering, in concert with local topography, climate, and organic material, also created soils that support specific vegetation communities at OBRI (see “Unique, Geologically Controlled Habitats, and Ecological Relationships”).

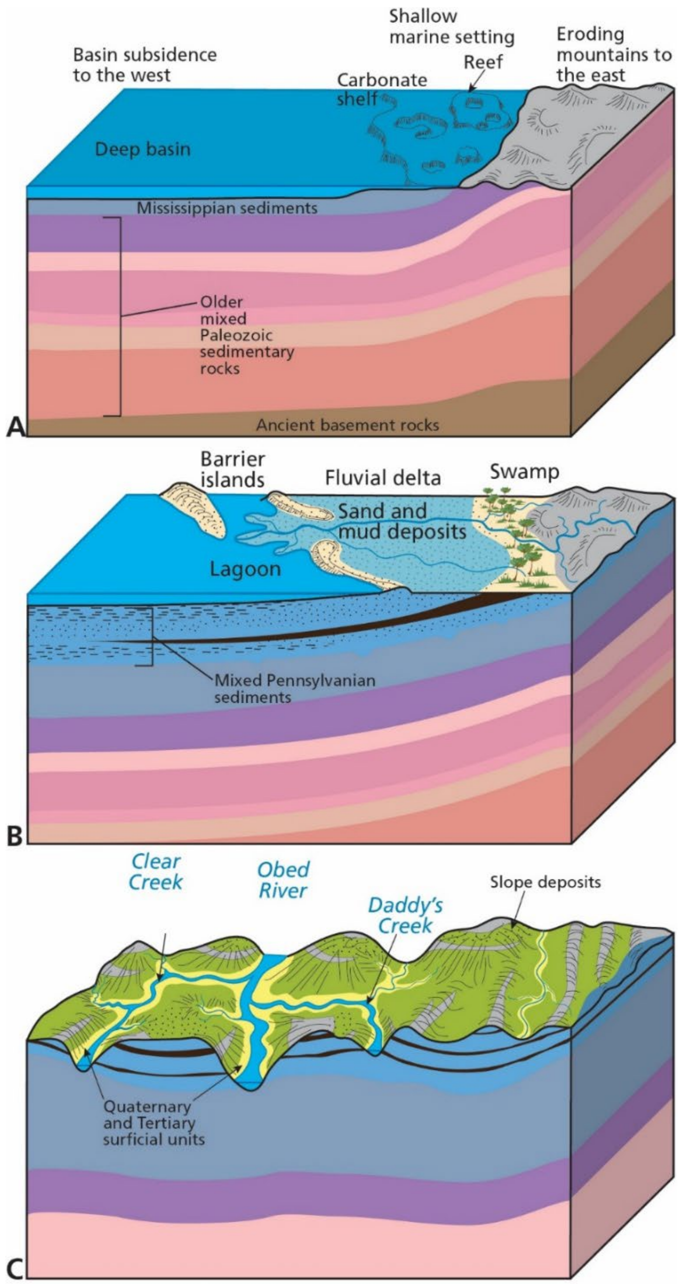

Figure 2. Block diagrams of the geologic evolution of the OBRI landscape. A) About 310 million years ago, fine-grained shales and limestones accumulated in a marine environment. B) Around 300 million years ago, erosion and uplift caused sea levels to drop, rivers deposited sand and pebbles from the rising Appalachian Mountains, and swamps formed organic debris that later became coal seams. Periodic marine incursions added fine-grained layers, forming the Cumberland Plateau. C) Regional rivers and streams carved deep gorges, creating the dissected plateau landscape seen today. Graphic by Trista L. Thornberry-Ehrlich (Colorado State University), with information from Rice et al. (1979) and Milici et al. (1979).

Geologic Heritage

Geologic heritage, or geoheritage, exists where geology overlaps with human experiences and values. It is our history told through the lens of geology. It encompasses the significant geologic features, landforms, and landscapes characteristic of our nation, which are preserved for the full range of scientific, aesthetic, cultural, ecosystem, educational, recreational, tourism, and other values that society places on them. Geoheritage sites are conserved so that their lessons and beauty endure as a legacy for future generations. Such areas generally have great potential for scientific studies, use as outdoor classrooms, and enhance public understanding and enjoyment. Geoheritage sites are fundamental to understanding dynamic earth systems, the succession and diversity of life, climatic changes over time, the evolution of landforms, and the origin of mineral deposits. Currently, the United States does not have a comprehensive national registry that includes all geoheritage sites, but many entities, including the NPS and the US Geological Survey (USGS), are working to introduce and advance the idea of geologic heritage (https://apps.usgs.gov/geoheritage_sites_of_the_nation/).

Geoheritage is prominent in OBRI's 1976 enabling legislation: OBRI was established for outstandingly remarkable aesthetics, wildlife, fish, as well as recreational, cultural, ecological, geological, and aquatic values. OBRI attracts more than 250,000 visitors per year (National Park Service 2026). The Obed River is one of the last free-flowing, wild river systems in the eastern United States (National Park Service 2015a). It is the only Wild and Scenic River in Tennessee and only one of two in the southeast United States (Hughes et al. 2018). Interactions between humans, the river, and rock features factor heavily in OBRI's significance statements as stated in the foundation document (National Park Service 2015a). These statements describe OBRI's distinctive nature and why it is important within a global, national, regional, and systemwide context.

- The narrow gorges, high water quality, and the dynamic, free-flowing nature of the Obed Wild and Scenic River system create an extraordinary, biologically diverse riverine system and provide habitat for rare and unique species.
- The remarkable interplay between ongoing geologic and erosional processes forms the dramatic gorges of the Obed River System, which contains a high density and diversity of geologic features, including overhanging cliffs, waterfalls, natural arches, and cobble bars (see "Cobble Bar Communities"). Cobble bars are elongated, raised features made of cobbles (stones 64–256 mm [2.5–10 in] in size) that form in rivers and streams due to the movement of water by the sorting action that deposits larger stones in linear patterns.
- The deep and narrow gorges of the Obed River System provide spectacular views of high bluffs, waterfalls, and remarkable scenic vistas unscarred by human development.
- The Obed River System provides a highly scenic, wild, and primitive setting allowing for diverse and challenging recreational experiences, most notably world-class climbing and regionally significant whitewater paddling.

- The steep and rugged terrain of the gorges and highly variable flows of the Obed River System limit river access and provide a remnant of primitive America where visitors experience a sense of solitude and an intimate experience with the landscape.

The Obed River and Gorge

The free-flowing Obed River and its tributaries carve 150 m (500 ft) deep scenic gorges and valleys through the layers of ancient bedrock of the Cumberland Plateau at OBRI. In some places, their courses trace regional faults or fractures in the rock layers—natural zones of weakness (Egloff 1986). OBRI is characterized by dendritic river drainage patterns and narrow, V-shaped gorges with river valleys dotted by huge boulders that have broken from the cliff faces. The rivers and streams at OBRI consist of stretches of churning whitewater rapids, flows around car-sized boulders, cobble bars, and quiet pools nestled below towering cliffs and forested talus slopes (Wolfe et al. 2008; National Park Service 2015a; Henderson et al. 2021).

The natural flow is flashy and variable with torrents following rainstorms alternating with slow, low flows during droughts (National Park Service 2015a). Flash floods accommodate great geomorphological changes (Mayfield 1989). After rainfall, geologic features have some control over streamflow response. Sandstones (e.g., Rockcastle Sandstone) with their characteristic fractures accommodate or amplify infiltration (movement of water through the rock), whereas shales (e.g., Vandever Formation) prevent infiltration, causing water to accumulate on their upper surfaces. This groundwater then flows laterally to streams as discharge (Knight et al. 2014).

The river systems are geomorphologically active, continually moving large amounts of sediment as they erode cliffs, slopes, and streambeds. This sediment transport that is vital in the creation and maintenance of the globally rare (less than 200 ha [500 ac] remain on Earth) cobble bar communities found in their channels (National Park Service 2015a; Wolfe et al. 2008). The gorge is the recreational focal point of OBRI, and its steep, nearly vertical cliffs and overhangs of sandstone are attractive to climbers (Thornberry-Ehrlich 2009).

At OBRI, erosion and weathering of the sedimentary rock layers above the Obed River and its tributaries form myriad geologic features such as arches (a hole in the rock with an opening of at least 1 m [3 ft]), fins (long, narrow walls or ridges of rock), alcoves (bowl-shaped recesses or hollowed out areas in a rock face), overhangs, balanced rocks, chimneys (tall, narrow vertical rock columns or shafts) and stone shelters (Figure 3). Notable OBRI examples of these types of features include an unnamed arch along Point Trail, Lilly Arch (Figure 4), and Devil's Breakfast Table. Fins, alcoves, and arches tend to form in resistant sandstones, which are locally undercut by the erosion of less resistant underlying shales and siltstones. A single ridge can host a suite of features ranging in erosional development from an overhang to a fin to an arch followed by a chimney or balanced rock, which are the last erosional remnants of a ridgeline (Thornberry-Ehrlich 2009). These places are noteworthy, and many are associated with local stories, as is reflected in their names.

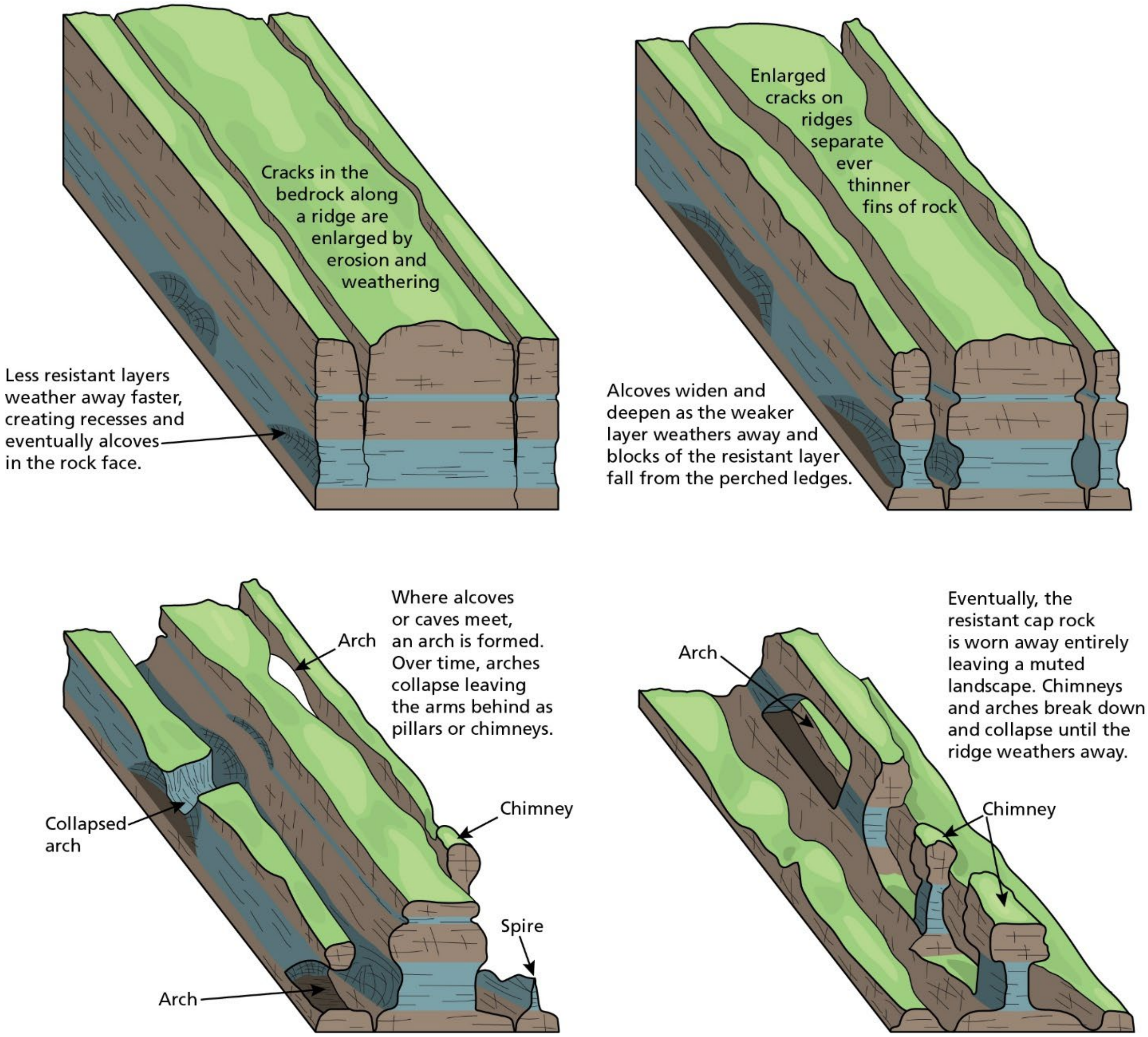

Figure 3. Block diagrams of rock formation evolution. At OBRI, massive layers of resistant sandstone, interbedded with layers of less resistant siltstone or shale, set the stage for the formation of arches, alcoves or shelters, chimneys, ledges, and spires (tall, slender, pointed rock that rises sharply from the ground, often resembling a tower). The process causes ridges of rock to slowly be whittled away to thinner and thinner fins, which are breached in some places, forming an arch or window. Over time, the arch collapses, reducing the fins to mere bumps on the topography. Graphic by Trista L. Thornberry-Ehrlich (Colorado State University).

Figure 4. Photograph of Lilly Arch. Blocky layers of Rockcastle Sandstone resisted erosion to form arches, such as Lilly Arch at OBRI. Weaker layers beneath the arch preferentially weathered away. Arches are one in a series of landforms that form as a column of resistant sandstone weathers away. NPS photograph (date unknown).

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. 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 (e.g., the Cretaceous Mesaverde Group named for Mesa Verde National Park, Colorado).

There are two kinds of stratotypes that are relevant to OBRI: type section and type locality. A type section is an important reference exposure for a named stratified (layered) geologic unit. It presents a relatively complete and representative example of this unit. Once a type section is assigned, it is never changed by geologists. Type localities are specific geographic locations encompassing the type section of a formally recognized and defined geologic unit (North American Commission on Stratigraphic Nomenclature 2021; Henderson et al. 2022).

There are no designated stratotypes identified within the boundaries of OBRI. However, 10 identified stratotypes occur within 48 km (30 mi) of OBRI boundaries: the Ordovician Lenoir Limestone (type locality), the Pennsylvanian Crooked Fork Group (type section and type locality), Dorton Shale (type locality), Crossville Sandstone (type locality), Newton Sandstone (type area), Coalfield Sandstone (type locality), Slatestone Formation (type section), Glenmary Shale (type locality), and Rockcastle Sandstone Member of the Bee Rock Formation (type locality; Henderson et al. 2021).

Rock Shelters and First Inhabitants

The natural rock shelters, arches, overhangs, and alcoves of the OBRI region, which now serve as popular recreational sites, once provided essential protection for the area’s earliest inhabitants (Figure 5; Neff 1981; Ferguson 1988; National Park Service 2015a). These Indigenous peoples left behind artifacts such as pottery and tools, offering glimpses into their lives (Neff 1981; National Park Service 2015a). The landscape, along with much of the flora and fauna at OBRI, still resembles the environment that Indigenous groups inhabited over 300 years ago (National Park Service 2015a). Indigenous people named many natural features in the region, including the Obed River (Wahlers 1992). The Emory River, however, was named after William Emory, a soldier who drowned while crossing the river following a raid on Indigenous villages in Chattanooga (Wahlers 1992).

Figure 5. Photograph of a stone overhang and climber at OBRI. Resistant sandstone and conglomerate are left as ledges and overhangs when less resistant underlying layers are weathered or eroded away. This forms both world-class climbing opportunities and natural shelters that humans have used for thousands of years, leaving a rich archeological record at OBRI. NPS photograph (date unknown).

Archaeological analyses indicate that the earliest and most intensive occupation of the Cumberland Plateau, including OBRI and Big South Fork National River and Recreation Area, occurred during the early Archaic period, about 10,000 years ago. During this time, Indigenous groups primarily inhabited open upland environments rather than gorge rock shelters (Ferguson 1988). A drier climate led to lighter occupation during the late Archaic and early Woodland periods, around 3,200 years ago. During the middle Woodland period, about 1,800 years ago, Indigenous groups increased their use of the area, favoring gorge rock shelters. This was followed by moderate use during the late Woodland period, more than 400 years ago (Ferguson 1988).

The sourcing of lithic materials such as chert, chalcedony, and other microcrystalline rocks provides insights into the procurement strategies, territoriality, and mobility of Indigenous groups. While OBRI's own rocks contain few microcrystalline materials suitable for toolmaking, Mississippian rocks of the eastern Highland Rim to the west and Mississippian and Ordovician rocks of the Valley and Ridge province to the east were likely sources (see Figure 1). The prevalence of non-local raw materials suggests active settlement and trade with adjacent regions, particularly to the west (Ferguson 1988).

Homesteading

Daniel Boone, the renowned frontiersman, explorer, and folk hero, played a significant role in shaping the history of the OBRI region. During the 1760s and 1770s, Boone explored the Cumberland Plateau, including the Obed River area, in search of hunting grounds and westward routes (Wahlers 1992). His explorations established early frontier trails that later guided settlers and traders into Tennessee. Today, parts of Boone's original trail remain visible and are used by hikers and paddlers navigating the rugged terrain of OBRI.

By 1780, people of European descent began hunting and exploring the OBRI area, followed by homesteaders who established permanent settlements by 1800. Many early settlers used natural rock shelters as homes (Thornberry-Ehrlich 2009). The Cumberland Plateau's rugged landscape posed significant challenges, with sparse soils on the tablelands, steep rocky slopes, and limited fertile land confined to narrow areas along rivers and streams that were prone to flooding. Settlers cleared land for farming and used controlled fires to improve grazing conditions for cattle (Schmalzer 1988).

Despite these challenges, pioneers thrived in the isolation and independence of the Cumberland Plateau, finding innovative ways to sustain themselves. Evidence of early industry can be seen at Lilly Bridge, where remnants of a gristmill demonstrate efforts to harness the river's hydrologic power (Wahlers 1992; National Park Service 2015a). The arrival of railroads between 1879 and 1900 marked a turning point, leading to widespread logging that stripped the area of its old-growth forests by 1945. This deforestation caused severe erosion and sedimentation in the region's rivers, altering the landscape and ecosystems (Figure 6; Schmalzer 1988). Until the 1950s, transportation in the area remained limited to railroads, horses, and foot travel, reflecting the enduring challenges of the rugged environment (Wahlers 1992).

Today, the legacy of Boone and the early settlers is preserved in the trails, historic sites, and the wild beauty of the Obed River region. The park serves as a window into the resilience and resourcefulness of those who first explored and settled this untamed landscape.

Figure 6. Historic photographs of railroads at OBRI. Railroads were essential to the local economy at OBRI, facilitating logging and mining operations. Left image shows the Nemo Depot and tunnel 24 as they appeared in 1936. Right image shows flood damage to a railway line at OBRI caused by a 1929 flood. NPS historic photographs, taken by Michael R. O’Neal.

Oil, Gas, and Coal

The Mississippian rocks that lie beneath the Pennsylvanian rocks at OBRI contain oil and gas resources (see “Abandoned Mineral Lands (AML) and Oil and Gas Operations”). These resources contributed to a long history of oil and gas development in OBRI. Exploration in the Cumberland Plateau began as early as the late 19th century, when shallow oil wells were first drilled in nearby counties. By the early to mid-20th century, oil and gas drilling had become a widespread economic activity across eastern Tennessee, with many local families and small companies holding mineral rights or operating wells (Glenn 1921). In some areas, remnants of old derricks, storage tanks, and pipelines still remain, reflecting a time when fossil fuel extraction was a significant part of the regional economy.

While much of this early fossil-fuel development was small-scale and technologically limited, it laid the groundwork for continued interest in the area's subsurface resources (Cumberland National Scenic Byway date unknown). OBRI’s enabling legislation prohibits oil and gas extraction and development within the gorge area but allows for permitted development in the adjacent areas. As technology advances and economic interest increases, exploration for deeper reservoirs and resources may accelerate in the OBRI area. New wells may encounter natural gas reservoirs, which produce for a longer period than traditional oil wells and have a longer-lasting impact on the environment (Thornberry-Ehrlich 2009).

The rocks, well exposed in the steep-sided gorges, contain abundant coal seams (Figure 7). The earliest recorded coal mining activity at OBRI dates to the late 1800s. Today, no active coal mining is happening in the Obed River watershed; one inactive permitted mine exists (Hughes et al. 2018).

Figure 7. Photograph of a coal seam exposed in an outcrop. Heterogeneous layers of sedimentary deposits characterize the rocks, recording shifting environmental conditions during their deposition. The coal seam (dark-colored layer toward bottom of photograph) records the existence of an ancient, long-standing swamp or marsh in this location. Organic material accumulated in the marsh and was later buried, heated, and compressed by overlying deposits to form coal. When the seams are thick enough, they become economically viable to mine and extract for energy production. Photograph location is within Big South Fork National River and Recreation Area but shows the same rocks present in OBED. Photograph by Trista L. Thornberry-Ehrlich (Colorado State University), taken in 2007.

Unique, Geologically Controlled Habitats, and Ecological Relationships

Important relationships exist between flora, fauna, soils, and geologic outcrops at Obed Wild and Scenic River (OBRI). The Cumberland Plateau is the world's longest expanse of hardwood-forested plateau, with nutrient-rich soils formed by the weathering of geologic units that support diverse forests (The Nature Conservancy 2003; Hughes et al. 2018). Factors such as landscape position, parent material, local climate, organic input, and time also influence the availability of plant nutrients in these soils (Blair 2010). At OBRI, nutrient-poor soils are derived from rock underlying gorges, hillsides, and ridgetops, while floodplain soils are richer in essential nutrients (Schmalzer 1988; Natural Resources Conservation Service 2013).

The OBRI area spans multiple climate zones and contains more families of woody plants than the Great Smoky Mountains (Schmalzer 1988). It supports one of the world's most diverse riverine systems and provides habitats for rare and unique species (Schmalzer 1988; Thornberry-Ehrlich 2009; National Park Service 2015b; Benck et al. 2017). Ravines and slopes are dominated by mesophytic forests of maple (*Acer* spp.), beech (*Fagus* spp.), ash (*Fraxinus* spp.), basswood (*Tilia* spp.), sweetgum (*Liquidambar styraciflua*), and oak trees (*Quercus* spp.), while upland forests are predominantly mixed oaks, hickory (*Carya* spp.), and shortleaf pine (*Pinus echinata*) (Wiken et al. 2011; Benck et al. 2017). Federally and state-listed rare, threatened, or endangered species, such as Cumberland rosemary (*Conradina verticillata*) and Virginia spiraea (*Spiraea virginiana*), grow in riparian habitats characterized by periodic scouring by high flows (Benck et al. 2017).

OBRI contains 34 unique vegetation communities, including globally rare ones directly tied to geology, such as Cumberland Plateau rockhouses, Cumberland riverside scour prairies (also known as Cumberlandian cobble bar communities), mountain laurel–huckleberry Cumberland sandstone heath glades, and Cumberland Plateau clifftop sandstone barrens (Wolfe et al. 2008; National Park Service 2015b; Benck et al. 2017). Other distinct communities are associated with moist, north-facing slopes, steep sandstone cliffs, and contacts between shale/coal and sandstone layers (Thornberry-Ehrlich 2009; National Park Service 2015a). Sandstone heath glades, located on dissected upland areas, feature dry, shallow soils (National Park Service 2015b).

The free-flowing rivers at OBRI provide critical aquatic and riparian habitats, including Cumberlandian cobble bar communities, which are unique to this region (National Park Service 2015a). These habitats, adapted to frequent flooding, limit the growth of competing woody species and support riparian plants such as herbs, grasses, shrubs, and forbs, some of which are species of concern (Benck et al. 2017). The rivers also harbor federally threatened species such as the spotfin chub (*Erimonax monachus*), crayfish, and at least 12 mussel species, including the federally endangered purple bean (*Villosa perpurpurea*) and Alabama lamp mussel (*Lampsilis virescens*). Clear Creek is federally designated as critical habitat for spotfin chubs, while mussels thrive in small gravel patches between boulders throughout OBRI's waterways (National Park Service 2015b; Benck et al. 2017).

The stone shelters and alcoves at OBRI provide habitats for at least nine species of bats, including the federally listed gray myotis (*Myotis grisescens*) and northern long-eared bat (*Myotis* *septentrionalis*), along with plants and other species seeking shelter in the region (Emmott et al. 2005; Benck et al. 2017). Riparian zones along OBRI's streams and rivers support 23 amphibian species, including the rare Cumberland dusky salamander (*Desmognathus abditus*), which is found throughout the Cumberland Plateau in Tennessee (Benck et al. 2017).

The sandstone cliffs lining OBRI's gorges are home to diverse plant communities, including vascular plants such as ferns, mosses, and lichens, which grow based on slope aspect, angle, and surface type (Boggess et al. 2017). The narrow gorges and bluffs provide essential nesting habitats for neotropical migratory birds and rare species such as the cerulean warbler, Swainson's warbler, and northern saw-whet owl (*Aegolius acadicus*). OBRI's vast forests are near a key migratory crossover location between the Atlantic and Mississippi flyways, making the park an important resource for bird conservation (Benck et al. 2017).

River Rapids and Recreation

The sheer cliffs along the gorges at OBRI are striking geologic features that indicate extreme local relief. This relief contributes to many waterfalls. Prevalent among them are Double Drop Falls and Jacks Rock Falls. The Obed River and its tributaries host abundant recreational opportunities, including canoeing, kayaking, rafting, and fishing. The flow of water around the bedrock layers and large blocks that have fallen from the cliffs above creates exciting rapids and obstacles for water enthusiasts. The Obed River was prominent in the history of paddling, and many innovations in whitewater boatcraft design were developed and tested at OBRI (National Park Service 2015a).

The Obed River and its tributaries include many named rapids (e.g., Billy Goat Bluff, The Grunch, Lilly, 90 Right 90 Left, Ohmigod, RockGarden, Camel Rock, Wootens Folly, Canoe Hole, Widow Maker, and Nemo Rapids), some of which are class IV, meaning they are long and powerful rapids with standing waves and boiling eddies that require power and precise maneuvering (Figure 8; Thornberry-Ehrlich 2009; Gordon 2025). The difficulty of rapids is directly correlated with the local geology and geomorphology of the river channels. At OBRI and rivers like it (e.g., Big South Fork of the Cumberland River), the steepness of the channel, the resistant bedrock layers forming ledges, the scouring floods, the pool-riffle sequences, the coarse bedload (material along the river bottom: large sandstone blocks, boulders, cobbles), and the winding nature of the gorges all work together with the water flow to create thrilling but potentially dangerous rapids (Thornberry-Ehrlich 2009; Maner 2010; Phillips et al. 2010).

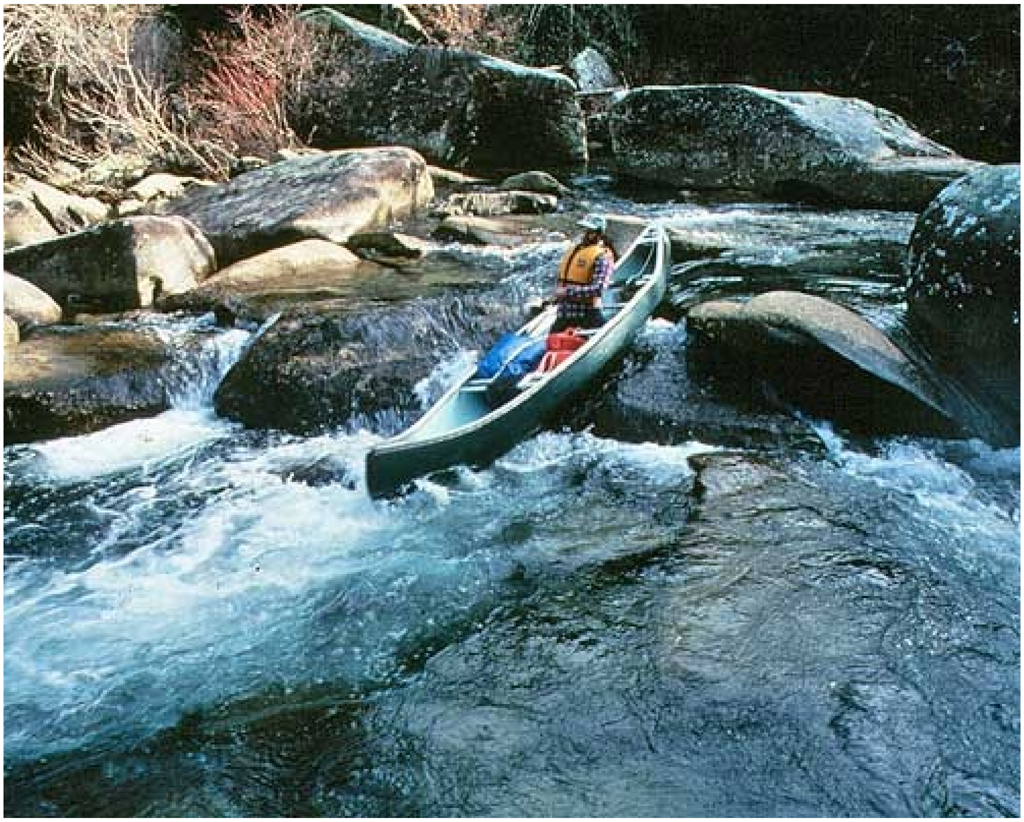

Figure 8. Photograph of a canoe in the rapids at OBRI. Large, car-sized boulders of sandstone and conglomerate litter the base of the slopes along the Obed River and Clear Creek gorges. In places where the river narrows and the geomorphology of the channel is appropriate, rapids, whirlpools, and eddies form. NPS photograph (date unknown).

Resource Management Issues and Inventory Needs

This section briefly summarizes the geologic resource management issues, inventory needs, and geologic hazards that have been identified through park documents and discussions with OBRI staff. Geologic issues refer to management concerns associated with geologic resources, including natural processes, conditions, or human activities that may affect resource integrity, visitor experience, or park operations. Inventory needs are highlighted to summarize what is currently known and what is needed to ensure best management practices at OBRI. Geologic hazards refer to notable hazards stemming from geologic features or processes that may require active management. Refer to the Guidance for Resource Management SharePoint for more information regarding geologic resource management.

Fluvial Issues

In accordance with mandates outlined in the Wild and Scenic Rivers Act, OBRI is managed to protect the natural resources, cultural resources, landscape character, and biodiversity of the Wild and Scenic River area (Lord 2003; Benck et al. 2017). The Obed River and its associated tributaries are the primary natural resources at OBRI and are significant because they are among the last free-flowing (undammed) stretches of water in the eastern United States (Thornberry-Ehrlich 2009). The inherent steepness of the river course leads to high-energy water-flow along the corridor as well as a series of rapids. Flows can range significantly over the course of a season—between 0.2 and 1,400 m^3 per second (10 and 50,000 ft^3 per second [cfs]; Thornberry-Ehrlich 2009). Protection of fluvial resources at OBRI is a challenge because its protected area is relatively small compared to the whole watershed, and many impacts originate outside park boundaries (Hughes et al. 2018).

OBRI contains only about 3% of the Obed River's 1,350 km^2 (520 mi^2) drainage area at its confluence with the Emory River. Upstream of OBRI, the rapidly growing communities of Crossville, Crab Orchard, and Fairfield Glade, Tennessee, withdraw water from and discharge treated wastewater into the Obed River and its tributaries (Knight et al. 2014).

The foundation document (National Park Service 2015a) and natural resource condition assessment (Benck et al. 2017) identify several management threats related to fluvial resources:

- Water harvesting in areas such as Daddy's Creek. This would change flow regimes in the entire OBRI system downstream of Daddy's Creek.
- Adjacent sewage treatment facilities continue expanding. This may introduce contamination into the system (contact the Water Resources Division for more information).
- Increased development and associated impermeable surfaces will increase surface runoff and river flow rates. This will cause extreme influxes of water, changing the natural flow regime.
- Flow increases from local communities (e.g., Crossville) stemming from stormwater runoff and treated wastewater releases.

- New wells drilled on private lands. This may reduce the available groundwater to the Obed River system.
- Decline in the natural mussel population.
- Lack of regional planning to address water demands.
- Contaminated drainage from abandoned mines (see "Abandoned Mineral Lands (AML) and Oil and Gas Operations").
- Climate change-related increases in temperature and precipitation and increased storm intensity/frequency. Since 1970, climate has warmed at a rate of 0.4°C (5.2°F) per century at OBED (National Park Service 2024a). This will result in alternating dry and wet periods, making extreme flows more likely to alter the river corridor. Extreme flows can move cobbles and larger rocks. If climate change affects the vegetation lining the rivers, dying vegetation will increase the erodibility of the adjacent slopes.
- More than 3,000 small impoundments (e.g., farm ponds, low head dams, and larger dams) are altering the headwaters of the upper tributaries to the Obed River.

Fluvial issues at OBRI include riverbank and head-cutting erosion. Erosion along river channels is a natural process that occurs as rivers adjust to disturbance events and to changes in water and sediment delivery over time (Field et al. 2025). The resulting migration (lateral movement) of river channels is fundamental to building complex, dynamic, and resilient landscapes and dependent habitats. Head-cutting erosion, specifically, is a type of erosion that happens at the origin or head of a stream or gully, causing it to move uphill over time. Natural erosion is crucial to maintaining healthy rivers and should be preserved whenever possible (Field et al. 2025). However, OBRI managers may deem protection from bank erosion necessary if bank retreat threatens infrastructure, developed land, or other valuable natural and cultural resources (Field et al. 2025). Field et al. (2025) describe various surface treatments and flow deflection treatments to protect designated riverbanks (Figure 9).

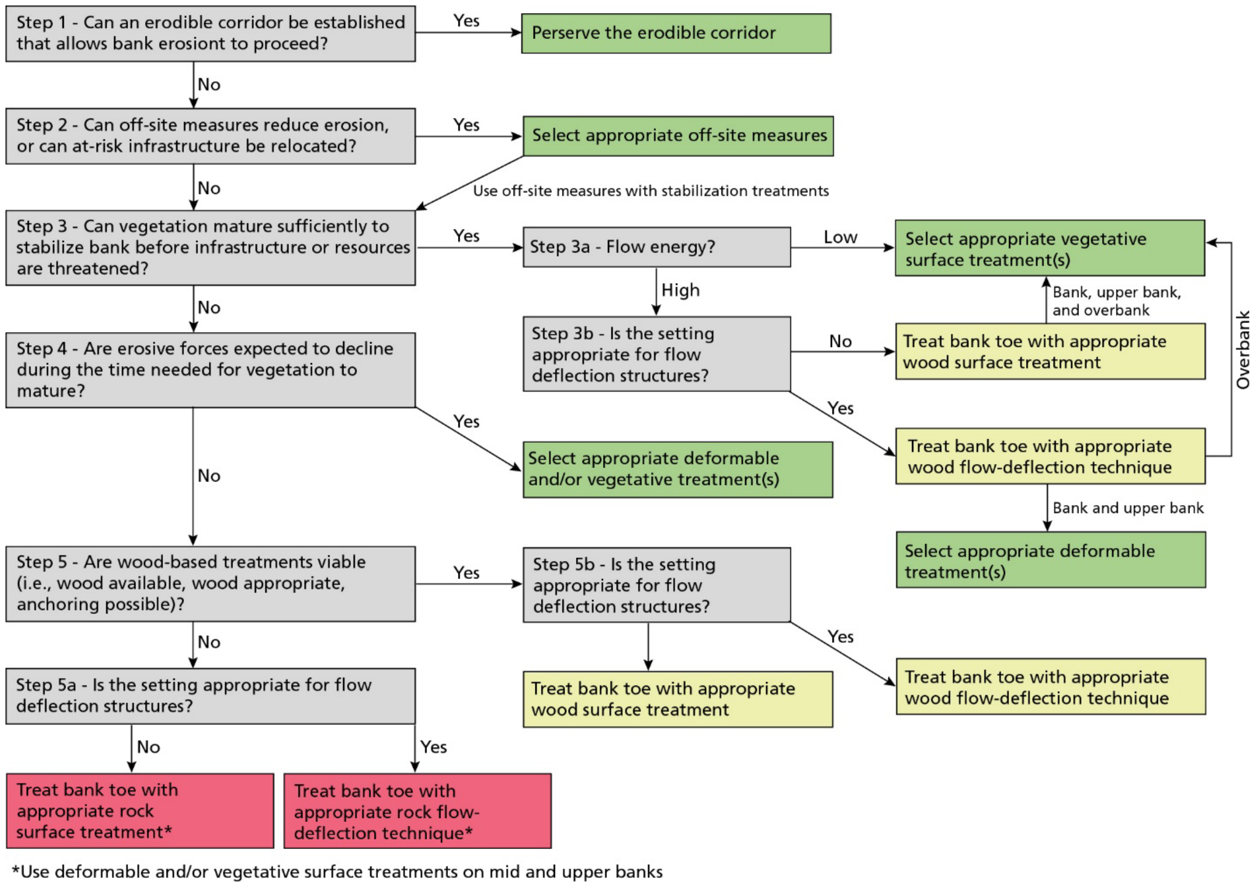

Figure 9. Decision tree to manage riverbank erosion. Step-by-step guidance to determine the best course of action to manage riverbank erosion. This is useful for OBRI managers assessing the feasibility of armoring or protecting a riverbank. The colored boxes represent a continuum of bank erosion management strategies going from more natural (green) to less natural (red) aligned with Wild and Scenic River values and NPS policies. The erodible corridor is a defined area wherein the river can freely migrate. Off-site measures are activities that slow bank erosion without stabilization techniques. Surface treatments are bank stabilization measures that rely on covering the bank with different types of erosion-resistant material: vegetation, wood (logs), deformable (erosion control blankets), and hard armoring (stone or concrete). Flow deflection treatments redirect the flow away from erosion-susceptible areas. Graphic is Figure 10 in Field et al. (2025), redrafted by Trista L. Thornberry-Ehrlich (Colorado State University).

Unnaturally increased sediment load (sedimentation) in the Obed River and its tributaries is a primary threat to fluvial resources. Sediments cloud the water, change natural water levels, and smother the bottom of the channel. These increases stem from past mining and oil and gas activities, roads and trails, forestry, and agriculture (Hann et al. 1994; Massey 2008; Hughes et al. 2018). Sediments are released by ground disturbances and are then passed downslope with runoff to the receiving water body (Massey 2008). Increased sedimentation also occurs in some streams near high-use areas such as horse or all-terrain vehicle (ATV) trails.

Flooding on the Obed River and its tributaries poses challenges for resource managers due to its dynamic hydrology, steep topography, and complex watershed interactions. The river and its tributaries are subject to both flash flooding and prolonged inundation events, particularly during periods of intense rainfall common in late winter and early spring. River levels can fluctuate from 0.6–6 m (2–20 ft) in depth in just five days (Estes and Fleming 2009). Notable floods in OBRI occurred in 1929, 1940, 1973, 1996, and 2003. The 1973 flood was a 500-year recurrence interval event that strongly changed certain stretches of the rivers (Knight 2014; National Park Service 2015c). These floods can result in significant geomorphological change including severe erosion along stream banks, head-cutting in tributaries, and sediment deposition that alters aquatic habitats and impairs water quality (Mayfield 1989).

Flooding can threaten park infrastructure (e.g., bridges and campgrounds) and adjacent communities (Wahlers 1992; Thornberry-Ehrlich 2009). As of 2026, minimal development within OBRI lies within the flood path of a notable flood. Most infrastructure consists of trails and access roads. The focus would be to maintain or stabilize existing infrastructure since it is usually located in the only feasible campground by the river when it is subject to flooding (Rachel Steffen, natural resource park staff, Obed Wild & Scenic River, written communication, 2 April 2026). Furthermore, flooding can degrade cultural sites and dislodge archeological materials, necessitating coordinated monitoring and conservation efforts. As climate variability increases, resource managers should consider adaptive strategies, such as riparian buffer restoration, improved hydrologic modeling, and floodplain reconnection, to enhance the watershed's resilience and protect both ecological and recreational values in OBRI.

Fluvial processes such as erosion, channel migration, and sediment transport play a critical role in shaping fluvial environments, though they are often difficult to predict (Babbit 2005; Hodges 2015; Thornberry-Ehrlich 2009). To effectively manage the fluvial resources at OBRI, additional modeling is necessary. Integrating geology, soils, slope, aspect, AML sites, hydrology, and vegetation communities into a GIS would create a robust dataset for analyzing and identifying streams in need of remediation and restoration. Current and future modeling efforts are expected to focus primarily on hydrology upstream of the park unit to aid regional water planning and management, as upstream activities pose the greatest threat to OBRI. However, limited in-park modeling is necessary to support stream restoration efforts. The primary objective is to preserve natural flow regimes and processes within the park (Rachel Steffen, natural resource park staff, Obed Wild & Scenic River, written communication, 2 April 2026).

Cobble Bar Communities

Cobble bars, or "Cumberland River scour prairies," are rare (globally imperiled) and unique plant communities endemic to the Cumberland Plateau of Tennessee and Kentucky (Figure 10; Fotinos and Raskin 2021). Cobble bars typically consist of rocks greater than 25 cm (9.8 in) but less than 1 m (3.3 ft) in diameter, with gaps filled by smaller cobbles (6–25 cm [2.4–9.8 in] in diameter) and sandy alluvium (Benck et al. 2017). Cobble bars are vulnerable to extinction. They exist on open, flood-scoured exposures of bedrock, cobble, or gravel along large rivers. Fewer than 200 ha (500 ac) of cobble bar communities remain, with the highest quality examples being inside Big South Fork National River and Recreation Area and OBRI (Fotinos and Raskin 2021).

River prairies, characterized by their thick grasses and flowering herbs, are similar to the tallgrass prairies of the American Midwest. In the deep river gorges of the Cumberland Plateau, water is the ecological driver, while fire sustains the midwestern prairies. Raging floods are the ecological drivers, washing over these habitats on multiple occasions each year, depositing silt and nutrients, and scouring out species that are not adapted to disturbance, including most trees and other woody species. Twenty-seven rare plant species, including some that are endemic, flourish in these riparian prairies (see "Unique, Geologically Controlled Habitats, and Ecological Relationships"). No other habitat type within OBRI supports such a large assemblage of globally rare plant species (Fotinos and Raskin 2021). Prior to 2005, the distribution of cobble bars in OBRI was unknown. Mapping and inventories since then have revealed over 60 sites. The Appalachian Highlands Network currently monitors some of these sites annually or biennially (Fotinos and Raskin 2021). Monitoring reveals the condition of 12 cobble bars in OBRI to be slightly degraded due to decreases in cover from flood-tolerant shrubs, trees, grasses, and herbs (Fotinos and Raskin 2021).

Figure 10. Photograph of a cobble bar at OBRI. Cobble bar communities are endemic to the Cumberland Plateau. Cobble bars require frequent scouring to reduce competitive vegetation and support the scour-resistant, rare plants that thrive there. Such habitats are under threat from changing river conditions. NPS photograph, taken by Nora Murdock, presented as photo 17 in Benck et al. (2017).

Threats to the cobble bar communities include changes in the frequency, timing, and volume of flood events (Benck et al. 2017). Because these unique communities rely upon frequent, high-energy flooding for their continued existence, any shifts in flood regime could have negative impacts (Wolfe et al. 2007; Murdock et al. 2013). Upstream water withdrawal, groundwater overextraction, or long-term increases in rainfall patterns could change flood frequency, magnitude, or duration. As a result, more woody species could survive on cobble bars, leading to increased competition for native herbaceous and short shrub species (Wolfe et al. 2007; Murdock et al. 2013; Benck et al. 2017).

Abandoned Mineral Lands (AML) and Oil and Gas Operations

Geologic resources (mostly hydrocarbons) at OBRI have driven interest in resource extraction and development for more than 200 years. The legacy of this ongoing history is profound and long-reaching. The NPS Energy and Minerals programs fund and support issues associated with AML and orphaned oil and gas wells. Please see the GRD Energy and Minerals Branch SharePoint and the Guidance for Geologic Resource Management for more information regarding the management of mining and minerals, AML, and oil and gas. Short issue descriptions are included here for reference and to highlight connections with other resource management issues.

AML

AML are areas that contain facilities, structures, improvements, and disturbances associated with past mineral exploration, extraction, processing, and transportation. The NPS acts under various authorities to mitigate, reclaim, or restore these areas to reduce hazards to and impacts on resources. There are three documented AML features or sites within OBRI (Burghardt et al. 2014); however, the exact number remains unknown due to the remoteness of past activity and current vegetative cover (Thornberry-Ehrlich 2009). Two documented mine openings were gated for visitor safety and resource protection in 2019 (Tom Blount, chief of resource management, Obed Wild & Scenic River, written communication, 2 April 2026). Closing open mine portals for safety reasons is listed in OBRI's foundation document (National Park Service 2015a) as a resource management need.

Local coal mining is an important component of OBRI's story and continues today. Remnant strip mine areas occur along the Cumberland Trail, and deep mine shafts are also within OBRI boundaries (Figure 11; National Park Service 2015a; Hughes et al. 2018). There is no current active mineral exploration at Obed Wild and Scenic River, but surrounding areas have historic coal mining and operations that may negatively impact OBRI resources (Benck et al. 2017). Coal mining has occurred in the watershed in the past, with abandoned strip mines located in the headwaters of Daddy's Creek and the Emory River as well as in proximity to several tributaries of Clear Creek (Emmott et al. 2005; Benck et al. 2017). Currently, there are no permitted coal mines in the watershed (Rachel Steffen, natural resource park staff, Obed Wild & Scenic River, written communication, 2 April 2026).

Runoff from abandoned mines poses a threat to the park's water quality from contaminated mine drainage and other waterborne pollutants associated with mining operations (Emmott et al. 2005; Benck et al. 2017). Advances in energy technology have made it possible to use less refined or pure coals, leading to renewed interest in areas that were once considered unviable due to the low quality of the coal, including the area surrounding OBRI (Thornberry-Ehrlich 2009). Increased availability of natural gas in Tennessee has resulted in a shift away from the use of Tennessee coal since gas is cheaper and produces less byproducts when burned (Rachel Steffen, natural resource park staff, Obed Wild & Scenic River, written communication, 2 April 2026).

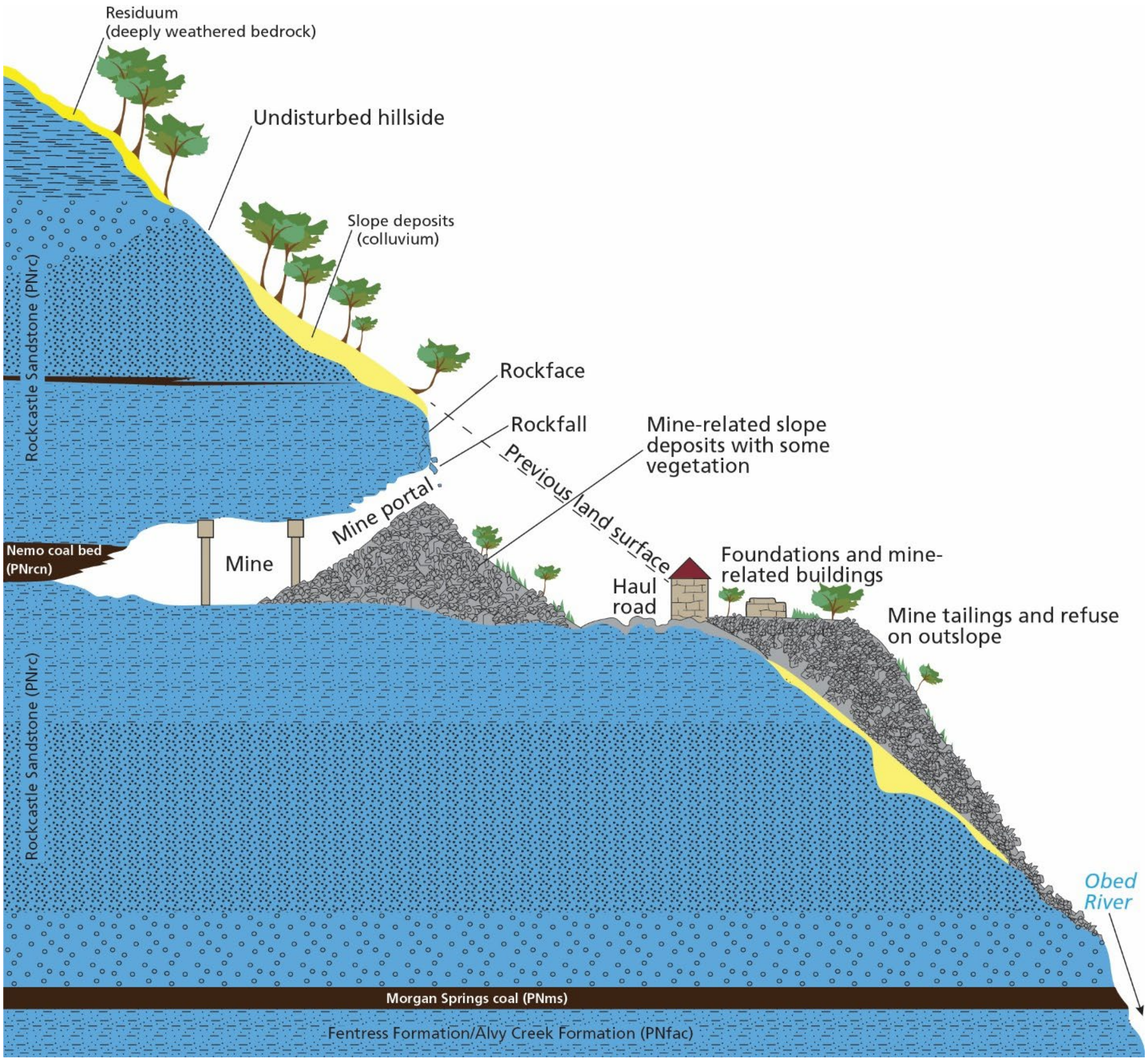

Figure 11. Diagram of abandoned coal mining features. Abandoned coal mines are present within OBED. Even with deep mines, the natural land surface is highly altered. Note the previous land surface (dashed line). Landform change continues as the mines collapse and tailings (refuse or spoil) piles undergo slope movement processes. Vegetation is slow to reestablish on mine tailings. Units were chosen to represent a mine into the Nemo coal bed. Graphic adapted from Diagram 1 in Pollio (1991) by Trista L. Thornberry-Ehrlich (Colorado State University).

Other mining-related issues at OBRI include hazards from remaining shafts and subsidence holes. Open shaft mines are dark, deep, uneven, and pose serious risks to human safety. Piles of soil and rock plug most abandoned mine openings, but as this unconsolidated material settles, slumps, or erodes away, some openings are exposed (Thornberry-Ehrlich 2009). Unconsolidated mine tailings or spoils are prone to slope failures.

Other mine features at OBRI include quarries for the sandstone units that make attractive building material and flagstones. In the 2000s, OBRI acquired an abandoned sandstone quarry near Clear Creek. Quarries cause significant surface disturbances that need to be remediated or evaluated for natural impacts and visitor safety concerns (Thornberry-Ehrlich 2009).

Contaminated Mine Drainage

Coal mining artificially exposes coal to air and water. When high-sulfur coal and pyritic shale deposits are exposed to air and water, oxidation reactions produce acidic runoff or drainage. High acidity then increases the solubility of some potentially harmful heavy metals exposed in coal and mine tailings, which then come out of solution as precipitates when the water is neutralized (Worsham et al. 2013). Where acid mine drainage in OBRI contains iron, heavy metals, or trace amounts of hydrocarbons in solutions, it is commonly referred to as contaminated mine drainage (CMD), which can then degrade local soils and harm plant and animal life (Thornberry-Ehrlich 2009; Benck et al. 2017; Hughes et al. 2018). Native mussels are particularly sensitive to contaminants in the sediments; they may function as marker species to overall river system health (Wang et al. 2013).

Oil and Gas

At OBRI, oil and gas wells are located mostly north of the park, with over 1,300 wells located in the watershed (Egloff 1986; Etta Spradlin, Environmental Protection Specialist, written communication, 29 August 2016; quoted in Benck et al. 2017). Seven wells have been drilled within OBED boundaries (Thornberry-Ehrlich 2009; Hughes et al. 2018). Approximately 140 wells exist within 0.8 km (0.5 mi) of the current OBED boundary, with the majority of these wells located in the Clear Creek watershed (Benck et al. 2017).

Howard White #1, located on Highpoint Road in Morgan County, was the site of a well blow-out (uncontrolled release of oil, gas, or other fluids from a well due to a failure in pressure control systems) that occurred on July 19, 2002 (Obed Wild and Scenic River Natural Resource Trustee Council 2008). This well blow-out continues to leak hydrocarbons into the Obed River system via Clear Creek and Whites Creek (Hughes et al. 2018). The aquatic resources appeared to have mostly recovered by 2006, based on studies of the macroinvertebrate communities; however, the forests affected by the spill and fire will require an estimated 170+ years before the age structure and standing biomass return to pre-spill conditions (Trustees 2008, National Park Service 2015b, Benck et al. 2017). A company called Montello Resources had plans to drill a new well adjacent to OBED near this site. The National Park Service prepared an oil and gas management plan and environmental impact statement (EIS) that will address issues related to current and future management of oil and gas operations in OBRI (Obed Wild and Scenic River Natural Resource Trustee Council 2008; Thornberry-Ehrlich 2009).

No new oil and gas drilling is permitted on OBRI lands or within easements (National Park Service 2015a). However, active oil and gas production within the boundaries of OBRI is permitted by the NPS. In 2024, the NPS approved a plan by ENREMA, LLC to continue operating five existing wells inside the park as part of the Smarsh Project, which does not involve hydraulic fracturing and is regulated under 36 CFR Part 9B to protect park resources (NPS 2024b; NPS 2024c). These activities reflect the presence of non-federal mineral rights within OBRI that are managed under strict environmental oversight.

Most oil and gas operations at OBRI were/are conducted by small oil and gas companies, some of whom in the past did not properly maintain infrastructure or correct problems associated with their operations (Thornberry-Ehrlich 2009). Oil and gas activities in the area include shothole drilling and detonation, construction of roads, well pads, production facilities, flowlines, pipelines, and ATV and truck access roads. Poor drilling practices and lack of maintenance have caused erosion, rutting, and compaction of access roads and well pads; loss of soil productivity; leaking pumpjacks, flowlines, and pipelines; contaminated pits; leaking gas wells; leaking tank batteries and loading areas; and brine water contamination. These issues have negatively impacted vegetation and riparian areas, leading to the degradation of the natural environment (Thornberry-Ehrlich 2009; Benck et al. 2017).

Lack of fencing around wellsites poses public safety problems. For most oil and gas production sites, the main sources of human health and ecosystem risk are hydrocarbons (especially the fraction that is dissolved in groundwater), brine water extracted with the hydrocarbons, and radionuclides, principally radium found in the brine water or its associated scale and sludge (Otton and Zielinski 2000). These can be detected quickly and relatively simply with appropriate equipment and techniques, allowing for prioritized site remediation (Otton and Zielinski 2000).

As technology advances and economic interest increases, exploration for deeper reservoirs and resources may accelerate in the OBRI region. Schenk et al. (2006) estimate the volumes of undiscovered oil and gas resources that may underlie OBRI at 14 million m^3 (0.5 billion ft^3) of gas, 0.6 thousand barrels of oil, and 10 thousand barrels of natural gas liquids. While the installation of oil and gas wells is no longer permitted on park lands or within easements, privately owned mineral resources that are under federal surfaces may be extracted if they can be accessed from outside the OBRI boundary (National Park Service 2015b). Horizontal drilling is also coming to the OBRI area and adjacent lands (National Park Service 2015a, c). This drilling process poses a new threat to OBRI by degrading the viewshed and geologic formations (Benck et al. 2017). Horizontal drilling can degrade geologic formations by altering natural fracture networks through hydraulic fracturing, which may destabilize rock layers and affect groundwater flow. Surface construction for well pads and access roads can damage or destroy exposed rock features, such as cliffs and outcrops. Additionally, the process can increase erosion, sedimentation, and even induce minor seismic activity, all of which threaten the integrity of the area's geologic landscape.

Land Use and Visitor Overuse

Land use within OBRI includes recreational activities such as climbing, hiking, and backcountry camping. This use becomes a geologic resource management issue when overuse or inappropriate use degrades the natural environment. Climbers are attracted to the nearly vertical cliffs and overhangs of Pennsylvanian-age sandstone at OBRI, for which the park has a climbing management plan to deal with the impacts and hazards associated with extensive rock climbing (Thornberry-Ehrlich 2009). No new bolted routes are permitted at OBRI; however, bolts on existing routes may be replaced for safety reasons (National Park Service 2015a). Popular climbing areas are often overused, causing local vegetation to be trampled and degraded at the top and bottom of the routes. Drilling anchors into the rock for securing ropes may degrade the rock face and be unsightly. Climbing may disturb delicate habitat along cliff faces and alcoves. Visitor safety in the face of potential rockfall is also a concern for OBRI managers. Climbers need permits to climb at OBRI, and restrictions are in place to control the development of any new rock-climbing routes. Removing some routes and diverting trails away from cliffs may protect the fragile habitat (Thornberry-Ehrlich 2009).

Listed in OBRI's foundation document (National Park Service 2015a) are the following conditions and threats related to both geologic resources and recreational use:

- trail damage from overuse and social trails (unofficial, user-created paths formed by repeated human or animal foot traffic, typically outside of designated trail systems)
- climbing access trails are not formally defined and tend to spread laterally forming braided patterns
- vandalism of rock faces (e.g., cliffs, rock shelters)
- erosion at stream crossings
- flooding at floodplain campgrounds

In addition to climbing, land-use activities such as ATV use are of concern to resource managers at OBRI ATV access is not allowed, but illegal use persists (Thornberry-Ehrlich 2009). Impacts from illegal ATV use include increased erosion, rutting, compaction, and ecosystem degradation. Early developers did not properly abandon access roads, and some abandoned roads from mining, logging, and oil and gas operations are now used for multi-purpose trails. Resource managers seek to concentrate use at public trailheads. Trail condition studies and climbing use studies are needed to better manage overuse concerns (Thornberry-Ehrlich 2009).

Landscape changes, such as negative impacts from adjacent development, population increases, agricultural land uses, habitat fragmentation, and alteration, could also harm OBRI's natural resources (Emmott and Murdock 2008; Worsham et al. 2013). As local populations increase and hydrocarbon demand and technological advances spur renewed interest, OBRI managers are concerned about negative impacts on natural resources. Very few regulations exist on urban development in the region around OBRI; landscape dynamics have a "significant concern" ranking (defined by OBRI resource managers and Appalachian Highlands Network I&M staff), with their condition deteriorating (Thornberry-Ehrlich 2009; Benck et al. 2017.

OBRI has scenic easements, but private landowners retained timber rights that allow limited logging with some oversight from the National Park Service (Thornberry-Ehrlich 2009). As populations increase and development proceeds, stabilizing forests will be logged, viewsheds will be irreparably harmed, and impermeable surfaces such as roads, parking lots, and driveways will increase, causing spikes in unfiltered surface runoff into the Obed River watershed (Emmott and Murdock 2008; Thornberry-Ehrlich 2009). The Appalachian Highlands Network planned monitoring landscape change at OBRI (Emmott and Murdock 2008), but this monitoring component was not continued

(Rachel Steffen, natural resource park staff, Obed Wild & Scenic River, written communication, 2 April 2026).

Slope Movements

Potential for slope movement exists on all OBRI slopes, particularly where the rivers and streams cut steeply through the sedimentary rocks in the gorges. Slope movements are the downslope transfer of material (e.g., soil, regolith, and rock; Figure 12). Slope movements can occur rapidly (e.g., debris flows or rockfalls) or over long periods of time (e.g., slope creep). The magnitude of slope failures depends on slope aspect, soil type, and geology. The Obed River and its tributaries cut through steep slopes, terraces, bluffs, and alluvial fans. Gravity, frost and plant root wedging, differential erosion, fluvial undercutting, and mining subsidence are the primary natural causes of slope instability at OBRI.

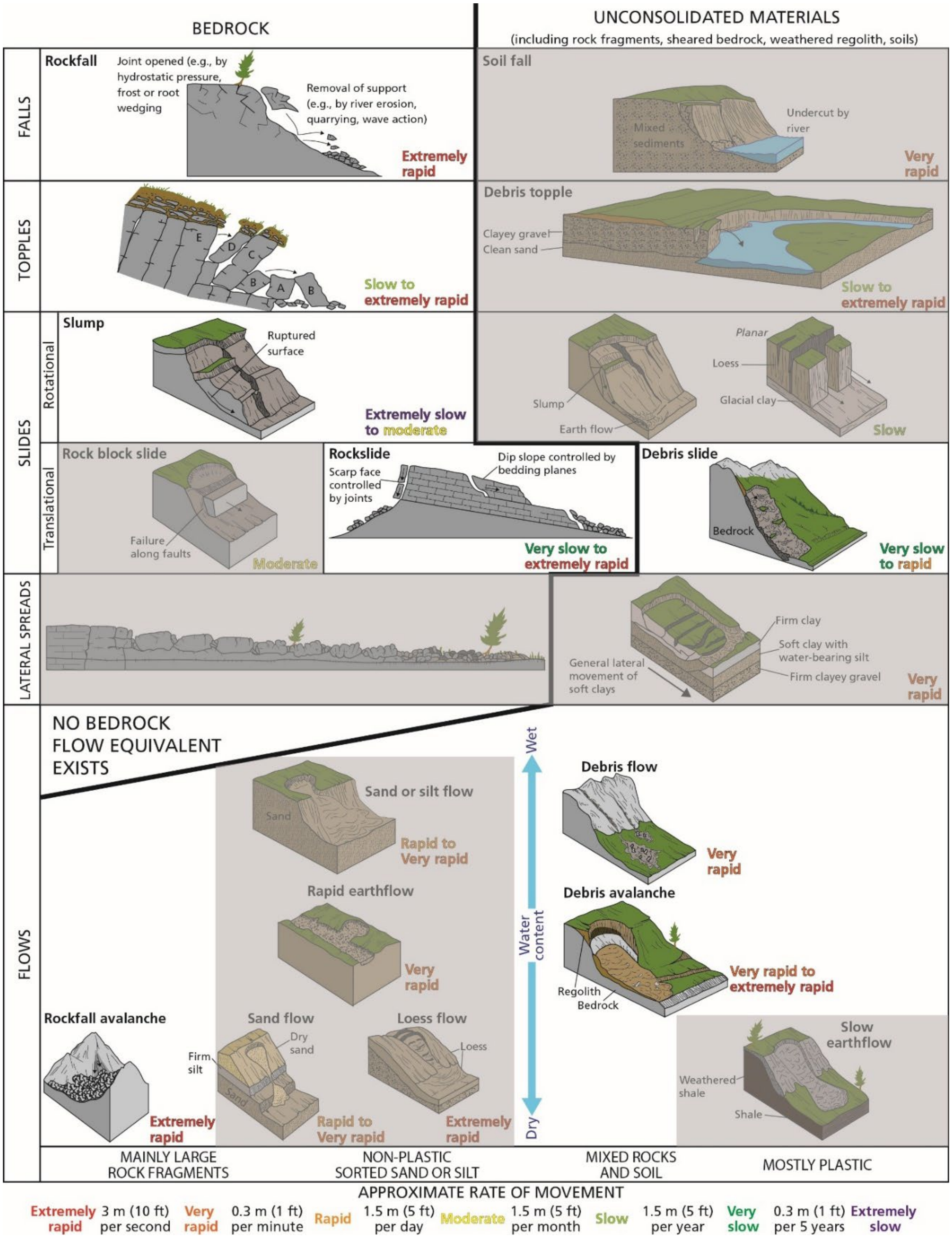

Figure 12. Illustrations of slope movements. Different categories of slope movement are defined by material type, nature of the movement, rate of movement, and moisture content. Grayed areas depict conditions unlikely to exist at OBRI. The abundant vegetation in the park stabilizes some slopes, but slope issues could be exacerbated by factors such as natural or anthropogenic removal of vegetation, upstream development, and climate change. Graphic by Trista Thornberry-Ehrlich (Colorado State University), redrafted after a graphic and information in Varnes (1978) and Cruden and Varnes (1996).

Anthropogenic land disturbances contribute heavily to slope instability. Anthropogenic changes to the hill slopes, such as road and trail construction, mining, undercutting, and deforestation, are the most common triggers of active sliding. Engineering structures designed to redirect water and stabilize riverbanks often lead to instability and reactivation of old landslides. Geologic units containing significant shale layers act as regional slip surfaces and are often present at the toe (base) of slides.

Evidence of former slope movements is widespread at OBRI. Talus and colluvial fans, which are composed of loose and incoherent deposits transported by gravity, occur at the base of many slopes and bluffs along the Obed River and its tributaries. Ancient rockfalls, slides, and debris flows left scars along the slopes of the river valleys, and large blocks of sandstone are ubiquitous with the valley floors (Thornberry-Ehrlich 2009).

Any steep slope at OBRI poses a landslide hazard, and rockfall is a threat along long stretches of the rivers. Visitors need to be aware of rockfall potential and warned about active slide and rockfall areas (Thornberry-Ehrlich 2009).

Seismicity

Seismicity refers to the ground shaking that occurs during earthquakes. Though not traditionally considered a seismically active area, OBRI is north of the Southern Appalachian seismic zone—an active earthquake zone that runs just northeast of Knoxville, Tennessee (Figure 13). Nearly 100 small earthquakes (too minor to be felt at the surface) occur every year along this diffuse zone (Thornberry-Ehrlich 2009). The potential for seismicity is present (moderate risk) at OBRI and may trigger landslides, rockfall, and damage infrastructure (Thornberry-Ehrlich 2009). The USGS and the Center for Earthquake Research and Information at the University of Memphis monitor seismic activity throughout the region.

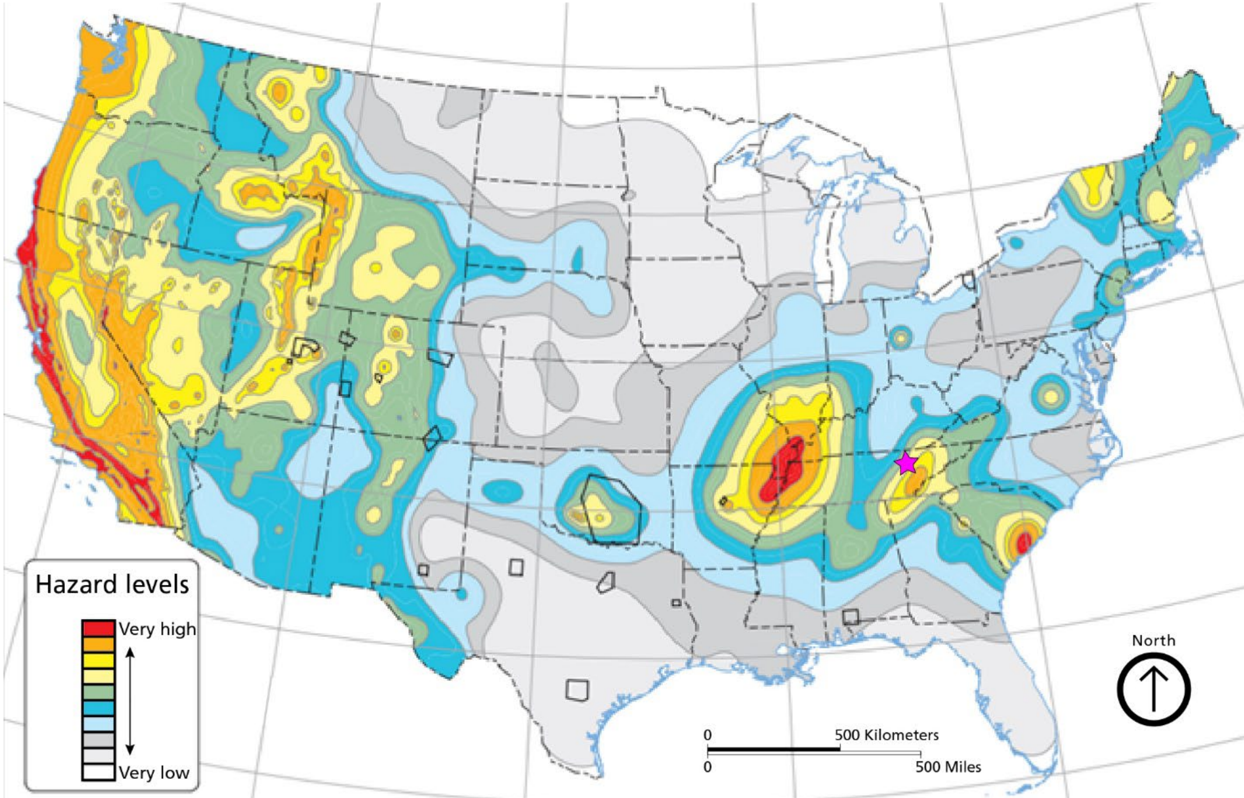

Figure 13. National seismic hazard map. The map shows the relative hazard associated with potential earthquakes in different areas. The map is based on USGS models that calculate the probability of a notable (felt at the surface by humans) earthquake within 50 years for a firm rock site based on seismicity, fault-slip rates, and the frequency of earthquakes of various magnitudes. Locally, the hazard may be greater than shown because site geology may amplify ground motions. The OBRI location is at the pink star, near the northwestern edge of the Southern Appalachian seismic zone, and of moderate hazard risk. Public domain graphic courtesy of the US Geological Survey; available at https://www.usgs.gov/media/images/2018-long-term-national-seismic-hazard-map.

Inventory Needs

Table 2 presents several geologic and soil resources inventory needs that were identified during the 2007 scoping meeting, in NPS planning documents, and through literature review.

Table 2. List of identified geologic and soil resource inventory needs for OBRI.

Subject	Inventory Need	Reference(s)
Abandoned Mineral Lands	Organize coal mine maps and drill hole information from state surveys into the OBRI GRI GIS data Inventory and digitize mine maps Identify which coal beds contain significant sulfur Spoil area mapping Acid mine drainage mapping for aquatic species restoration Identify all AML sites (low priority) Identify unplugged/unremediated oil and gas wells in the watershed	Thornberry-Ehrlich (2009); National Park Service (2015a)
Geohazards	Landslide area mapping Slope movement potential mapping (slope analysis with geology correlation; low priority) Document gaps in cliff lines and gorge access points for GIS analysis	Thornberry-Ehrlich (2009); National Park Service (2015a); Benck et al. (2017)
Geoscience Research	Geoheritage inventory (e.g., geologic assessment and inventory of rock shelters and other features; medium priority) Inventory effects from urban and exurban sprawl	National Park Service and American Geosciences Institute (2015a); Benck et al. (2017)
Cave and Karst	Cave and karst feature identification and mapping Identify talus cave areas	Thornberry-Ehrlich (2009)
Mapping	Cave and karst mapping Landscape evolution mapping Land-use planning mapping Boundary survey (medium priority) Private mineral rights ownership study (medium priority) Visual resource inventory (medium priority)	Thornberry-Ehrlich (2009); Santucci et al. (2008); National Park Service (2015a)
Paleontology	Field inventories, formal site documentation, and condition assessment of fossil resources Develop a monitoring plan Fossil recovery from private collections (low priority)	Thornberry-Ehrlich (2009); Santucci et al. (2008)
Stratotypes	Increase awareness and understanding about the geoheritage of geologic stratotypes and those present in the area surrounding OBRI	Henderson et al. (2021)
Hydrogeology	Groundwater flow mapping Impoundment inventory and study Watershed map coverage Streambed mapping to determine aquatic habitat potential Regional water management plan (high priority) Map location of Cumberlandian cobble bar communities (high priority) Develop basin-wide hydrogeologic model (high priority) Study and inventory for “warm wet” and “hot dry” future climate change scenarios	Thornberry-Ehrlich (2009); National Park Service (2015a) National Park Service (2024a) Knight et al. (2014)
Cliff management (e.g., climbing access)	Study consolidating climbing access trails, especially those that are not well defined Trails management plan (high priority)	National Park Service (2015a)

Legislatively Required Geologic Inventories

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

Caves and Karst

Karst is a landscape that forms through the dissolution of soluble rocks, commonly carbonate rocks such as limestone or dolomite (Toomey 2009). Dissolution occurs when acidic water reacts with carbonate rock surfaces along cracks and fractures.

Caves are naturally occurring underground voids such as solutional caves (commonly associated with karst), lava tubes (tunnel-like caves in a lava flow after lava has stopped flowing), sea caves (clefts or cavities in a sea cliff), talus caves (a void among collapsed boulders), regolith caves (formed by soil piping), and glacier caves (ice-walled caves; Toomey 2009). All cave features are nonrenewable resources. The Federal Cave Resources Protection Act of 1988 stipulates that all "significant caves" in NPS areas will be identified; regulation or restriction of use will be employed as needed to protect cave resources; and significant caves will be included in land management planning. The act also imposes penalties for causing harm to a cave or cave resources and exempts park staff from releasing specific location information for significant caves in response to a Freedom of Information Act request.

At OBRI, karst dissolution would occur in every unit composed of carbonate or carbonate cements, primarily Mississippian limestones. However, unlike areas of Kentucky (e.g., Mammoth Cave), karst features at OBRI have not developed because the Mississippian limestone units are buried beneath the Pennsylvanian units. Cave features include limited small cavities or caves formed in the blocks of sandstone littering the base of slopes (Thornberry-Ehrlich 2009). Further cave feature identification, mapping, and digitization could be resource management needs at OBRI. All caves are at risk of vandalism and archeological looting (Thornberry-Ehrlich 2009). Caves provide vital habitat for bats and other creatures.

Geothermal Features and Springs

Geothermal refers to heat or energy produced in Earth's interior. Geothermal features may include geysers, fumaroles, hot springs, and bubbling mud pits. The Geothermal Steam Act of 1970, amended in 1988, prohibits geothermal leasing in parks and authorizes the Secretary of the Interior to mitigate or not issue geothermal leases outside parks that would have a significant adverse impact on significant thermal features in the 16 park units listed in the act. Geothermal features are not known within OBRI.

Paleontological Resources Inventory and Protection

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. All paleontological resources are nonrenewable and subject to science-informed inventory, monitoring, protection, and interpretation as outlined by the 2009 Paleontological Resources Preservation Act (PRPA).

Fossils are known from nearly all of the flat-lying, sedimentary rock units at OBRI; however, no fossil localities are currently known within park boundaries (Santucci et al. 2008). Potential paleontological resources that may be found within these units are as follows:

- Whitewell Shale—amphibian trackways
- Vandever Shale—plant remains
- Rockcastle Sandstone— tetrapod trackways (early reptile), plant remains, palynological (pollen or spores) species *Florinites mediapudens*
- Potential for Pleistocene animal remains (e.g., cave bears, mastodons, mammoths) in rock shelters, notches, and small caves

Many fossils occur in friable (easily split or broken apart) shales and at the tops of coal beds, which flex and swell with humidity and are not viable for long-term preservation (Thornberry-Ehrlich 2009). These resources should be inventoried (field-based) and monitored. As outlined in 2024 by fact sheets produced for OBRI, there is an unfilled resource management and interpretive role for paleontological resources (Acres et al. 2024).

Summary of Geologic and Soil Hazards

The natural resources that attract visitors to a park (e.g., waterfalls, steep terrain, and caves) may also be hazardous. Geologic hazards, or "geohazards," are naturally occurring, dynamic geologic processes that have the potential to cause damage, loss of property, injury, or loss of life. The Natural Hazards Handbook (NPS 2025) provides a process and information to help teams and decision-makers identify, avoid, and mitigate risks associated with natural hazards and their effects on planned and proposed facility investments. The handbook supports reviews made during the regional or bureau investment review board (BIRB) process. Managers should apply the guidance in the handbook to identify options to manage natural hazard risks throughout all levels of facility planning and design. The handbook is maintained and updated by the Associate Director for Park Planning, Facilities, and Lands (PPFL).

Table 3 includes selected geologic and soil hazards listed in Part 1 of National Park Service (2025). The GSRI team has added additional hazards where appropriate for the park. Part 2 outlines the process to follow and decisions to be made throughout the project, if a potential hazard is identified in Part 1. Contact the NPS GRD with any questions.

Table 3. Geologic and soil hazards checklist. This checklist includes selected hazards listed in Part 1 of National Park Service (2025).

Hazard	Examples of Risk or Secondary Hazard	Best Professional Judgment	Source(s) of Information (some links require DOI network access)
Sea Level Change	Inundation. Shoreline erosion. Destruction of infrastructure (e.g., through saturation). Water quality effects. Water supply diminished.	Not applicable	DOI Strategic Hazard Identification and Risk Assessment (SHIRA) SHIRA - Home (sharepoint.com).
Coastal Storm Surge	Wind driven rising water (e.g., hurricane, nor'easter).	Not applicable	DOI SHIRA - Home (sharepoint.com)
Flash Flood	Sudden rising water (e.g., in a dry wash or canyon). Loss of life due to unexpected flooding. Destruction of infrastructure (e.g., through impact or saturation). Reduced or precluded visitation. Power failure due to areawide power outages.	Known hazard	Natural Resource Condition Assessment (Benck et al. 2017) Estes and Fleming (2009) GRI Scoping Summary (Thornberry-Ehrlich 2009) DOI SHIRA - Home (sharepoint.com) FEMA: NFHL https://www.fema.gov/flood-maps/national-flood-hazard-layer
Riverine Flood	Inundation. Destruction of infrastructure (e.g., through impact or saturation). Stream channel migration and streambank erosion. Water quality effects. Water supply diminished. Reduced or precluded visitation.	Known hazard (extreme to high per SHIRA)	Natural Resource Condition Assessment (Benck et al. 2017) GRI Scoping Summary (Thornberry-Ehrlich 2009) DOI SHIRA - Home (sharepoint.com) FEMA: NFHL https://www.fema.gov/flood-maps/national-flood-hazard-layer

Hazard	Examples of Risk or Secondary Hazard	Best Professional Judgment	Source(s) of Information (some links require DOI network access)
Lake and Reservoir Level Change or dam failure	Water supply diminished. Flooding and erosion impacts to infrastructure. Diminished or lost recreational opportunities. Release of sediments. Streambank erosion. Reduced or precluded visitation.	Not applicable	DOI SHIRA - Home (sharepoint.com) USGS: Lakes and reservoirs dataset https://waterdata.usgs.gov/nwis/current/?type=lake&group_key=state_cd US Bureau of Reclamation Water Operations https://www.usbr.gov/main/water/#GP
Precipitation: Increased Extreme Events	Surface erosion. Floods. Water damage to structures from driven rain. Unstable saturated soils. Reduced or precluded visitation. Power failure due to areawide power outages.	Potential hazard	NPS: National Park historical and projected climate change trends https://irma.nps.gov/DataStore/Reference/Profile/2266988 NASA: DAYMet gridded climate data https://daymet.ornl.gov/ DOI SHIRA - Home (sharepoint.com) National Park Service (2024a)
Precipitation: Altered Patterns and Changing Humidity	Local flooding. Mold growth. Wood decay. Drought. Fire. Water supply change.	Potential hazard	National Park Service (2024a) NPS: National Park historical and projected climate change trends https://irma.nps.gov/DataStore/Reference/Profile/2266988 Climate Toolbox: Climate Mapper (for Western US) https://marine.usgs.gov/coastalchangehazardsportal/ NASA: DAYMet gridded climate data https://daymet.ornl.gov/
Drought: Increased Frequency, Intensity, Magnitude, and Duration	Limited water supply for visitors, staff, and operational needs (e.g., potable and fire suppression water). Increased competition for available water and water supply impacts (e.g., water supply curtailment by state agencies). Crack/heave damage in drier soils. Increased vulnerability to wildfire.	Potential hazard	National Park Service (2024a) FEMA: Drought risk https://hazards.fema.gov/nri/drought University of Nebraska-Lincoln: Drought Monitor https://droughtmonitor.unl.edu/ DOI SHIRA - Home (sharepoint.com)

Hazard	Examples of Risk or Secondary Hazard	Best Professional Judgment	Source(s) of Information (some links require DOI network access)
Permafrost Dynamics	Thawing. Surface collapse. Increased landslide susceptibility. Road/service disruption. Frost heave.	Not applicable	DOI SHIRA - Home (sharepoint.com)
Landslide	Rockfall. Mud or debris slides or flows onto or from under structures. Reduced or precluded visitation. Avalanche	Known hazard (very high per SHIRA)	GRI Scoping Summary (Thornberry-Ehrlich 2009) Tennessee Geological Survey: https://www.tn.gov/environment/section/geo-geology FHWA Unstable Slope Management Program (USMP): Geologic and Geotechnical Services | FHWA (dot.gov). FEMA: Landslide risk https://hazards.fema.gov/nri/landslide USGS: Emergency Assessment of Post-Fire Debris-Flow Hazards https://landslides.usgs.gov/hazards/postfire_debrisflow/ DOI SHIRA - Home (sharepoint.com)
Earthquake	Falling objects. Collapsing structures. Inoperability of major building systems (e.g., power, sewer, water). Liquefaction - loss of strength to foundations, silt deposition, standing water. Trigger to other hazards (e.g., landslides, debris flows).	Known hazard (high to moderate per SHIRA)	GRI Scoping Summary (Thornberry-Ehrlich 2009) Tennessee Geological Survey: https://www.tn.gov/environment/section/geo-geology USGS: Earthquake Probability Mapping https://www.usgs.gov/natural-hazards/earthquake-hazards/hazards FEMA: Earthquake risk https://hazards.fema.gov/nri/earthquake DOI SHIRA - Home (sharepoint.com)
Tsunami	Coastal area inundation.	Not applicable	DOI SHIRA - Home (sharepoint.com)
Shrink/Swell Soils	Damage to structure. "Heaving" of ground beneath structure. Increased landslide susceptibility.	Potential hazard (low per SHIRA)	NPS: https://irma.nps.gov/DataStore/Reference/Profile/1048823 USDA: Soils Survey https://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/survey/ (look for "linear extensibility" data).

Hazard	Examples of Risk or Secondary Hazard	Best Professional Judgment	Source(s) of Information (some links require DOI network access)
Volcanic Eruption	Lava flows. Fire. Seismicity. Tsunamis. Toxic gas releases. Ash and air quality degradation. Reduced or precluded visitation.	Not applicable	DOI [SHIRA - Home (sharepoint.com)]
Hydrothermal Activity (e.g., geysers)	Toxic gas release. Explosion. Boiling water. Steam. Surface collapse into void.	Not applicable	NREL: Geothermal resource data, tools, and maps https://www.nrel.gov/gis/geothermal.html USGS: Geothermal resources https://www.usgs.gov/programs/energy-resources-program/science/science-topics/geothermal
Subsurface Hazards: Abandoned Mineral Lands Oil and Gas Infrastructure Cave/Karst (sinkholes)	Mine shaft access hazards. Surface subsidence. Surface collapse. Contamination. Flammable or toxic sites. Surface water pollutant discharge.	Known hazard	Tennessee Geological Survey, Mineral Industry: https://www.tn.gov/environment/program-areas/geo-geology/mineral-industry.html USGS: Karst in the United States: A Digital Map Compilation and Database (Weary and Doctor 2014) Thornberry-Ehrlich (2009) Evaluation of cave and karst programs and issues at US national parks (Land et al. 2013) DOI SHIRA - Home (sharepoint.com)
Toxicological Soil	Unhealthy levels of Bacillus anthracis, asbestos or erionite, arsenic, cadmium, lead, selenium, and/or valley fever fungus.	Known hazard (very low to very high per SHIRA)	DOI SHIRA - Home (sharepoint.com)
Toxicological Geology	Elevated radon levels.	Known hazard (moderate per SHIRA)	DOI SHIRA - Home (sharepoint.com)

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