NCSS National Cooperative Soil Survey

SOIL, ENERGY, and AGRICULTURE for Resilient Ecosystems

National Conference

Field Tours — July 9 and 12, 2023

NORTH DAKOTA

USDA Natural Resources Conservation Service
U.S. DEPARTMENT OF AGRICULTURE

NDSU NORTH DAKOTA STATE UNIVERSITY

National System of Public Lands, U.S. Department of the Interior, Bureau of Land Management

WPC, Inc. Western Plains Consulting

Forest Service, U.S. Department of Agriculture

School of Natural Resource Sciences, NDSU

North American Coal, A NACCO Company

PSCAND Professional Soil Classifiers Association of North Dakota

North Dakota Geological Survey 1895

National Park Service

Theodore Roosevelt Medora Foundation

USDA Agricultural Research Service
U.S. DEPARTMENT OF AGRICULTURE

Acknowledgements

NCSS Conference Field Tours

Individuals and Organizations

A special thank you to the following individuals and organizations for making the 2023 tours possible:

- Ken and LuAnn Solberg, Landowners – Belfield
- Steven and Kathrine Hegger, Landowners – Washburn
- Robert Krumwede, Landowner – Washburn
- USDA Agricultural Research Service (ARS) – Northern Great Plains Research Laboratory
- National Ecological Observatory Network (NEON)
- The Falkirk Mining Company
- National Park Service Staff
- Theodore Roosevelt Medora Foundation
- McLean County Sheriff's Department

Field Tour Staff

Thank you to the following for your assistance and hard work in making the 2023 field tours possible:

- Wade Bott, NRCS North Dakota State Soil Scientist
- David Hopkins, North Dakota State University Professor of Soils
- Lance Duey, NRCS North Dakota Assistant State Soil Scientist
- Susan Samson-Liebig, NRCS Soil Quality Specialist
- Jeanne Heilig, NRCS SPSD MLRA Soil Survey Leader
- Krista Bryan, NRCS SPSD Soil Scientist
- John Kempenich, NRCS Resource Soil Scientist
- Perry Sullivan, NRCS SPSD MLRA Soil Survey Leader
- Kyle Thomson, NRCS SPSD Soil Scientist

- Mackenzie Ries, NRCS SPSD Soil Scientist
- Keith Anderson, NRCS SPSD MLRA Soil Survey Leader
- Brianna Wegner, NRCS SPSD Soil Scientist
- Jordaan Larson-Thompson, NRCS Resource Soil Scientist
- Joseph Cooper, NRCS Resource Soil Scientist
- Mark Liebig, ARS Research Soil Scientist
- David Toledo, ARS Research Rangeland Management Specialist
- Justin Feld, ARS Biological Science Technician
- Jay Fuhrer, Menoken Farm
- Darrell Oswald, Burleigh County Soil Conservation District
- Mike Ulmer, Retired NRCS Soil Scientist
- Steve Sieler, Retired NRCS Soil Scientist
- CJ Heidt, Retired NRCS Soil Scientist
- Alan Gulsvig, Retired NRCS Soil Scientist
- Larry Cihacek, North Dakota State University Professor of Soils
- Tom DeSutter, North Dakota State University Professor of Soils
- Bernhardt Saini-Eidukat, North Dakota State University Professor of Geology
- Andera Anteau, National Ecological Observatory Network
- Matt Wenzel, National Ecological Observatory Network
- To the countless others whose contributions came after the publication of this document

Important Information About the Field Tours

Preparedness, Hazards, Warnings, and Contact Information

Wednesday July 9th Tour

Participants will travel directly to the Black Leg Ranch for the NCSS Awards Banquet following the Wednesday field tour. Buses **WILL NOT** stop at the hotel or Bismarck State College. Please pack any specialized equipment, apparel, foods, liquids, or medications you may require for the day and evening.

Field Tours and Preparedness

Participants are expected to be prepared for field tours, no matter rain, sunshine, heat, or cold. Individuals may experience weather conditions that may require adjustments to apparel and footwear. Participants will also encounter various terrains and walking conditions. Please provide your own if you require specialized items, such as sensitive sunscreen or specific insect repellents.

The following items will be provided or available to participants during the field tours:

- Water (please bring water bottles to fill)
- Light Snacks
- Lunch
- Mosquito repellant (limited)
- Sunscreen (limited)
- Rain Ponchos
- Portable Outhouse

Hazards and Warnings

While on the field tour, you should take precautions to protect yourself by being aware of plants and insects which could result in sickness or injury. We will be in areas with ticks and mosquitos.

Ticks: There are many different species of ticks, but only a few bite and transmit diseases. North Dakota is home to a few of them — the American dog tick (also known as a wood tick), the blacklegged tick (also known as a deer tick), and the lone star tick. If you spot black dots crawling on someone or yourself, remove the dots as soon as possible.

Mosquitoes: Mosquitoes are carriers of many diseases. The species of mosquitoes that carry West Nile Virus are found in North Dakota and bite until the first heavy frost.

Snakes: North Dakota has many species of snakes, but only the prairie rattlesnake is venomous. Snakes should be avoided. If you leave a snake alone, it will leave you alone.

Fragile Prickly Pear Cactus: Western North Dakota is home to many beautiful plants. One that is not so beautiful is the Fragile Prickly Pear Cactus. Care should be taken to check the ground for any cacti before sitting or kneeling. Trust us; embedded needles are very painful.

Hydrogen Sulfide (H_2S) Gas: Hydrogen sulfide gas occurs naturally in crude oil and natural gas wells, and at low concentrations, it is noticeable by its distinctive rotten egg smell. Inhaling H_2S at low concentrations causes headaches, nausea, and eye and skin irritation but is deadly to humans and most other animals at higher concentrations.

Emergency Contacts

Name	Cell Phone Number
Wade Bott	(701) 426-3391
Lance Duey	(701) 934-1359
Susan Samson-Liebig	(701) 934-5158
David Hopkins	(701) 367-4011

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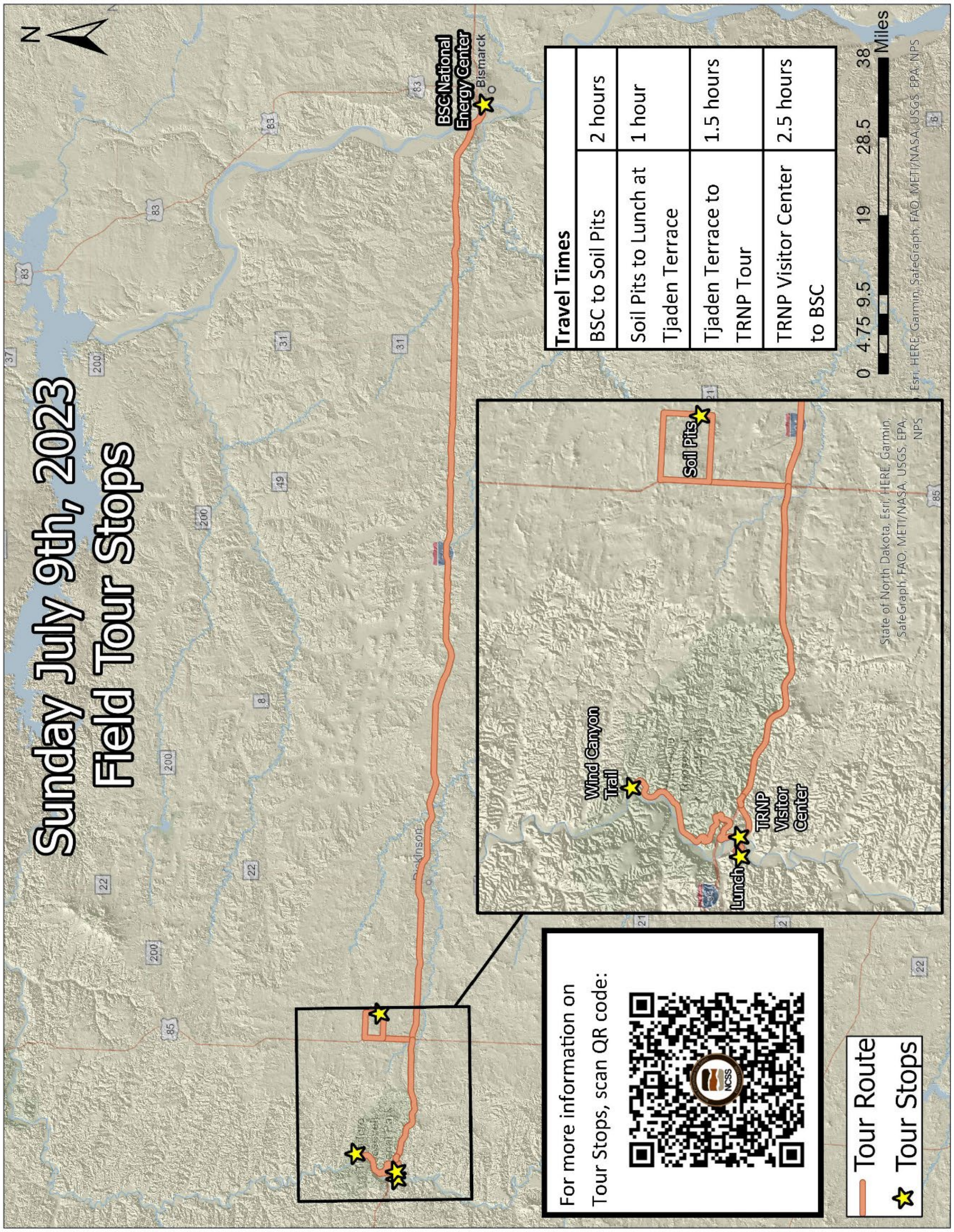
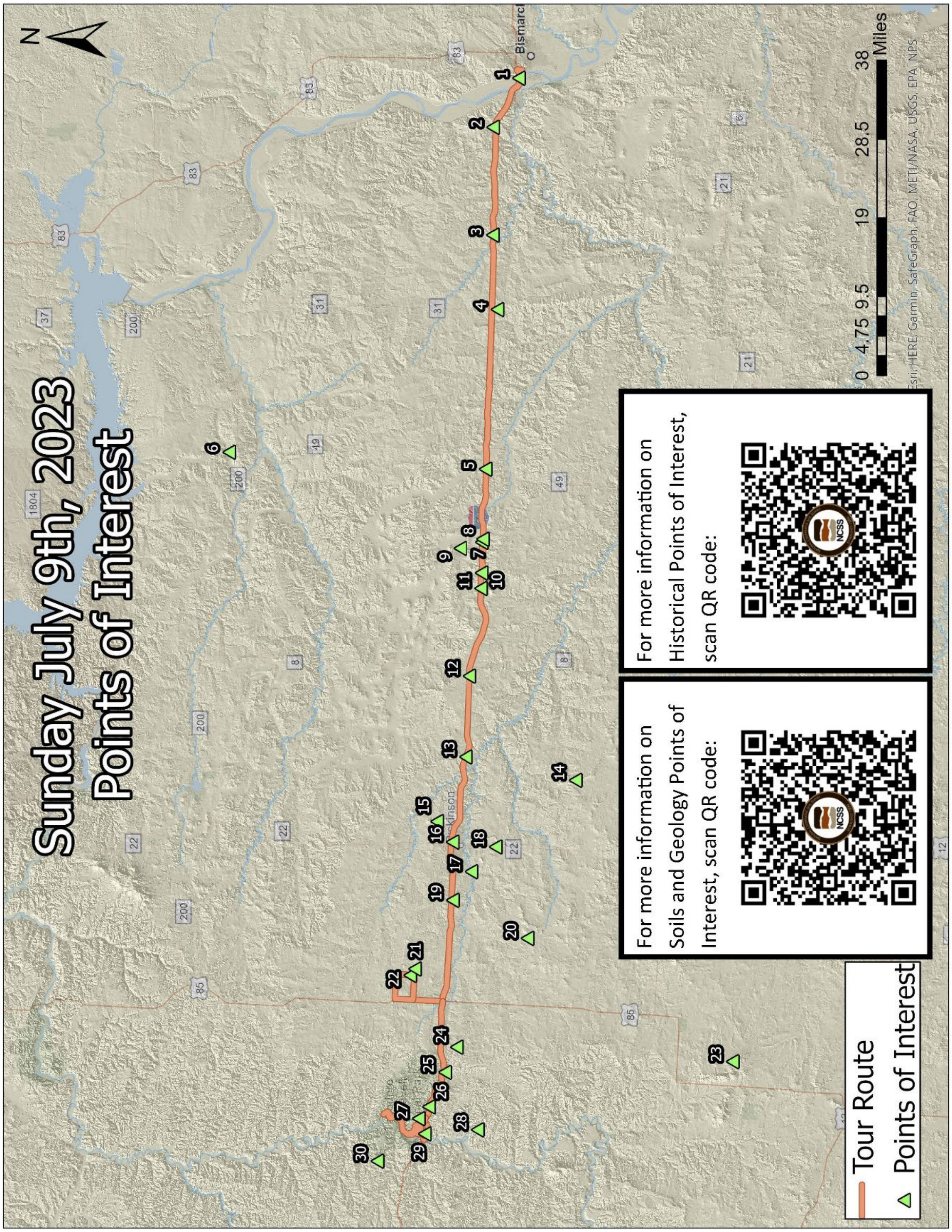
Field Tour Schedule

Sunday, July 9, 2023

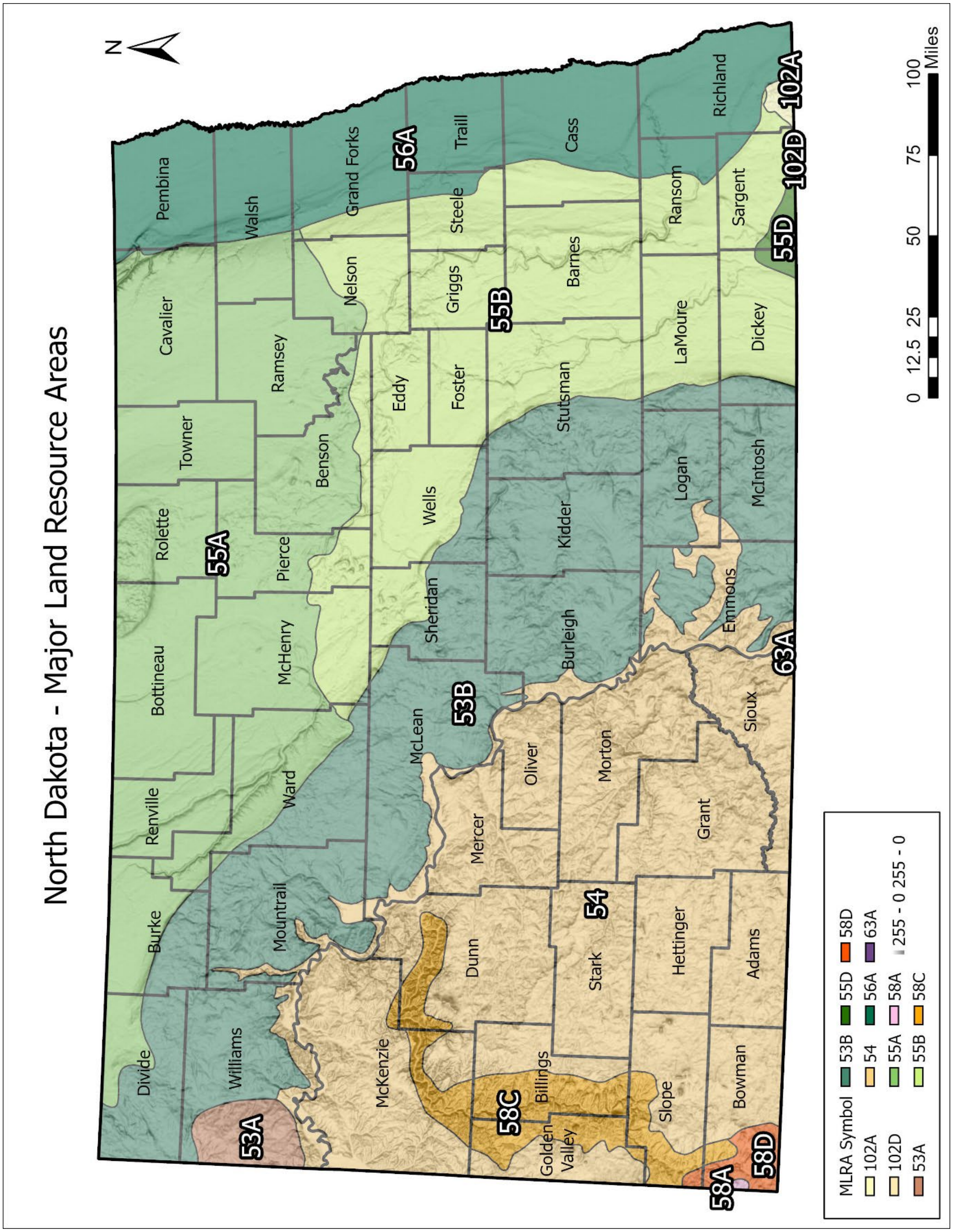
Time	Activity
6:45 a.m. (CDT)	Meet in the parking lot on the north side of the National Energy Center of Excellence (NECE) building to load the buses.
7:00 a.m. (CDT) 6:00 a.m. (MDT)	Travel by bus from Bismarck to the Belfield sodic soil site.
8:45 a.m. (CDT) 7:45 a.m. (MDT)	Arrive at the Belfield field site and unload the buses. Landscape overview and general information about the Belfield site.
9:00 a.m. (CDT) 8:00 a.m. (MDT)	Divide into 3 groups and rotate between 3 soil pits concurrently. Groups will spend 30 minutes at each pit and then rotate to the next pit with 10 minutes transition time for moving between pits.
11:00 a.m. (CDT) 10:00 a.m. (MDT)	Load buses.
11:15 a.m. (CDT) 10:15 a.m. (MDT)	Travel to the Burning Hills Amphitheater in Medora.
12:00 p.m. (CDT) 11:00 a.m. (MDT)	Unload buses.
12:15 p.m. (CDT) 11:15 a.m. (MDT)	Box lunch on the Tjaden Terrace overlooking the scenic Badlands and the Little Missouri River. Lunch presentation will occur.
1:15 p.m. (CDT) 12:15 p.m. (MDT)	Load buses and travel to Theodore Roosevelt National Park entrance gate.
1:30 p.m. (CDT) 12:30 p.m. (MDT)	Driving tour into Theodore Roosevelt National Park with a stop and bus unload at Wind Canyon Trail. A short presentation will follow. Load buses.
3:00 p.m. (CDT) 2:00 p.m. (MDT)	Stop at Theodore Roosevelt Park South Unit Visitors Center for restroom break.
3:20 p.m. (CDT) 2:20 p.m. (MDT)	Load buses.
3:30 p.m. (CDT) 2:30 p.m. (MDT)	Travel back to Bismarck
6:00 p.m. (CDT) 5:00 p.m. (MDT)	Arrive in Bismarck. Evening meal on your own.

Field Tour Maps




Sunday July 9th, 2023
Points of Interest
N
Bismarck
Tour Route
Points of Interest
For more information on Soils and Geology Points of Interest, scan QR code:
For more information on Historical Points of Interest, scan QR code:
NCSS
0 4.75 9.5 19 28.5 38 Miles
Esri, HERE, Garmin, SafeGraph, FAO, METI/NASA, USGS, EPA, NPS

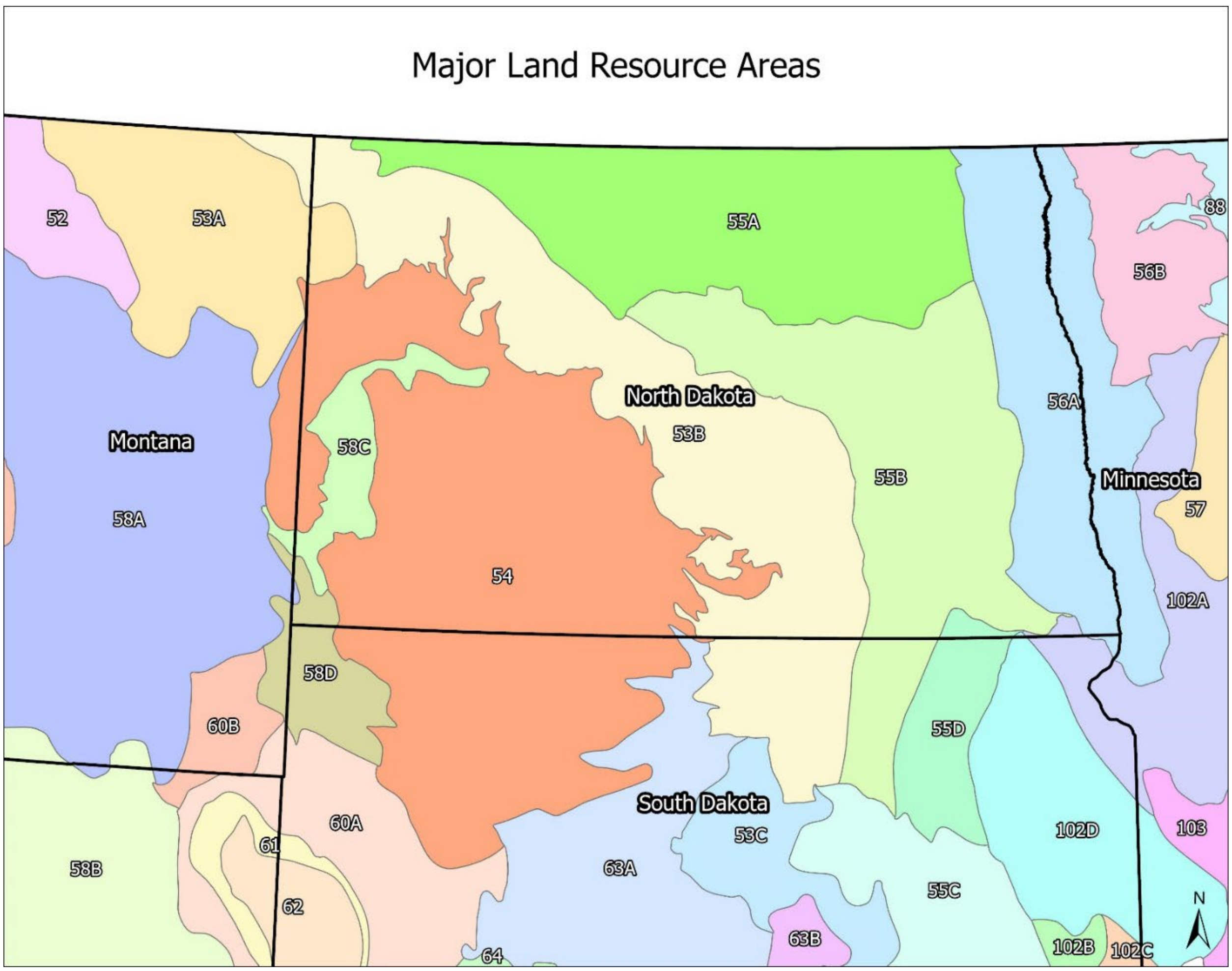
North Dakota MLRA Map



Major Land Resource Areas of Western North Dakota

Sunday Tour: July 9, 2023

The Sunday, July 9th Tour will kick off the 2023 NCSS National Conference, where participants will travel between Bismarck and Medora. This tour will showcase many beautiful, interesting natural and anthropogenic features across MLRAs 54 and 58C in southwest North Dakota. Stops will include viewing sodic soils, lunch on the Tjaden Terrace in Medora overlooking the scenic Little Missouri River, a drive through Theodore Roosevelt National Park, and numerous points of interest along the way.



MLRA 54—Rolling Soft Shale Plain

A typical landscape of MLRA 54—Rolling Soft Shale Plain (photo courtesy of NRCS).

MLRA 54 covers 29,280 square miles and encompasses approximately 18.7 million acres spanning three states. Sixty-four percent of MLRA 54 is in North Dakota, 33% is in South Dakota, and 3% is in Montana.

The MLRA 54 landscape is characterized by old, moderately dissected rolling plains with small areas of local badlands, buttes, and isolated hills. Gravelly and sandy terraces are adjacent to broad flood plains along most of the major drainages. Most of MLRA 54 is underlain by soft, calcareous shale, siltstone, and sandstone of the Tertiary Fort Union Group and the Cretaceous Fox Hills and Hell Creek Formations.

MLRA 54 is predominantly unglaciated, and most of the soils developed from residuum weathered in place. Along the eastern and northern edges of the MLRA, where MLRA 54 transitions into the glaciated Missouri plateau, remnants of glacial till parent material remain on the high areas of the landscape. The dominant soil orders in this MLRA are Mollisols and Entisols.

The average annual precipitation is 13 to 19 inches (340 to 500 millimeters). Most of the rainfall comes from convective thunderstorms during the growing season. About half of the annual precipitation occurs as snow during the winter. Elevation is 1,650 feet (505 meters) on the eastern side of the MLRA, with a gradual rise to 3,600 feet (1,100 meters) on the western side.

The Missouri River runs along the north and east side of MLRA 54. Privately owned farms and ranches that produce a combination of cash-grain crops and livestock make up about 90 percent of the MLRA. About 55% of MLRA 54 is in grazed rangeland, and about 35% of the MLRA is used for dryland crops like wheat, barley, oats, canola, and flax. Corn for grain and silage, sunflowers, and alfalfa also are important crops. Some small tracts on the bottom land along the Missouri River are irrigated. The major soil resource concerns are wind erosion, water erosion, maintenance of organic matter and productivity of the soils, management of soil moisture, and control of saline seeps.

MLRA 58C— Northern Rolling High Plains, Northeastern Part

A typical landscape of MLRA 58C—Northern Rolling High Plains, Northeastern Part (photo courtesy of NRCS).

MLRA 58C covers 2,300 square miles and encompasses approximately 1.8 million acres. The MLRA spans two states, with 96% in North Dakota and the remaining 4% in Montana. The Little Missouri River flows through the entire length of MLRA 58C and empties into Lake Sakakawea, which was formed by the Garrison Dam on the Missouri River. Elevation ranges from 1,835 feet (560 meters) to 3,400 feet (1,036 meters).

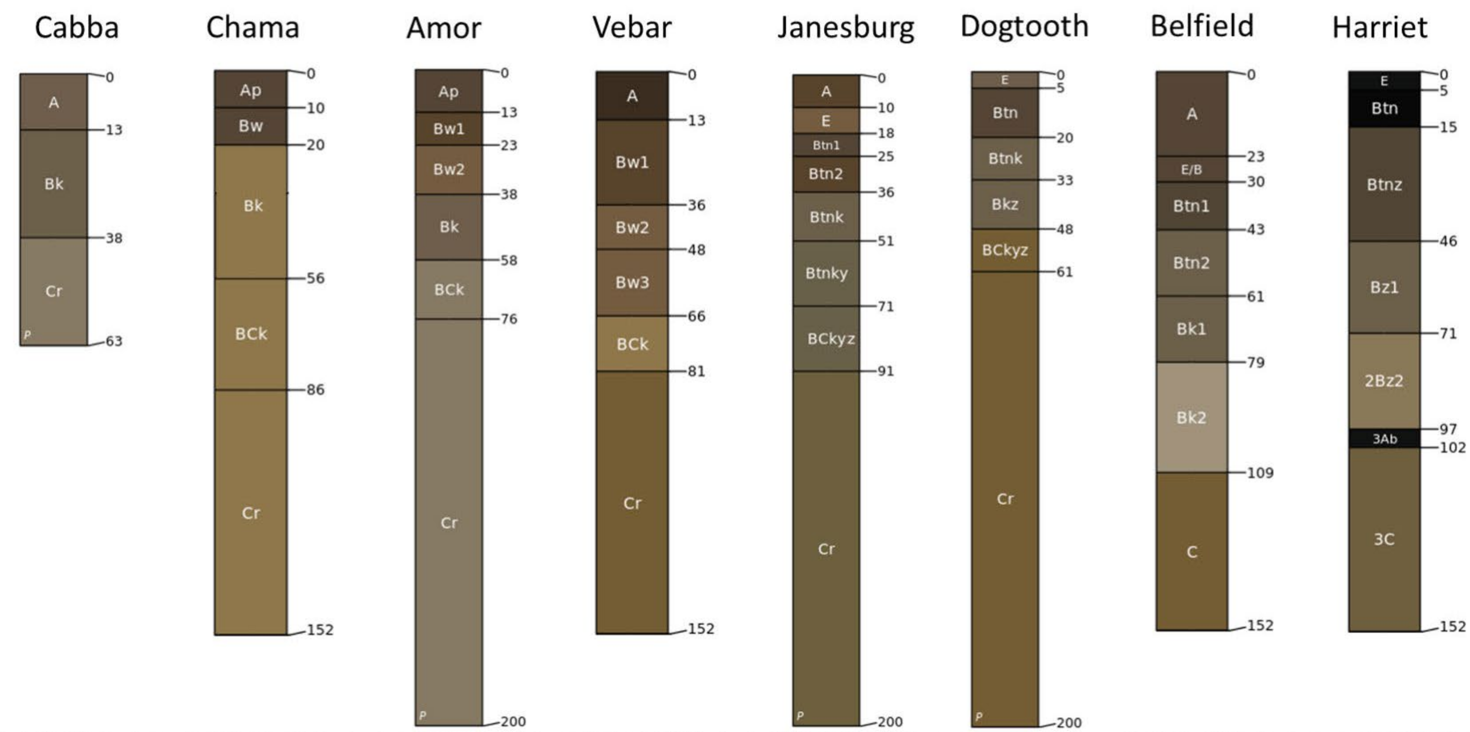
The MLRA 58C landscape is characterized by sparsely vegetated, steeply sloping, dissected badlands along the Little Missouri River and its tributaries. MLRA 58C is surrounded on three sides by MLRA 54 (Rolling Soft Shale Plain), but the boundary between MLRA 58C and adjacent MLRA 54 is abrupt and unmistakable as it is based on topography and land use.

MLRA 58C is known as the Little Missouri Badlands, which formed when the Little Missouri River was diverted along a shorter, steeper course by Pleistocene glaciers. Due to the increased gradient after its eastward diversion by the glaciers, the Little Missouri River began rapidly downcutting into the soft, calcareous sedimentary shale, siltstone, and sandstone of the Fort Union and Hell Creek geological formations. This rapid downcutting eroded and carved the badlands of MLRA 58C, and this cycle of erosion and deposition continues today.

Microclimates inherent in badlands landscapes influence both variety and abundance of vegetation in MLRA 58C. South- and west-facing exposures are dry, hot, and sparsely vegetated. More humid and cooler north- and east-facing exposures are favorable for abundant forage and woody vegetation.

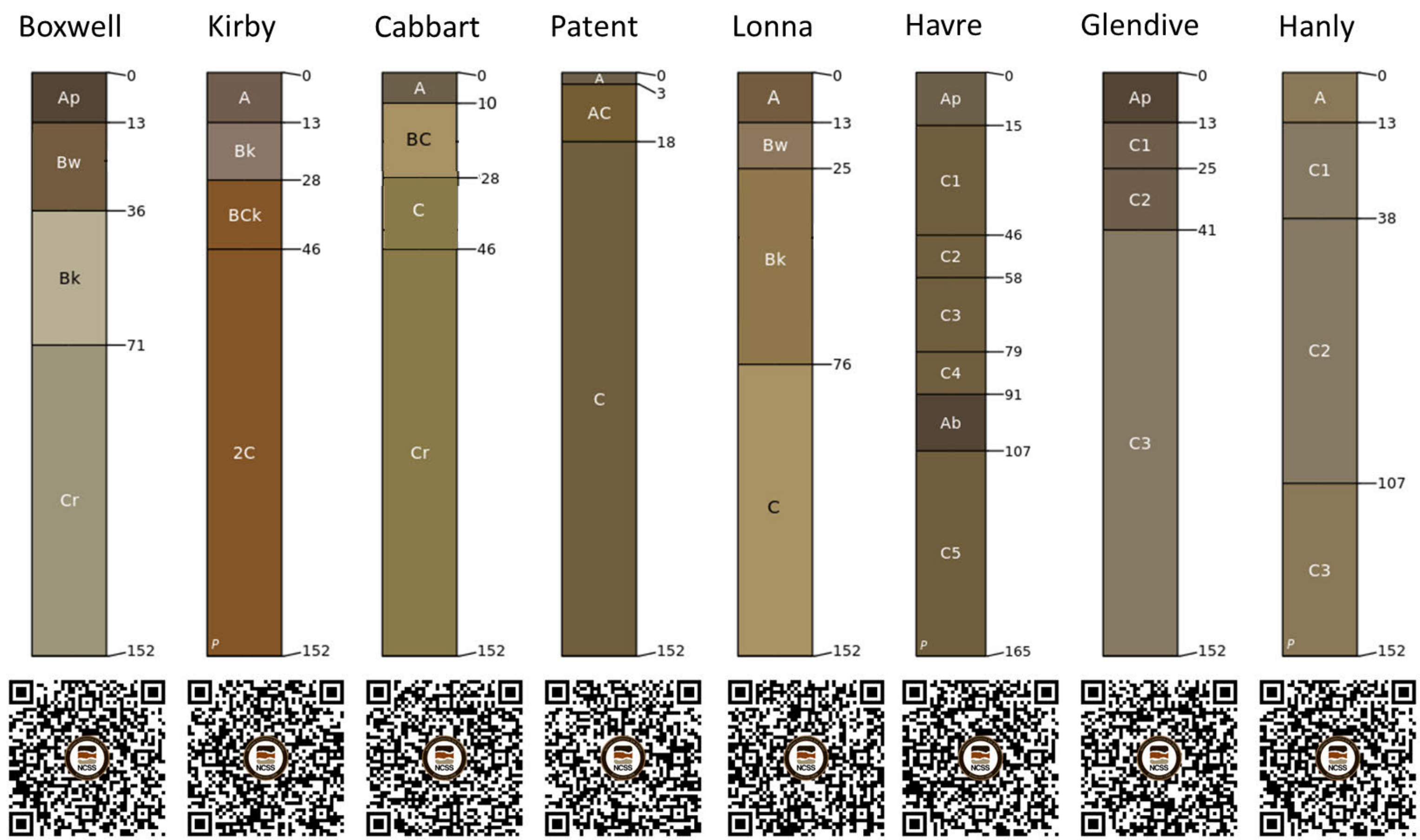
Most of the soils in MLRA 58C developed from residual parent materials. As a result of constant erosion and deposition, the majority of soils in MLRA 58C are Entisols and Inceptisols. Mollisols have formed on the high, stable drainage divides and plateaus above the steeper, dissected hillslopes and fans that define the Little Missouri Badlands. About 85% of MLRA 58C is rangeland used for grazing beef cattle, mainly run as cow-calf operations. The remaining 15% is used for dryland farming of small grains and hay production or as wildlife habitat. Major soil resource concerns are wind erosion, water erosion, maintenance of organic matter and productivity of the soils, and management of soil moisture.

Common Soils of MLRA 54



Scan the QR code for the Official Series Description for each soil series.

Common Soils of MLRA 58C



Scan the QR code for the Official Series Description for each soil series.

Geology of Southwest North Dakota

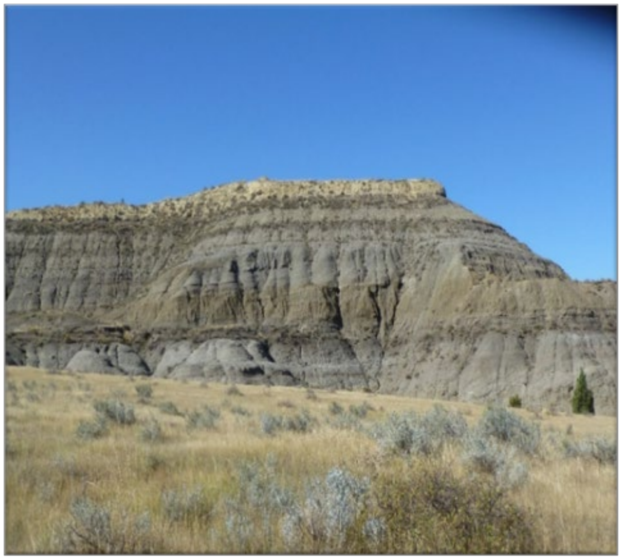


Photo courtesy of NRCS

Most soils in southwest North Dakota have residual parent material derived from the soft sedimentary bedrock of the Fort Union Group geological formations (Paleocene). Most of the exposed formations visible on the pictured escarpment are part of the Fort Union Group.

The Bullion Creek Formation is at the top, with older Fort Union Group formations beneath. Thin bands of lignite coal are visible within these formations. The gray stratum at the bottom of the escarpment is the Hell Creek Formation of the Montana Group, which is famous for its Cretaceous-age fossils.

Photo courtesy of NRCS

This outcrop is of the Golden Valley Formation (Eocene) in northern Billings County. The bright white, gray-lavender, and yellow colors of the beds are characteristic of the Golden Valley Formation. Much of this formation has been eroded, but remnants still cap many of the buttes in southwestern North Dakota.

Soils that developed from the highly weathered Golden Valley Formation have unique soil properties that are atypical of most soils in southwest North Dakota. Properties include low pH throughout the profile, a low cation exchange capacity (CEC), and low activity kaolinitic clays with 1:1 clay mineralogy.

Photo by Krista Bryan

White Butte is the highest natural point in North Dakota at an elevation of 3,506 ft (1,069 m). White Butte is capped with light-colored rock and sandstone from the White River Group (Oligocene) and is overlain by bentonite clay.

Formations of the White River Group are the youngest formations deposited in southwest North Dakota. Most exposed areas have eroded away, except for some of the highest buttes. Formations of the White River Group contain fossil fish and mammals, as well as leaf and stem imprints.

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Geology of Western North Dakota — Porcelanite

Photo by Jeff Printz

Outcrops of porcelanite or "clinker" cap many ridges and hills throughout southwest North Dakota. Locally called "scoria," the porcelanite in North Dakota is not volcanic in origin like the true igneous scoria that it resembles.

It is a sedimentary rock that has undergone metamorphism from the intense heat generated by underground seams of lignite coal that have burned, baking the soft sedimentary bedrock into a form of natural brick.

Photo courtesy of NRCS

Porcelanite is created when an exposed lignite coal seam catches fire, usually from a range fire started by a lightning strike or spontaneous combustion. Once ignited, the coal seam burns underground until it runs out of fuel or encounters a barrier that will no longer sustain combustion.

Underground coal seam fires can burn for decades, with temperatures reaching 540 degrees C (1,000 degrees F). In the photo, the coal seam is visible on the right side of the escarpment. That same coal seam burned and was replaced by porcelanite on the left side of the escarpment.

Photo courtesy of NRCS

Large clinker plugs scattered across the landscape are thought by geologists to be what remains of the fissures or vents (chimneys) that extended through the soil between the burning coal veins and the ground surface that allowed oxygen in to sustain the smoldering underground coal seam fires.

The sharp edges on these isolated clinker boulders made very effective scratching posts, and some have areas on them that have been rubbed smooth and shiny by centuries of itchy bison shedding their winter hair.

Photo by Krista Bryan

When coal seams burn underground, the intense heat generated from the burning coal bakes and hardens the soft, fine-grained sedimentary shale, siltstone, mudstone, or sandstone bedrock immediately above and below the burning coal vein into hard, fragmented metamorphic rock that ranges in color from yellow to red.

The color of the porcelanite varies depending on the amount of iron oxide in the clay and how hot the temperature was as the coal vein burned.

Photo by Jeff Printz

Knobs, ridges, and conical hills capped with porcelanite resist erosion since the porcelanite caprock is harder than the underlying unbaked sedimentary material.

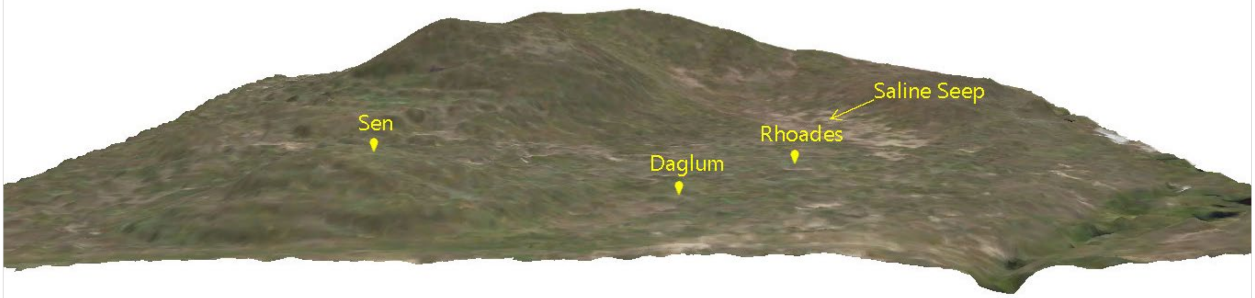
Over time, erosion removes the less resistant material, leaving behind knobs, ridges, and buttes topped with durable porcelanite caps standing above the more level topography sculpted from the adjacent unbaked sediments.

Photo courtesy of NRCS

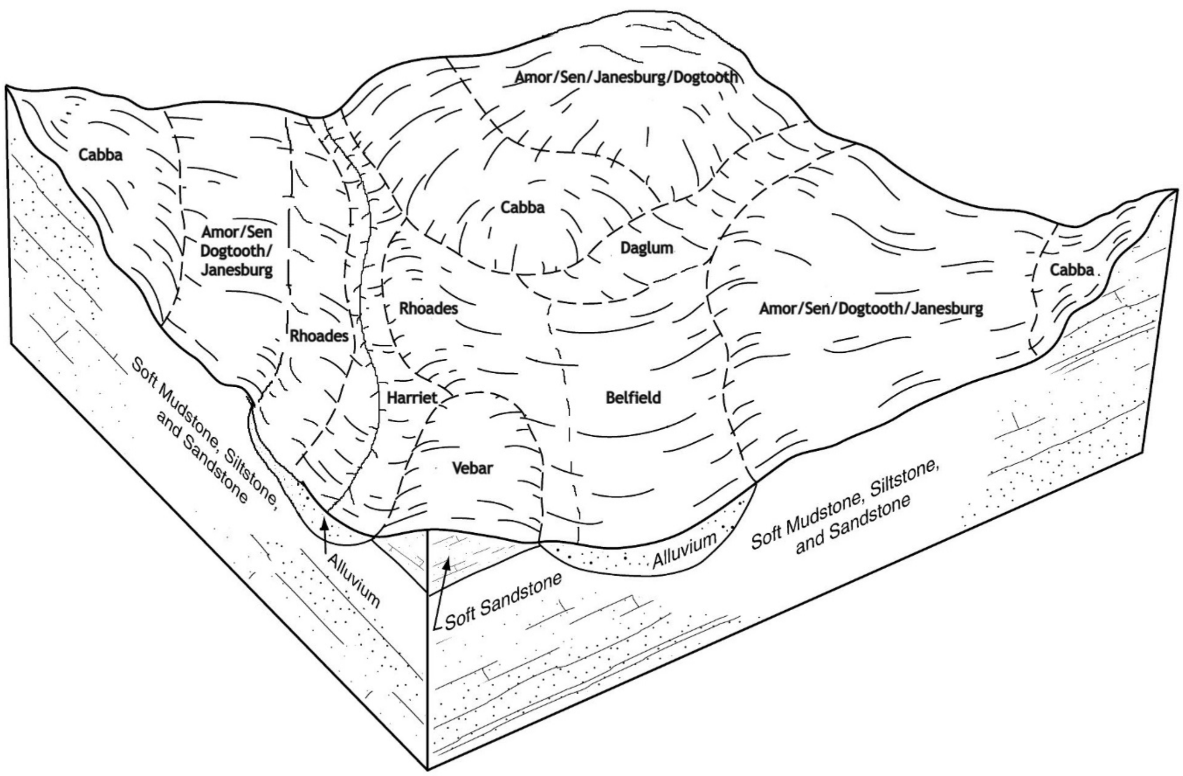
Because porcelanite is abundantly available in southwest North Dakota and gravel is not, porcelanite is often used as a surface for oil well pads, stock tank aprons, and as road surfacing material on many rural and county roads.

Clinker fragments are very angular with sharp points and edges and resemble shards of broken clay flowerpots. Ten-ply tires with all-weather tread are must-haves if traveling on these roads.

Soil Pit Site Information



Landscape diagram of the sodic soil pits tour.



Natric soil catena in MLRA 54.

Natric and Salt Affected Soils

Salinity, Erosion, and Conservation Case Study

This site in Hettinger County North Dakota depicts conservation at work. The farmer was cropping right up to the edge of this waterway resulting in major nutrient, chemical, and sediment load to the system. In addition, a salt crust was visible along the bank. The build-up of carbonates, soluble salts, and sodium along the waterway is detrimental to soil health and plant growth. The landowner enrolled in the Conservation Stewardship Program (CSP) and installed filter strips between the field edge and the waterway and began leaving unharvested grain as a food plot for wildlife. The photos below show the “before” pictures taken in 2018 and the “after” pictures taken in 2022 (photos courtesy of NRCS).

Spring of 2018—Ponded water at the edge of the field, which extends right up to the edge of the waterway.

Spring of 2018—Waterway that crosses the field. Note the white salt crusts along the edge of the drainageway.

Spring of 2018—Cropland extending to the edge of the waterway.

Fall of 2022—View of the cropland and waterway after conservation practices were implemented.

Fall of 2022—View of the cropland, filter strips, and waterway after conservation practices were implemented.

Fall of 2022—Filter strip between the field edge and the waterway.

Sodium-affected Soils in MLRA 54

In MLRA 54, there are over 3 million acres of sodium-affected soils with elevated levels of sodium which negatively affect plant establishment and growth, reducing crop yields. High levels of sodium occur naturally in many western North Dakota soils that are derived from the soft, sedimentary shale, siltstone, mudstone, and sandstone beds underlying MLRA 54.

Soluble salts and sodium are inherent in the soil parent material and were washed in and deposited when western ND was covered by a vast, shallow inland swamp during the Paleocene epoch. Shown at the left is the characteristic micro-relief of a southwest North Dakota landscape dominated by sodium-affected soils (photo courtesy of NRCS).

Soils high in sodium present chemical and physical restrictions to plant growth. High pH levels (> 8.2) in sodic soils reduce nutrient availability and have an adverse effect on seed germination and seedling establishment. Sodium ions also cause dispersion of clay particles in the soil, resulting in the formation of a dense layer (claypan) that is impenetrable to plant roots when it dries. In natric soils, the dense claypan layer typically develops within 50 cm (20 inches) of the soil surface and is often at the surface in Leptic natric soils (photo courtesy of NRCS).

Sodium-affected soils typically have an argillic (Btn) horizon with strong columnar structure. The columns have dense rounded caps, sometimes referred to as "biscuit tops" because of their appearance. Since sodium is inherent in the sedimentary parent material and evapotranspiration is greater than precipitation in southwest North Dakota, the highest levels of sodium in the soil profile are in the horizons below the Btn horizon (photo by Dr. Jim Arndt).

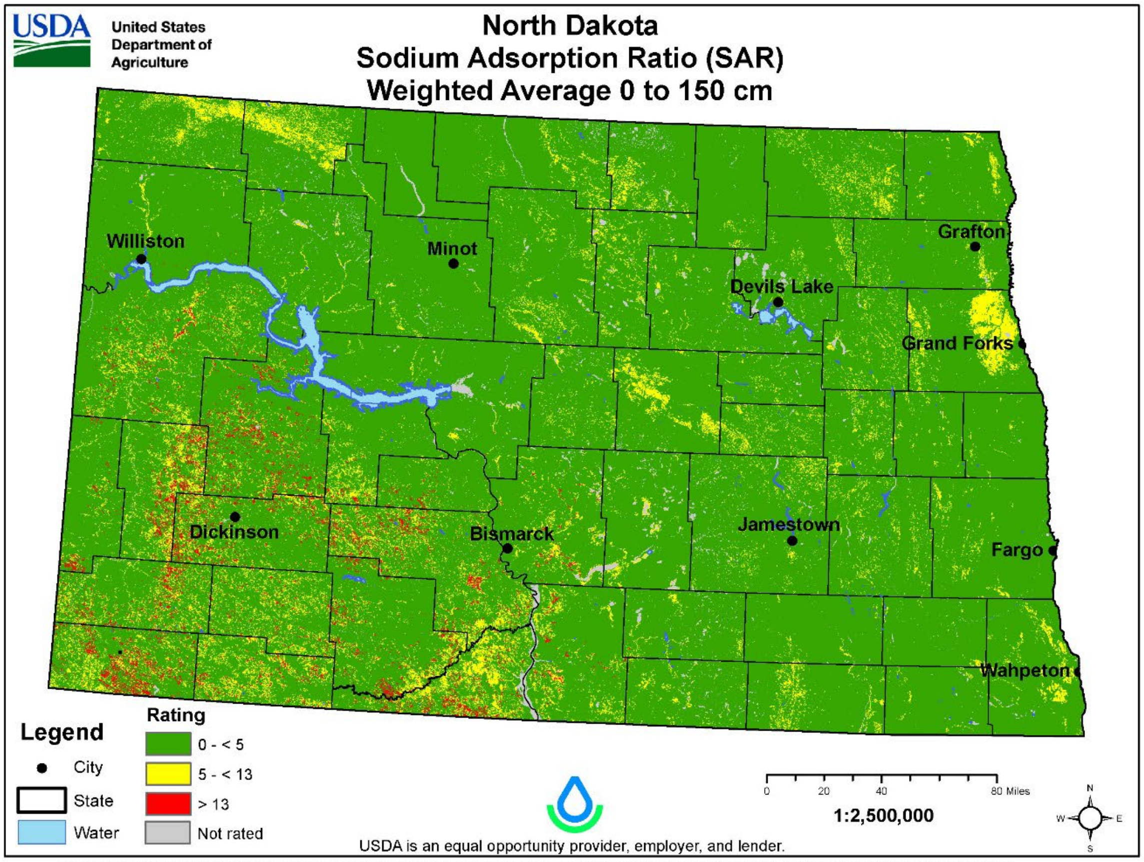
When the dense claypan layer is at or near the soil surface as is the case with Leptic natric soils such as the Rhoades series, plant growth is severely restricted. In rangeland, the surface pan spots are often devoid of vegetation or only have prickly pear cactus and a few sparse club moss or western wheatgrass growing on them (photo courtesy of NRCS).

Soil structure in sodic soils is poor and permeability is slow or very slow. Sodic soils will typically pond water after brief, intense thunderstorms during the summer months. If the dense claypan layer was dry before the thunderstorm, ponded water is not able to infiltrate down through the claypan into the soil profile but will remain ponded on the surface until the water eventually evaporates. The overall effect of this soil structure on plant growth is one of stress similar to that caused by drought conditions (photo courtesy of NRCS)

The dense claypan layer that forms in sodic soils is restrictive to root growth. In sodic soils, most roots are concentrated in the topsoil above the claypan layer and form a tangled root mat on top of the columns. A few hardy roots will try and grow between the columns, but the root structure is poor and is usually limited to one main root. Sodic soils are characterized by significant swelling when wet and shrinking as they dry, so the fine root hairs are sheared off the roots growing between the columns when the soils expand and contract (photo courtesy of NRCS).

The micro-relief that is typical across sodium-affected landscapes in North Dakota is evident in annual cash crops grown on sodium-affected soils in southwestern ND. Even when management and crop variety are the same, annual crops (such as the spring wheat in the picture) growing on sodic soils exhibit this uneven appearance across a field. Short, poorly producing plants that mature early are growing in the micro-lows where the dense claypan is close to the surface (Leptic natrics), and the taller, greener, healthier looking plants are growing on the micro-high areas of the field where the dense claypan layer is deeper (Typic natrics) (photo courtesy of NRCS).

Rangeland (perennial grass) response to sodic soils in MLRA 54. Rangeland also exhibits the uneven appearance of native grasses and forbs growing on the micro-lows and micro-highs that are characteristic of sodium-affected landscapes in southwestern North Dakota. The uneven, pock-marked appearance is more exaggerated on rangeland than in cropland since in cropland, the mechanical action of tillage tends to mix the topsoil and sodic subsoil and evens out the appearance of the landscape (photo courtesy of NRCS).



Soil Survey Staff. Gridded Soil Survey Geographic (gSSURGO) Database for State name. United States Department of Agriculture, Natural Resources Conservation Service. Available online at https://gdg.sc.egov.usda.gov/. 10/31/2022 (FY2023 official release)

Sodium Adsorption Ratio (SAR)

Sodium adsorption ratio is a measure of the amount of sodium (Na) relative to calcium (Ca) and magnesium (Mg) in the water extract from saturated soil paste. It is the ratio of the Na concentration divided by the square root of one-half of the Ca + Mg concentration. Soils that have SAR values of 13 or more may be characterized by an increased dispersion of organic matter and clay particles, reduced saturated hydraulic conductivity (Ksat) and aeration, and a general degradation of soil structure.

For each soil layer, this attribute is actually recorded as three separate values in the database. A low value and a high value indicate the range of this attribute for the soil component. A "representative" value indicates the expected value of this attribute for the component. For this soil property, only the representative value is used.

Daglum Series Information

LOCATION DAGLUM ND+MT SD

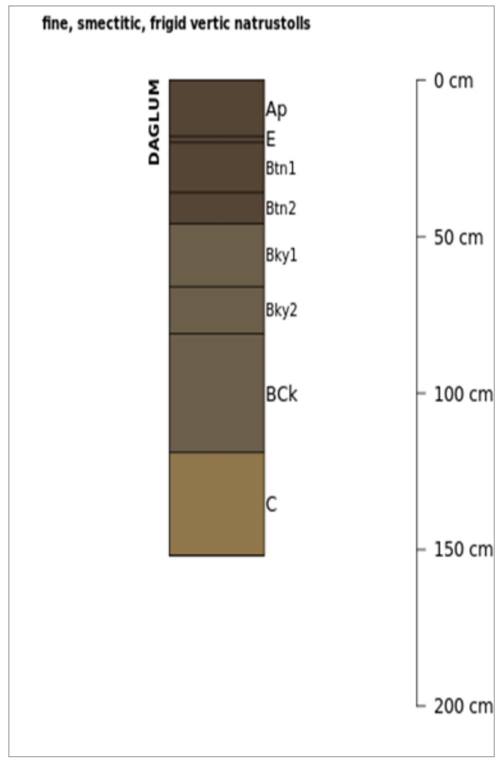
Established Series

TMC-CJH 8/98

Scan the QR code for the full description.

DAGLUM SERIES

The Daglum series consists of deep and very deep, moderately well and well drained soils formed in clayey alluvium or residuum on foot slopes and swales on terraces and uplands. These soils have slow or very slow permeability. Slopes range from 0 to 25 percent. Mean annual air temperature is about 42 degrees F, and the mean annual precipitation is about 16 inches.



TAXONOMIC CLASS: Fine, smectitic, frigid Vertic Natrustolls

TYPICAL PEDON: Daglum silt loam - on a broad upland flat having a 1 percent slope in cropland. (Colors are for dry soil unless otherwise stated. Where described the soil was dry throughout.)

Ap--0 to 7 inches; dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; moderate medium granular structure; slightly hard, friable, slightly sticky and slightly plastic; many very fine roots; slightly acid; abrupt smooth boundary. (4 to 15 inches thick)

E--7 to 8 inches; grayish brown (10YR 5/2) silt loam, very dark grayish brown (10YR 3/2) moist; moderate medium and coarse subangular blocky structure parting to moderate fine subangular blocky and weak medium platy; slightly hard, friable, slightly sticky and slightly plastic; many very fine pores; light gray (10YR 7/2 coatings; slightly acid; clear smooth boundary. (0 to 5 inches thick)

Btn1--8 to 14 inches; dark grayish brown (10YR 4/2) clay, very dark grayish brown (10YR 3/2) moist; strong fine and medium columnar structure parting to strong fine and medium angular blocky; extremely hard, very firm, very sticky and plastic; common very fine roots along faces of peds; many very fine pores; light gray (10YR 7/2) silt coatings on tops of columns; many faint clay films on faces of peds; very dark brown (10YR 2/2) moist coatings on faces of peds; slightly alkaline; gradual smooth boundary.

Btn2--14 to 18 inches; dark grayish brown (10YR 4/2) clay, very dark grayish brown (10YR 3/2) moist; strong medium and coarse prismatic structure parting to strong fine and medium angular blocky; extremely hard, very firm, very sticky and very plastic; common very fine roots along faces of peds; many very fine pores; many faint clay films on faces of peds; very dark brown (10YR 2/2) moist coatings on faces of peds; moderately alkaline; clear smooth boundary. (Combined Btn horizons 7 to 16 inches thick)

Bky1--18 to 26 inches; grayish brown (2.5Y 5/2) clay loam, dark grayish brown (2.5Y 4/2) moist; strong fine and medium angular and subangular blocky structure; very hard, very firm, very sticky and very plastic; common very fine roots; many very fine pores; few faint clay films on faces of peds; very dark grayish brown (10YR 3/2) moist coatings on faces of peds; few fine gypsum crystals; common fine and medium irregularly shaped masses of lime; strong effervescence; strongly alkaline; clear smooth boundary.

Bky2--26 to 32 inches; grayish brown (2.5Y 5/2) clay loam, dark grayish brown (2.5Y 4/2) moist; weak coarse prismatic structure parting to moderate medium subangular blocky structure; hard, firm, sticky and plastic; common very fine roots; common very fine pores; common fine and medium gypsum crystals; common fine and medium irregularly shaped masses of lime; violent effervescence; strongly alkaline; clear smooth boundary. (Combined Bky horizons 0 to 20 inches thick)

BCk--32 to 47 inches; grayish brown (2.5Y 5/2) clay loam, dark grayish brown (2.5Y 4/2) moist; weak medium subangular blocky structure; hard, firm, sticky and plastic; few very fine roots; many very fine pores; common fine threads of lime; violent effervescence; moderately alkaline; clear wavy boundary.

C--47 to 60 inches; light yellowish brown (2.5Y 6/4) clay, light olive brown (2.5Y 5/4) moist; common fine distinct brownish yellow (10YR 6/8)redoximorphic concentrations; weak medium and coarse subangular blocky structure; extremely hard, very firm, very sticky and very plastic; few very fine roots; common very fine pores; few fine gypsum crystals; common fine irregularly shaped masses of lime; strong effervescence; moderately alkaline.

TYPE LOCATION: Adams County, North Dakota; about 8 miles north and 1 mile east of Reeder; 1950 feet east and 1355 feet north of the southwest corner, sec. 26, T. 132 N., R. 98 W.

RANGE IN CHARACTERISTICS: Soft sedimentary beds of shale, siltstone or fine grained sandstone are below depths of 40 inches. Stony and saline phases are recognized. Some pedons have Ab horizons.

The A horizon has hue of 10YR, value of 3 to 5 and 2 or 3 moist, and chroma of 2. It typically is clay loam or silty clay loam, but some is fine sandy loam, silt loam, loam or silty clay. It is moderately acid to neutral.

The E horizon has hue of 10YR or 2.5Y, value of 4 to 7 and 3 to 5 moist, and chroma of 1 or 2. It is very fine sandy loam, loam, silt loam, clay loam or silty clay loam. It is moderately acid to neutral. It has weak prismatic or blocky structure parting to weak or moderate platy. In some tilled pedons all of the E horizon has been mixed with the Ap horizon.

The Btn horizon has hue of 10YR or 2.5Y, value of 3 to 6 and 2 to 5 moist, and chroma of 2 or 3. It is clay, silty clay, silty clay loam or clay loam containing 35 to 60 percent clay. It has strong columnar structure in the upper part grading to moderate or strong prismatic and blocky in the lower part. The Btn horizon ranges from slightly acid to moderately alkaline in the upper part and slightly alkaline to strongly alkaline in the lower part. The exchangeable sodium exceeds 15 percent or the sodium plus magnesium exceeds calcium plus hydrogen. Salt crystals and some carbonate masses are in the lower part in some pedons.

The Bk horizon has hue of 10YR or 2.5Y, value of 4 to 6 and 3 to 5 moist, and chroma of 2 or 3. It is clay loam, clay or silty clay. It is slightly alkaline to strongly alkaline. Some pedons have salt or gypsum accumulations and some do not. Some pedons have Byz, By or Bz horizons up to 10 inches thick.

The BC and C horizons have hue of 2.5Y or 5Y, value of 5 to 7 and 3 to 6 moist, and chroma of 1 to 4. They are clay loam, silty clay, silty clay loam or clay. They are slightly alkaline to strongly alkaline. Some pedons have gypsum accumulations and some do not. The C horizon is stratified in some pedons. Texture of loam is allowed below a depth of 40 inches. Soft sedimentary beds of shale, siltstone or fine grained sandstone are below depths of 40 inches in some pedons.

COMPETING SERIES: This is the Janesburg series as previously classified. Janesburg soils are moderately deep to soft siltstone, shale or mudstone.

GEOGRAPHIC SETTING: Daglum soils are on level and nearly level terraces and on level to moderately steep uplands. They are on foot slopes and swales. Slope gradients range from 0 to 25 percent. The soils formed in clayey alluvium or residuum from shale, siltstone, or fine grained sandstone. The mean annual air temperature ranges from 39 to 45 degrees F, and mean annual precipitation from 13 to 19 inches. Most of the precipitation comes in the spring and summer.

GEOGRAPHICALLY ASSOCIATED SOILS: These are the Belfield, Farland, Grail, Lawther, Moreau, Morton, Reeder, Regent, Rhoades, Savage and Shambo soils. Belfield and Rhoades soils are in complex with the Daglum series. Belfield soils have interfingering of an E horizon into the Btn horizon and do not have strong columnar structure. Rhoades soils have visible salts or gypsum within a depth of 16 inches. None of the other soils have natric horizons. They are on nearby terraces and uplands.

DRAINAGE AND PERMEABILITY: Moderately well and well drained. Runoff is negligible to high depending on slope. Permeability is slow or very slow.

USE AND VEGETATION: Used for range, pasture, and small grains. Native vegetation is western wheatgrass, blue grama, green needlegrass, needleleaf sedge and forbs.

DISTRIBUTION AND EXTENT: Western North Dakota, northwestern South Dakota, and eastern Montana. The soil is of large extent.

MLRA SOIL SURVEY REGIONAL OFFICE (MO) RESPONSIBLE: Denver, Colorado

SERIES ESTABLISHED: Bowman County, North Dakota, 1969.

REMARKS: Diagnostic horizons and features recognized in this pedon are: mollic epipedon - the zone from the surface of the soil to a depth of 18 inches (Ap, E, Btn1 and Btn2 horizons); natric horizon - the zone from 8 to 18 inches (Btn1 and Btn2 horizons); vertic criteria - LE of more than 6 cm in the upper meter.

ADDITIONAL DATA: North Dakota Agricultural Experiment Station laboratory data number S62ND-45-1.

National Cooperative Soil Survey
U.S.A.

USDA NRCS, MLRA 54—Claypan Ecological Site Description

Site stage: Provisional

Provisional: An Ecological Site Description (ESD) at the provisional status represents the lowest tier of documentation that is releasable to the public. It contains a grouping of soil units that respond similarly to ecological processes. The ESD contains: 1) enough information to distinguish it from similar and associated ecological sites and, 2) a draft state-and-transition model capturing the ecological processes, vegetative states, and community phases as they are currently conceptualized. The provisional ESD has undergone both quality control and quality assurance protocols. It is expected that the provisional ESD will continue refinement towards an approved status.

Scan the QR code for the full ecological site description.

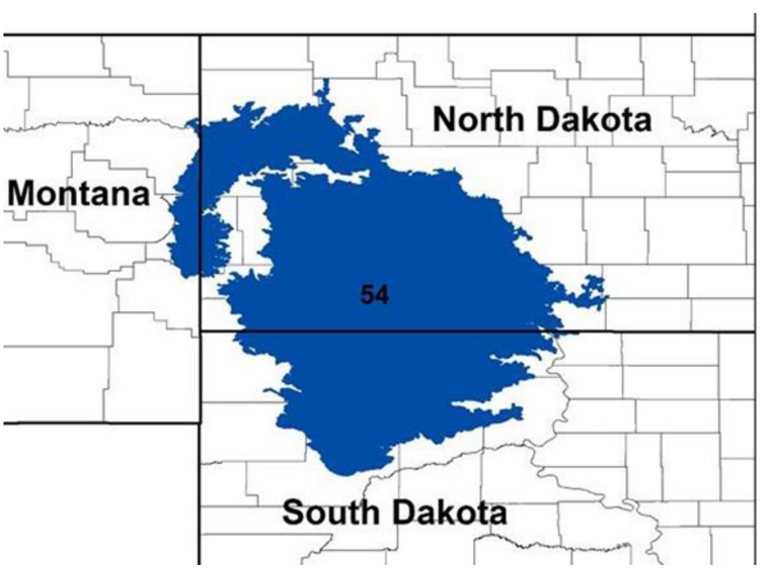
Site Name: Claypan

Site Type: Rangeland

Site ID: RO54XY021ND

Major Land Resource Area 54: Rolling Soft Shale Plain

For more information on MLRA's, refer to the following web site:
https://www.nrcs.usda.gov/resources/data-and-reports/major-land-resource-area-mlra



Location of MLRA 54, Rolling Soft Shale Plain in North Dakota, South Dakota, and Montana

MLRA 54 covers 29,280 square miles and encompasses approximately 18.7 million acres. MLRA 54 spans three states with 64 percent of it in North Dakota, 33 percent in South Dakota, and 3 percent in Montana. Most of MLRA 54 is underlain by soft, calcareous shale, siltstone, and sandstone of the Tertiary Fort Union Group and the Cretaceous Fox Hills and Hell Creek Formations. Most of the soils in MLRA 54 developed from residuum weathered in place. Along the eastern and northern edges of the MLRA where MLRA 54 transitions into the glaciated Missouri plateau, remnants of glacial till parent materials still remain on the high areas of the landscape. The MLRA 54 landscape is characterized by old, moderately dissected rolling plains with areas of local badlands, hills, and isolated buttes. Elevation is 1,650 feet (505 meters) on the eastern side of the MLRA with a gradual rise to 3,600 feet (1,100 meters) on the western side. The Missouri River runs along the north and east side of MLRA 54. Most of the Standing Rock Indian Reservation, the northwest third of the Cheyenne River Indian Reservation, and the Grand River National Grasslands are in the southern part of the MLRA.

Ecological Site Concept

The Claypan ecological site occurs on backslopes and erosional footslopes of hillslope landforms in MLRA 54. Soils are moderately deep to very deep with soft, sedimentary bedrock parent material below 20 inches. Surface textures range from fine sandy loam to silty clay loam, and form a ribbon less than 2 inches long. The dense, root-limiting subsoil (claypan) ranges from heavy silty clay loam to clay, and forms a ribbon greater than 2 inches long. The heavy-textured, sodium-affected claypan is below 6 inches from the soil surface, and has columnar structure with visible salts and gypsum crystals below 16 inches. The slopes range from 0 to 25 percent. This site occurs on well drained or moderately well drained uplands in conjunction with Thin Claypan and Clayey ecological sites. Saline Lowland sites occur in the shallow drainageways that crisscross these landforms. Vegetation in the Reference site consists primarily of mid-statured, cool-season grasses (e.g., western wheatgrass and needlegrasses) and short-statured, warm-season bunchgrass (e.g., blue grama).

Physiographic Features

This site occurs on level to moderately steep sedimentary uplands in MLRA 54.

Landform: (1) Hillslopes

	Minimum	Maximum
Elevation (feet):	1650	3600
Slope (percent):	0	25
Water table depth (inches):	48	None
Flooding:	---	---
Frequency:	None	None
Ponding:	---	---
Frequency:	None	None
Runoff class:	Low	High
Aspect:	No influence on this site.	No influence on this site.

Representative Soil Features

The Claypan ESD in MLRA 54 is represented by moderately deep to very deep, fine-textured sodium-affected soils. Representative soils in MLRA 54 include the deep or very deep Daglum series and the moderately deep Janesburg series. Slopes range from 0 to 25 percent. The soils in this ecological site are well or moderately well drained, and developed in soft sedimentary shale and siltstone parent materials, or from alluvium derived from soft shale and siltstone residuum.

The surface layer is generally 4 to 10 inches thick, and textures range from fine sandy loam to silty clay loam. In native rangeland, the upper horizons have not been mixed by tillage operations, and so a light-colored subsurface layer immediately below the surface horizon may be visible. This layer is lighter-textured than the surface layer and ranges from 1 inch to 5 inches thick with thin platy structure. Permeability is moderate or moderately slow in the surface horizons, and slow or very slow in the subsoil. Cryptobiotic crusts are present, but their function is not well understood. Some pedestalling of plants may occur, but it is not very evident on casual observation and occurs on less than 5 percent of the plants. Water flow paths are broken and irregular in appearance or are discontinuous with numerous debris dams or vegetative barriers. There is a risk of rills and eventually gullies if vegetative cover is not adequate.

Claypan and Thin Claypan ecological sites typically occur in conjunction with one another on the rolling, complex residual and alluvial landforms in MLRA 54. Claypan sites are on micro-highs and Thin Claypan sites are in the micro-lows, resulting in the pock-marked appearance of the ground surface that is characteristic of sodium-affected landscapes in MLRA 54.

The following soil properties listed in the following table represent the soil profile above the sedimentary beds.

Major soil series correlated to this ecological site can be found in Section II of the Natural Resources Conservation Service (NRCS) Field Office Technical Guide or the following web sites:

- http://www.nrcs.usda.gov/technical/efotg/
- http://soildatamart.nrcs.usda.gov/
- http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm

Parent materials
Kind: Residuum, slope alluvium
Origin: Shale, siltstone
Surface texture:
(1) Clay loam
(2) Silty clay loam
(3) Silt loam
Subsurface texture group: Clayey

	Minimum	Maximum
Surface fragments <=3" (% cover):	0	0
Surface fragments >3" (% cover):	0	0
Subsurface fragments <=3" (% volume):	0	0
Subsurface fragments >3" (% volume):	0	0
Drainage class: Moderately well drained or well drained		
Permeability class: Slow or very slow		

	Minimum	Maximum
Depth (inches):	20	80
Available water capacity (inches):	3.00	8.00
Electrical conductivity (mmhos/cm):	0	16
Sodium adsorption ratio:	0	25
Calcium carbonate equivalent (percent):	0	25
Soil reaction (1:1 water):	5.6	9.0

Plant Communities

Ecological Dynamics of the Site:

The site developed under Northern Great Plains climatic conditions and included the natural influences of large herbivores and occasional fire. Changes will occur in the plant communities due to climatic conditions and/or management actions. Due to the nature of the soils, the site is considered moderately resilient. Under continued adverse impacts, a slow decline in vegetative vigor and composition will occur. If the existing plant community is in Reference State, implementing favorable vegetative management treatments may return to the Reference Plant Community. However, if existing plant community is outside the Reference State, returning to the Reference State is not feasible. The natural disturbance regime consisted of frequent fires caused both by natural and Native American ignition sources. These fires occurred during any season of the year, but were concentrated in the spring and late summer or early fall. Lightning fires occurred most frequently in July and August, while fires started by Native Americans occurred in April, September, and October. Large ungulate grazing was heavy and occurred often, but usually for short durations. Grazing may have been severe when occurring after a fire event, or in association with reliable water sources. The grazing and fire interaction, especially when coupled with drought events, set up the dynamics discussed and displayed in the following state–and-transition diagram and descriptions.

The plant community upon which interpretations are primarily based is the Reference Plant Community. The Reference Plant Community has been determined by study of rangeland relic areas, areas protected from excessive disturbance, and areas under long-term rotational grazing regimes. Trends in plant community dynamics ranging from heavily grazed to lightly grazed areas, seasonal use pastures, and historical accounts also have been considered. Subclimax plant communities, states, transitional pathways, and thresholds have been determined through similar studies and experience.

This ecological site has been grazed by domestic livestock since they were introduced into the area. The introduction of domestic livestock and the use of fencing and reliable water sources have radically changed the disturbance regime of this site. Heavy continuous grazing and/or continuous seasonal (spring) grazing, without adequate recovery periods following each grazing occurrence, causes this site to depart from the Reference State. Production of blue grama and buffalograss will begin to increase. Western wheatgrass will increase initially and then begin to decrease. Green needlegrass will decrease in frequency and production.

In time, heavy continuous grazing will likely cause blue grama and buffalograss to dominate and pioneer perennials, annuals, and club moss (when present) to increase. This plant community is relatively stable, and the competitive advantage prevents other species from establishing. This plant community is less productive than the Reference State. Runoff increases, and infiltration will decrease. Soil erosion will be minimal. Extended periods of non-use and/or lack of fire will result in a plant community with high litter levels, which favors an increase in exotic cool-season species (Kentucky bluegrass, crested wheatgrass, and/or smooth bromegrass).

Due to a general invasion of exotic cool-season species and alterations in historic disturbance regimes (i.e., reduced fire frequency) across the MLRA, returning to the Western Wheatgrass-Blue Grama-Needlegrasses Plant Community Phase 1.1 is not possible. Today, the 2.1 Western Wheatgrass-Blue Grama-Needlegrasses Plant Community Phase most resembles the 1.1 Reference Plant Community Phase in appearance and function.

Within the natural disturbance regime, droughts of varying length and severity are common. Long- term drought reduced plant vigor and seed production, and increased bare ground.

Extended periods of non-use and/or lack of fire results in a plant community with high litter levels, favoring an increase in exotic cool-season grasses such as Kentucky bluegrass, crested wheatgrass, and/or smooth bromegrass

Due to a general invasion of exotic cool-season species and alterations in historic disturbance regimes (i.e., reduced fire frequency) across the MLRA, returning to the Western Wheatgrass-Needlegrasses-Blue Grama Plant Community Phase 1.1, is not possible. Today, the Western

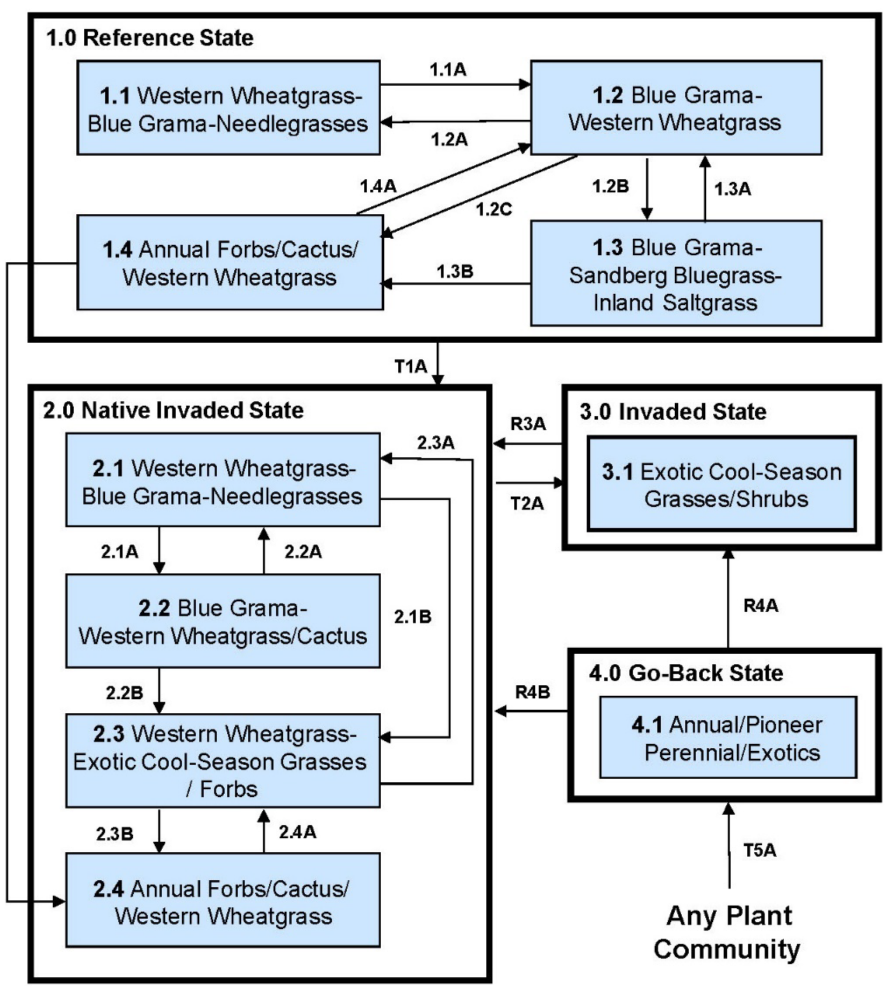
Wheatgrass-Needlegrasses-Blue Grama Plant Community Phase 2.1 most resembles the 1.1 Reference Plant Community Phase in appearance and function.

State-and-Transition Models (STM) are ecological process-driven models. The ecological dynamics characterized by the STM reflect the functional changes in ecological drivers and feedback mechanisms (pathways), and the resulting changes in plant community composition (phases or states). The application of various management actions coupled with weather variables impact the ecological processes/drivers/feedback mechanisms drive plant community composition changes. The pathway narratives describing the ecological dynamics of the site reference various management inputs (i.e., prescribed grazing, prescribed fire), it is the manager’s responsibility to understand how these various management actions impact the ecological processes/drivers/feedback mechanisms.

Plant Community and Vegetation State Narratives

Following are the narratives for each of the described plant communities. These plant communities may not represent every possibility, but they are the most prevalent and repeatable plant communities. The plant composition tables shown above have been developed from the best available knowledge at the time of this revision. As more data are collected, some of these plant communities may be revised or removed, and new ones may be added. None of these plant communities should necessarily be thought of as "Desired Plant Communities." According to the U.S. Department of Agriculture (USDA) NRCS National Range and Pasture Handbook, Desired Plant Communities (DPCs) will be determined by the decision-makers and will meet minimum quality criteria established by the NRCS. The main purpose for including any description of a plant community here is to capture the current knowledge and experience at the time of this revision.

Plant Communities and Transitional Pathways



2.3 Western Wheatgrass- Exotic Cool-Season Grasses/ Forbs

Diagram Legend — MLRA 54 Claypan

	T1A	Introduction of exotic cool-season grasses	
	T1B	Long-term prairie dog occupation coupled with introduction of exotic grasses and forbs	
	T2A	Extended periods of non-use or very light grazing, no fire	
	T5A	Cessation of annual cropping	
	R3A	Long-term prescribed grazing and prescribed fire with possible reseeding	
	R4A	Cropped go-back with continuous grazing; failed native seeding	
	R4B	Native seeding with prescribed grazing and prescribed fire	
	CP 1.1 - 1.2 (1.1A)	Long-term drought with/without heavy, long-term grazing	
	CP 1.2 - 1.1 (1.2A)	Return to average growing conditions and reduced grazing pressure	
	CP 1.2 - 1.3 (1.2B)	Long-term occupation by prairie dogs	
	CP 1.2 - 1.4 (1.2c)	Long-term occupation by prairie dogs with long-term drought	
	CP 1.3 - 1.2 (1.3A)	Removal of prairie dogs	
	CP 1.3 - 1.4 (1.3B)	Continued occupation by prairie dogs with long-term drought	
	CP 1.4 - 1.2 (1.4A)	Removal of prairie dogs, return to normal precipitation	
	CP 2.1 - 2.2 (2.1A)	Heavy continuous grazing with or without drought	
	CP 2.1 - 2.3 (2.1B)	Light (<20%) or no grazing; no fire	
	CP 2.2 - 2.1 (2.2A)	Reduced grazing pressure and return to average precipitation	
	CP 2.2 - 2.3 (2.2B)	Heavy continuous grazing coupled with long-term drought	
	CP 2.3 - 2.1 (2.3A)	Prescribed grazing and possibly prescribed burning	
	CP 2.3 - 2.4 (2.3B)	Long-term prairie dog occupation	
	CP 2.4 - 2.1 (2.4A)	Removal of prairie dogs	

Plant Community Composition and Group Annual Production

			1.1 Western Wheagrass- Blue Grama-Needlegrasses				
COMMON/GROUP NAME	SCIENTIFIC NAME	SYMBOL	Group	lbs./acre		% Comp	
GRASSES & GRASS-LIKES				*1275 - 1425*		*85*	*95*
MID-STATURED COOL-SEASON GRASSES				300 - 450		20 - 30	
western wheatgrass	Pascopyrum smithii	PASM	1	300	450	20	30
needle and thread	Hesperostipa comata ssp comata	HECOC8	1	75	225	5	15
green needlegrass	Nassella viridula	NAVI4	1	75	150	5	10
SHORT-STATURED COOL-SEASON GRASSES				75 - 150		5 - 10	
prairie Junegrass	Koeleria macrantha	KOMA	2	30	75	2	5
plains reedgrass	Calamagrostis montanensis	CAMO	2	0	75	0	5
WARM-SEASON GRASSES				150 - 225		10 - 15	
blue grama	Bouteloua gracilis	BOGR2	3	150	300	10	20
inland saltgrass	Distichlis spicata	DISP	3	15	45	1	3
OTHER NATIVE GRASSES				15 - 75		1 - 5	
buffalograss	Buchloe dactyloides	BUDA	4	15	75	1	5
thickspike wheatgrass	Elymus lanceolatus ssp. lanceolatus	ELLAL	4	0	150	0	10
prairie sandreed	Calamovilfa longifolia	CALO	4	15	45	1	3
other native grasses		2GN	4	15	30	1	2
GRASS-LIKES				30 - 105		2 - 7	
needleleaf sedge	Carex duriuscula	CADU6	5	15	75	1	5
threadleaf sedge	Carex filifolia	CAFI	5	15	75	1	5
FORBS			*6*	*75 - 225*		*5*	*- 15*
common yarrow	Achillea millefolium	ACMI2	6	15	30	1	2
onion	Allium spp.	ALLIU	6	0	15	0	1
rosy pussytoes	Antennaria rosea ssp. arida	ANROA	6	0	15	0	1
white sagebrush	Artemisia ludoviciana ssp. albula	ARLUA	6	0	15	0	1
wavyleaf thistle	Cirsium undulatum	CIUN	6	15	30	1	2
blanketflower	Gaillardia spp.	GAILL	6	15	30	1	2
prairie smoke	Geum triflorum	GETR	6	0	15	0	1
rush skeletonweed	Lygodesmia juncea	LYJU	6	0	15	0	1
leafy wild parsley	Musineon divaricatum var. divaricatum	MUDID	6	0	15	0	1
purple locoweed	Oxytropis lambertii var. articulata	OXLAA2	6	15	30	1	2
silverleaf scurfpea	Pediomelum argophyllum	PEAR6	6	15	30	1	2
woolly Indianwheat	Plantago patagonica	PLPA2	6	0	15	0	1
sticky cinquefoil	Potentilla glandulosa	POGL9	6	0	15	0	1
prairie coneflower	Ratibida columnifera	RACO3	6	15	30	1	2
Missouri goldenrod	Solidago missouriensis	SOMI2	6	0	15	0	1
scarlet globemallow	Sphaeralcea coccinea	SPCO	6	0	15	0	1
heath aster	Symphyotrichum ericoides	SYER	6	15	30	1	2
Nuttall's violet	Viola nuttallii	VINU2	6	0	15	0	1
other native forbs		2FN	6	0	15	0	1
SHRUBS			*7*	*15 - 75*		*1*	*- 5*
silver sagebrush	Artemisia cana	ARCA13	7	0	30	0	2
fringed sagewort	Artemisia frigida	ARFR4	7	15	30	1	2
Nuttall's saltbush	Atriplex nuttallii	ATNU2	7	15	30	1	2
rubber rabbitbrush	Ericameria nauseosa	ERNA10	7	0	30	0	2
purple pincushion	Escobaria vivipara var. vivipara	ESVIV	7	0	15	0	1
broom snakeweed	Gutierrezia sarothrae	GUSA2	7	0	15	0	1
winterfat	Krascheninnikovia lanata	KRLA2	7	15	30	1	2
brittle cactus	Opuntia fragilis	OPFR	7	0	15	0	1
other shrubs		2S	7	0	15	0	1
	Annual Production lbs./acre			LOW	RV	HIGH	
	GRASSES & GRASS-LIKES		920		1305	- 1690	

Daglum Pedon Description

Print Date: Feb. 17, 2023
Description Date: June 22, 2022
Describer: Wade Bott, John Kempenich
Site ID: S2022ND089001

Soil Survey Area: ND089 -- Stark County, North Dakota 5-DIC -- Dickinson, North Dakota

Pedon ID: S2022ND089001

Quad Name:
Lab Source ID: KSSL
Lab Pedon #: 22N0292

Country:
State: North Dakota
MLRA: 54 – Rolling Soft Shale Plain

Map Unit: E0515B -- RHOADES-DAGLUM COMPLEX, 2 TO 6 PERCENT SLOPES

Std Latitude: 46.9570170
Std Longitude: -103.1272750

User Transect ID:
Soil Name as Described/Sampled: Daglum
Classification: Fine, smectitic, frigid Vertic Natrustolls
Soil Name as Correlated:
Classification:
Pedon Type: classifies to current taxon name, full description
Pedon Purpose: laboratory sampling site
Taxon Kind: series
Associated Soils:
Physiographic Division:
Physiographic Province:

Physiographic Section:
State Physiographic Area:

Local Physiographic Area:
Geomorphic Setting: microhigh on footslope of hillslope on sedimentary plains
Upslope Shape: linear
Cross Slope Shape: linear
Particle Size Control Section: 27 to 77 cm.
Description origin: NASIS

Primary Earth Cover: Grass/herbaceous cover
Secondary Earth Cover: Grassland rangeland
Vegetation:
Parent Material: slope alluvium derived from sedimentary rock
Bedrock Kind:
Bedrock Depth:
Bedrock Hardness:
Bedrock Fracture Interval:
Surface Fragments:
Description database: KSSL

Diagnostic Features:

mollic epipedon 0 to 18 cm.
albic materials 10 to 27 cm.
albic horizon 18 to 27 cm.

redox concentrations 18 to 27 cm.

argillic horizon 27 to 89 cm.
natric horizon 27 to 89 cm.
secondary carbonates 61 to 177 cm.

gypsum accumulations 61 to 177 cm.
redox concentrations 89 to 245 cm.

Cont. Site ID: S2022ND089001 **Pedon ID:** S2022ND089001

Slope (%)	Elevation (meters)	Aspect (deg)	MAAT (C)	MSAT (C)	MWAT (C)	MAP (mm)	Frost-Free Days	Drainage Class	Slope Length (meters)	Upslope Length (meters)
0.0								Well drained		

A1--0 to 5 centimeters (0.0 to 2.0 inches); dark grayish brown (10YR 4/2) silt loam, very dark brown (10YR 2/2), moist; 15 percent sand; 25 percent clay; moderate fine granular structure; slightly sticky, slightly plastic; many very fine roots throughout; common very fine dendritic tubular pores; noneffervescent; clear smooth boundary. Lab sample # 22N01269

A2--5 to 10 centimeters (2.0 to 3.9 inches); dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2), moist; 15 percent sand; 25 percent clay; weak medium subangular blocky parts to moderate fine granular structure; slightly sticky, slightly plastic; many very fine roots throughout and ; common very fine dendritic tubular pores; noneffervescent; clear smooth boundary. Lab sample # 22N01270

AE--10 to 18 centimeters (3.9 to 7.1 inches); 70 percent dark gray (10YR 4/1) and 30 percent gray (10YR 5/1) silt loam, 70 percent black (10YR 2/1) and 30 percent very dark gray (10YR 3/1), moist; 17 percent sand; 25 percent clay; weak medium prismatic parts to moderate medium platy structure; slightly sticky, slightly plastic; many very fine roots throughout; common very fine dendritic tubular pores; noneffervescent; clear wavy boundary. Lab sample # 22N01271

E--18 to 27 centimeters (7.1 to 10.6 inches); gray (10YR 6/1) silt loam, dark gray (10YR 4/1), moist; 20 percent sand; 25 percent clay; moderate medium prismatic parts to moderate medium platy structure; slightly sticky, slightly plastic; many very fine roots throughout; common very fine dendritic tubular pores; 10 percent fine faint spherical 10YR 4/4) masses of oxidized iron with diffuse boundaries On faces of peds; noneffervescent; clear wavy boundary. Lab sample # 22N01272

Btn--27 to 61 centimeters (10.6 to 24.0 inches); grayish brown (10YR 5/2) silty clay, dark grayish brown (10YR 4/2), moist; 10 percent sand; 47 percent clay; moderate coarse columnar parts to weak medium angular blocky structure; slightly sticky, moderately plastic; common very fine roots throughout; common very fine dendritic tubular pores; 60 percent faint 10YR 3/2) clay films on all faces of peds; noneffervescent; clear wavy boundary. Lab sample # 22N01273

Btnky--61 to 89 centimeters (24.0 to 35.0 inches); light brownish gray (10YR 6/2) silty clay, dark grayish brown (10YR 4/2), moist; 10 percent sand; 42 percent clay; weak coarse prismatic parts to weak medium angular blocky structure; slightly sticky, moderately plastic; common very fine roots throughout; common very fine dendritic tubular pores; 2 percent prominent 10YR 7/2) gypsum coats on surfaces along pores and 50 percent faint 10YR 3/2) clay films on all faces of peds; carbonate, finely disseminated throughout and 1 percent fine distinct spherical 10YR 7/2) carbonate masses in matrix; slight effervescence; gradual wavy boundary. Lab sample # 22N01274

Bky--89 to 177 centimeters (35.0 to 69.7 inches); silty clay, dark grayish brown (10YR 4/2), moist; 10 percent sand; 43 percent clay; weak coarse prismatic structure; slightly sticky, moderately plastic; common very fine roots throughout; many very fine dendritic tubular pores; 3 percent prominent 10YR 7/2) gypsum coats on surfaces along pores; 1 percent fine faint spherical 10YR 6/6) masses of oxidized iron with diffuse boundaries On faces of peds; carbonate, finely disseminated throughout and 1 percent fine distinct spherical 10YR 7/2) carbonate masses in matrix; strong effervescence; gradual wavy boundary. Lab sample # 22N01275

C--177 to 245 centimeters (69.7 to 96.5 inches); clay, grayish brown (10YR 5/2), moist; 10 percent sand; 52 percent clay; massive; slightly sticky, very plastic; common very fine dendritic tubular pores; 2 percent fine faint spherical 10YR 6/6) masses of oxidized iron with diffuse boundaries on faces of peds; very slight effervescence. Lab sample # 22N0127.

Daglum Characterization Data

Pedon ID: S2022ND089001

Sampled Date: 6/2/2022

Series: Daglum

Classification: Fine, smectitic, frigid Vertic Natrustoll

Particle Size Control Section: 27 – 77

Clay Weighted Average: 48

CEC Activity, CEC7/Clay, Weighted Average: 0.58

Horizon	Depth	Texture	Clay (%)	Silt (%)	Sand (%)	Core Db (g/cm-3)	Est. OC (%)	Fine Silt (%)	Coarse Silt (%)	V. Fine Sand (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	V. Coarse Sand (%)	Coarse Fragments (%)
A1	0-5	sicl	34.1	52.6	13.3	1.12	5.77	36.9	15.7	8.1	4	1.1	tr	0.1	-
A2	5-10	sic	40.7	47.3	12.0	1.50	3.6	34.9	12.4	7.2	3.5	1	0.2	0.1	-
AE	10-18	sic	42.6	47.0	10.4	1.29	3.4	35.8	11.2	6.6	3.5	0.2	0.1	tr	-
E	18-27	sicl	36.7	57.5	5.8	1.55	1.9	39.4	18.1	2.9	2	0.9	tr	-	-
Btn	27-61	sic	50.7	42.8	6.5	1.52	1.3	32.6	10.2	4.3	1.6	0.6	tr	-	-
Btnky	61-89	sic	43.1	45.2	11.7	1.39	1.2	39.6	5.6	6.7	3.9	1	0.1	tr	-
Bky	89-177	sic	44.6	44.3	11.1	1.39	2.1	33.7	10.6	4.2	4.6	1.8	0.2	0.3	-
C	177-245	sic	48.7	42.8	8.5	1.58	0.7	35.2	7.6	3.6	3.2	1.6	0.1	-	-

Horizon	Depth	CEC7 (cmo/kg)	CEC7/Clay	Base Saturation (%)	EC (dS/m)	ESP (%)	SAR	Ext. Ca (cmol/kg)	Ext. Mg (cmol/kg)	Ext. Na (cmol/kg)	Ext. Acidity (cmol/kg)	pH Water	CaCO3 (%)
A1	0-5	26.7	0.78	95	-	1	-	16.5	7.0	0.2	13.6	6.7	-
A2	5-10	23.6	0.58	87	-	2	-	13.0	6.2	0.5	16.0	6.5	-
AE	10-18	27.2	0.64	91	-	4	-	15.5	7.3	1.1	15.5	6.3	-
E	18-27	19.6	0.53	100	-	8	-	12.4	5.9	1.6	9.8	7.0	-
Btn	27-61	29.8	0.59	100	-	11	-	18.8	10.5	3.3	10.6	7.8	-
Btnky	61-89	24.4	0.57	100	2.60	10	10	39.7	10.5	3.9	-	8.2	2
Bky	89-177	32.4	0.73	100	2.61	11	8	55.6	10.0	4.8	-	8.4	2
C	177-245	26.4	0.54	100	3.65	16	12	49.2	12.4	7.5	-	8.5	3

Rhoades Series Information

LOCATION RHOADES ND+MT SD

Established Series

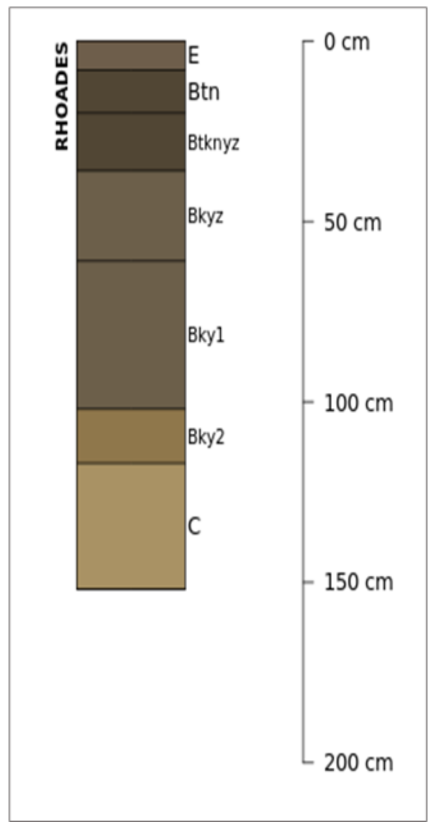
TMC-CJH

03/2000

Scan the QR code for the official series description.

RHOADES SERIES

The Rhoades series consists of deep and very deep, well or moderately well drained, very slowly permeable soils formed in stratified loamy and clayey materials derived from soft shale, siltstone or mudstone. These soils are in swales on uplands and terraces and have slope of 0 to 25 percent. Mean annual air temperature is 42 degrees F, and mean annual precipitation is 16 inches.



TAXONOMIC CLASS: Fine, smectitic, frigid Leptic Vertic Natrustolls

TYPICAL PEDON: Rhoades silt loam on a southeast facing slope of 1 percent in native grassland. (Colors are for dry soil unless otherwise stated)

E--0 to 3 inches; light brownish gray (10YR 6/2) silt loam, dark grayish brown (10YR 4/2) moist; moderate thin and medium platy structure; slightly hard, friable, slightly sticky and slightly plastic; common fine and very fine and few coarse roots; common fine and few coarse pores; slightly acid; abrupt smooth boundary. (1 to 5 inches thick)

Btn--3 to 8 inches; dark grayish brown (2.5Y 4/2) silty clay, very dark grayish brown (2.5Y 3/2) moist; strong medium columnar structure parting to strong fine and very fine angular blocky; extremely hard, very firm, very sticky and very plastic; common fine roots a faces of peds; common fine pores; light brownish gray (10YR 6/2) coatings on tops of columns; many faint clay films on faces of peds; moderately alkaline; clear wavy boundary. (4 to 20 inches thick)

Btknyz--8 to 14 inches; grayish brown (2.5Y 5/2) silty clay, very dark grayish brown (2.5Y 3/2) moist; moderate coarse prismatic structure parting to moderate fine angular blocky; very hard, very firm, very sticky and very plastic; common fine roots on faces of peds; common fine pores; common faint clay films on faces of peds; common fine flecks of gypsum and other salt crystals; few fine masses of carbonates; strong effervescence; strongly alkaline; gradual wavy boundary. (0 to 15 inches thick)

Bkyz--14 to 24 inches; grayish brown (2.5Y 5/2) silty clay, dark grayish brown (2.5Y 4/2) moist; weak coarse prismatic structure parting to moderate medium subangular blocky; very hard, very firm, very sticky and very plastic; common fine roots; common fine pores; few faint clay films on faces of peds; common fine flecks of gypsum and other salt crystals; few fine masses of carbonates; strong effervescence; strongly alkaline; gradual wavy boundary.

Bky1--24 to 40 inches; grayish brown (2.5Y 5/2) silty clay, dark grayish brown (2.5Y 4/2) moist; weak coarse prismatic structure parting to weak medium subangular blocky; very hard, very firm, very sticky and very plastic; few fine roots, common fine pores; common fine gypsum accumulations; common fine masses of carbonates; strong effervescence, strongly alkaline; gradual wavy boundary.

Bky2--40 to 46 inches; light yellowish brown (2.5Y 6/4) silty clay, light olive brown (2.5Y 5/4) moist; few fine prominent strong brown (7.5YR 5/6) redoximorphic concentrations; weak coarse subangular structure; hard, firm, very sticky and very plastic; few fine pores; few fine gypsum accumulations; common fine masses of carbonates; strong effervescence, strongly alkaline; clear wavy boundary. (Combined Bky horizons 0 to 50 inches thick)

C--46 to 60 inches; pale yellow (2.5Y 7/4) stratified silt loam and silty clay loam, light yellowish brown (2.5Y 6/4) moist; few fine prominent strong brown (7.5YR 5/6) redoximorphic concentrations; massive; hard, firm sticky and plastic; few fine masses of carbonates; violent effervescence; strongly alkaline.

TYPE LOCATION: Adams County, North Dakota; 350 feet south and 125 feet east of the northwest corner, sec. 16, T. 131 N., R. 96 W.

RANGE IN CHARACTERISTICS: Depth to soft shale, siltstone or mudstone is more than 40 inches. Some pedons have a thin A horizon. Combined A and E horizon thickness is 1 to 5 inches.

The E horizon has hue of 10YR, value of 4 to 6 and 2 to 5 moist, and chroma of 2 or 3. The A and E horizons are loam, silt loam, very fine sandy loam, fine sandy loam, silty clay loam, clay loam or silty clay. They are moderately acid to neutral.

The Btn horizons have hue of 10YR or 2.5Y, value of 3 to 5 and 2 to 4 moist, and chroma of 2 or 3. They are silty clay loam, clay loam, clay or silty clay and have less than 15 percent fine sand and coarser sand and average between 35 and 50 percent clay. They are neutral to strongly alkaline. They have coarse or medium columnar structure. The columns separate to blocks in some pedons. They are firm or very firm. Clay films and organic stains are on faces of columns.

The Bky horizon has hue of 10YR, 2.5Y, or 5Y, value of 4 to 7 and 3 to 5 moist, and chroma of 2 to 4. It commonly is clay loam, loam, silty clay loam, silty clay or clay. It is moderately alkaline or strongly alkaline. It has few to common gypsum crystals. Some pedons have a By, Bk, BC or BCy horizon.

The C horizon has hue of 10YR, 2.5Y or 5Y, value of 4 to 7 and 3 to 6 moist, and chroma of 1 to 4. It is silt loam, loam, clay loam, silty clay loam, silty clay or clay. Coarser textures are allowed below 40 inches. It is stratified in some pedons. It is moderately alkaline or strongly alkaline. Some pedons have a Cy or Cz horizon. Some pedons do not have a C horizon.

The Cr horizon, when present, typically is massive soft shale, siltstone or mudstone. Some pedons have a Cr horizon at depths of 40 to more than 60 inches.

COMPETING SERIES: These are the Adger, Dogtooth, Exline, Ferney, Mekinock, Miranda and Scairt series as previously classified. Adger soils have an ustic moisture regime that borders on aridic. Dogtooth, Mekinock and Scairt soils have shale bedrock at depths of 20 to 40 inches. Exline soils have chroma of 1 in the A horizon and formed in lacustrine sediments. Ferney soils have redoximorphic features, have more than 15 percent fine sand and coarser in the particle-size control section, a udic moisture regime and formed in till. Miranda soils formed in till and have 1 to 10 percent rock fragments throughout.

GEOGRAPHIC SETTING: Rhoades soils are on level to steep concave swales on uplands and terraces. Slope gradients commonly are 1 to 9 percent but range from 0 to 25 percent. The soils formed in stratified loamy and clayey materials derived from soft shale, siltstone or mudstone. Mean annual air temperature ranges from 39 to 45 degrees F, and mean annual precipitation from 13 to 18 inches.

GEOGRAPHICALLY ASSOCIATED SOILS: These are the Arnegard, Belfield, Daglum, Grail, Lawther, Morton, Regent and Vebar soils. Arnegard, Belfield, Grail and Lawther soils occur in nearby swales. Arnegard, Grail and Lawther soils do not have natric horizons. Belfield soils do not have visible salts or gypsum within a depth of 16 inches. Daglum soils occur on similar positions as Rhoades soils. Daglum soils do not have visible gypsum within depths of 16 inches. Morton, Regent and Vebar soils are on slightly higher position than Rhoades soils on terraces and uplands. These soils do not have do not have natric horizons.

DRAINAGE AND PERMEABILITY: Moderately well and well drained. Runoff is medium to very high depending on slope. Permeability is very slow. A seasonal high water table is at a depth of 3.5 to 5.0 feet at some time during the period of April through June in the moderately well drained phase. It is at a depth of 4 to more than 6 feet for the same period in the well drained phase.

USE AND VEGETATION: Mostly in grassland used for range and pasture. Native vegetation is short- and mid-prairie grasses such as western wheatgrass, blue grama, sedges and also some legumes, prickly pear and clubmoss. Some areas are cultivated mostly to small grains.

DISTRIBUTION AND EXTENT: Southwestern North Dakota, northwestern South Dakota, and eastern Montana. The soil is extensive.

MLRA SOIL SURVEY REGIONAL OFFICE (MO) RESPONSIBLE: Denver, Colorado

SERIES ESTABLISHED: McKenzie County, North Dakota, 1932.

REMARKS: Diagnostic horizons and features recognized in this pedon are: mollic epipedon - the zone from the surface of the soil to a depth of 14 inches after mixing the upper 7 inches (E, Btn and Btknyz horizons); natric horizon - the zone from 3 to 14 inches (Btn and Btknyz horizons).

The series includes some soils formerly placed in the Moline and Wade series. Soils formerly included in the Rhoades series but now separated are in the Absher, Beckton, Belfield and Daglum series.

ADDITIONAL DATA: Type location lab sample number S61ND-45-6. Other lab samples S54SD-53-1, S54SD-53-2 and S61ND-45-8.

National Cooperative Soil Survey

U.S.A.

USDA NRCS, MLRA 54 – Thin Claypan Ecological Site Description

Site stage: Provisional

Provisional: an ecological site description (ESD) at the provisional status represents the lowest tier of documentation that is releasable to the public. It contains a grouping of soil units that respond similarly to ecological processes. The ESD contains 1) enough information to distinguish it from similar and associated ecological sites and 2) a draft state and transition model capturing the ecological processes and vegetative states and community phases as they are currently conceptualized. The provisional ESD has undergone both quality control and quality assurance protocols. It is expected that the provisional ESD will continue refinement towards an approved status.

Scan the QR code for the full ESD.

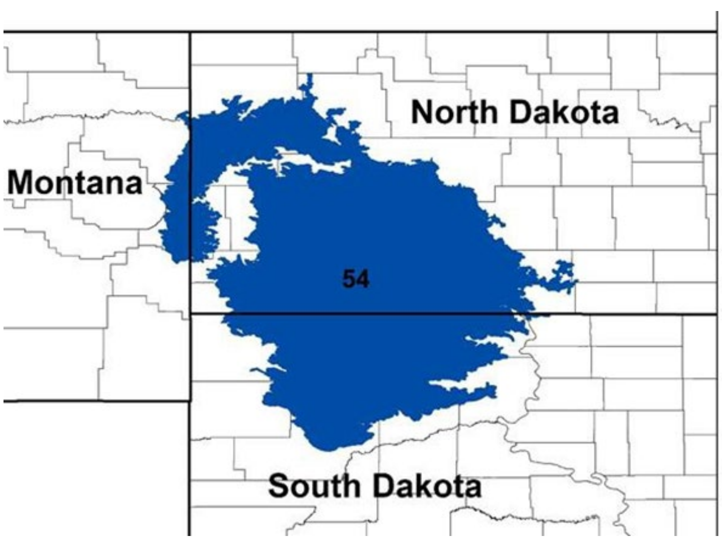
Site Name: Thin Claypan

Site Type: Rangeland

Site ID: RO54XY033ND

Major Land Resource Area (MLRA): 054-Rolling Soft Shale Plain

For more information on MLRA's, refer to the following web site:
https://www.nrcs.usda.gov/resources/data-and-reports/major-land-resource-area-mlra



Location of MRLA 54, Rolling Soft Shale Plain in North Dakota, South Dakota, and Montana

MLRA 54 covers 29,280 square miles and encompasses approximately 18.7 million acres. MLRA 54 spans three states with 64 percent of it in North Dakota, 33 percent in South Dakota, and 3 percent in Montana. Most of MLRA 54 is underlain by soft, calcareous shale, siltstone, and sandstone of the Tertiary Fort Union Group and the Cretaceous Fox Hills and Hell Creek Formations. Most of the soils in MLRA 54 developed from residuum weathered in place. Along the eastern and northern edges of the MLRA where MLRA 54 transitions into the glaciated Missouri plateau, remnants of glacial till parent materials still remain on the high areas of the landscape. The MLRA 54 landscape is characterized by old, moderately dissected rolling plains with areas of local badlands, hills, and isolated buttes. Elevation is 1,650 feet (505 meters) on the eastern side of the MLRA with a gradual rise to 3,600 feet (1,100 meters) on the western side. The Missouri River runs along the north and east side of MLRA 54. Most of the Standing Rock Indian Reservation, the northwest third of the Cheyenne River Indian Reservation, and the Grand River National Grasslands are in the southern part of the MLRA.

Ecological Site Concept

The Thin Claypan site occurs on backslopes and erosional footslopes of hillslope landforms and on sodium-affected floodplains in MLRA 54. Severely eroded areas with sparse or no vegetation are common. These non-vegetated areas are a severely eroded phase of the Thin Claypan ecological site and are commonly referred to as slickspots (aka pan spots).

Soils on Thin Claypan sites are mainly susceptible to water erosion. The hazard of water erosion greatly increases on slopes greater than 6 percent. As water erosion occurs, slickspots begin to develop. These severely eroded slickspots are sparsely vegetated with annual forbs and prickly pear cactus but are dominated by a high percentage of bare ground. Slickspots appear to slowly progress uphill as dislodged soil material from the upslope side of the slickspot is deposited along the downslope edge. As deposition continues and the thickness of the sediments increases, vegetation establishes along the downslope edge of the slickspot. Soils are moderately deep to very deep with soft, sedimentary bedrock parent material below 20 inches. Surface textures range from loamy fine sand that will remain in a ball when squeezed to silty clay that will form a ribbon greater than 2 inches long. On sites with fine- and medium-textured soils, the dense, root-limiting subsoil (claypan) is heavy silty clay loam to clay that forms a ribbon greater than 2 inches long. On sites with coarse-loamy textured soils, the dense, root-limiting subsoil (claypan) is sandy loam to loam that forms a ribbon less than 1 inch long before breaking. The sodium-affected claypan is within 6 inches of the soil surface and has columnar structure with visible salts and gypsum crystals above 16 inches. Slopes range from 0 to 25 percent. This site occurs on well drained or moderately well drained uplands in conjunction with Claypan and Clayey sites on the level to hilly complex residual and alluvial landforms in MLRA 54. Thin Claypan sites are in the micro-lows and Claypan sites are on micro-highs, resulting in the pock-marked appearance of the ground surface that is characteristic of sodium-affected landscapes.

Physiographic Features

This site occurs on level to moderately steep sedimentary uplands and on sodium-affected floodplains in MLRA 54.

Landform: (1) Hillslopes
(2) Floodplains

	Minimum	**Maximum**
Elevation (feet):	1,650	3,600
Slope (percent):	0	25
Water table depth (inches):	48	None
Flooding:	---	---
Frequency:	None	Occasional
Ponding:	---	---
Frequency:	None	Frequent
Runoff class:	Negligible	Very High
Aspect:	No influence on this site.	No influence on this site.

Representative Soil Features

The Thin Claypan ESD in MLRA 54 is represented by moderately deep to very deep sodium-affected soils with textures that range from coarse-loamy to clayey. Representative soils in MLRA 54 include the clayey Rhoades and Dogtooth series and the coarse-loamy Lakota and Whitebird series. Common features of the soils on this site are fine sandy loam to clay textured subsoils and slopes that range from 0 to 25 percent. Based on landscape position, the soils in this ecological site are well or moderately well drained and developed in soft, sodium-affected shale, siltstone, and sandstone parent materials or from alluvium derived from those residual parent materials.

The surface layer is generally 2 to 4 inches thick, and surface textures range from fine sandy loam to silty clay. In native rangeland, the upper horizons have not been mixed by tillage operations so a light-colored subsurface layer (E horizon) immediately below the surface horizon is often visible. High sodium within the soil causes dispersion of clay particles, so this E horison is typically lighter textured than the surface layer and is 1 to 5 inches thick with thin platy structure. Below the platy E horizon is a dense, root-restrictive subsoil layer with columnar structure (Btn horizon). The hard column tops of the Btn horizon are rounded or bun-shaped, and this "claypan" layer is generally 2 to 4 inches below the soil surface. Although the columnar Btn horizon is high in sodium, the highest accumulation of sodium in Thin Claypan soils is directly below the Btn horizon.

In Thin Claypan soils, Electrical Conductivity (EC), Sodium Absorption Ratio (SAR), and Soil Reaction (pH) are lowest near the soil surface and increase with depth lower in the soil profile. The relatively impermeable Btn horizon acts as a barrier to upward movement of water, salts, and sodium in the soil profile, so these soil properties significantly increase immediately below the Btn horizon. Although the available water capacity within the upper 40 inches of the soil profile ranges from 2 to 6 inches, the water that is available for use by the plants is significantly limited due to poor root penetration through the dense Btn horizon. Plant roots grow downward and extract water and nutrients between the columns rather than growing horizontally and extracting water and nutrients throughout the Btn horizon.

Soils on Thin Claypan sites are mainly susceptible to water erosion, and severely eroded areas with sparse or no vegetation are common. These non-vegetated or sparsely vegetated areas are severely eroded and are commonly referred to as slickspots. On non-vegetated or sparsely vegetated slickspots, the hard, root-limiting column tops of the Btn horizon are often at the surface.

Permeability is moderately rapid to slow in the surface horizons above the claypan and slow or very slow in the subsoil. Wet surface compaction can occur with heavy traffic. Cryptobiotic crusts are present, but their function is not well understood. Some pedestalling of plants may occur on steeper slopes, but it is not very evident on casual observation unless the site is a non-vegetated slickspot. Water flow paths are broken and irregular in appearance or are discontinuous with numerous debris dams or vegetative barriers. There is a risk of rills and eventually gullies if vegetative cover is not adequate. The following soil properties listed in the table below represent the soil profile above the sedimentary beds or from 0 to 40 inches if the sedimentary beds are deeper than 40 inches. Major soil series correlated to this ecological site can be found in Section II of the Natural Resources Conservation Service Field Office Technical Guide or the following web site:

- http://www.nrcs.usda.gov/technical/efotg/
- http://soildatamart.nrcs.usda.gov/
- http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm

Parent materials
Kind: Residuum, Slope alluvium
Origin: Shale, Siltstone, Sandstone
Surface texture:
(1) Loam
(2) Silt loam
(3) Fine sandy loam
Subsurface texture group: Clayey, Fine-loamy, or Coarse-loamy

	Minimum	**Maximum**
Surface fragments <=3" (% cover):	0	0
Surface fragments >3" (% cover):	0	0
Subsurface fragments <=3" (% volume):	0	0
Subsurface fragments >3" (% volume):	0	0
Drainage class: Moderately well drained or well drained		
Permeability class: Slow or very slow		

	Minimum	**Maximum**
Depth (inches):	20	80
Available water capacity (inches):	2.00	6.00
Electrical conductivity (mmhos/cm):	0	24
Sodium adsorption ratio:	0	40
Calcium carbonate equivalent (percent):	0	30
Soil reaction (1:1 water):	5.0	9.6

Plant Communities

Ecological Dynamics of the Site:

The site developed under Northern Great Plains climatic conditions and included natural influence of large herbivores and occasional fire. Changes will occur in the plant communities due to climatic conditions and/or management actions. Due to the nature of the soils, the site is considered moderately resilient. Under continued adverse impacts, a slow decline in vegetative vigor and composition will occur. If existing plant community is in Reference State, implementing favorable vegetative management treatments may return to the Reference Plant Community. However, if existing plant community is outside the Reference State, returning to the Reference State is not feasible. The natural disturbance regime consisted of frequent fires caused both by natural and Native American ignition sources. These fires occurred during any season of the year, but were concentrated in the spring and late summer or early fall. Lightening fires occurred most frequently in July and August while fires started by Native Americans occurred in April, September and October. Large ungulate grazing was heavy and occurred often, but usually for short durations. Grazing may have been severe when occurring after a fire event, or in association with reliable water sources. The grazing and fire interaction especially when coupled with drought events, set up the dynamics discussed and displayed in the following state and transition diagram and descriptions.

The plant community upon which interpretations are primarily based is the Reference Plant Community. The Reference Plant Community has been determined by study of rangeland relic areas, areas protected from excessive disturbance, and areas under long-term rotational grazing regimes. Trends in plant community dynamics ranging from heavily grazed to lightly grazed areas, seasonal use pastures, and historical accounts also have been considered. Subclimax plant communities, states, transitional pathways, and thresholds have been determined through similar studies and experience.

Soil conditions, such as depth of surface layer, is a major influence on the vegetation growing on this ecological site. Soil surface layer thickness across the site is highly variable, ranging from zero to six inches over the claypan within a few feet. Those areas with five to six inches of soil surface can support a diverse (e.g., western wheatgrass, blue grama, Sandberg bluegrass) and productive (considering site limitations) plant community. Areas of the site without a soil surface over the claypan, are generally devoid of vegetation or have a minimal presence of Nostoc blue-green algae, fragile cactus and annual for Thin Claypan ecological site showing natural variability in soil surface depth and plant community.

Mid- and short-statured grasses would dominate this site in reference condition. Principle species are western wheatgrass, blue grama, Sandberg bluegrass, needle and thread, and various forbs. Other species include prairie Junegrass, plains reedgrass, inland saltgrass and upland sedges. A diversity of forbs such as Heath aster, prairie coneflower, silverleaf scurfpea, western yarrow, and wild parsley are found on this site, constituting approximately 10 percent of the herbage production. A variety of shrubs may make up a minor component of the total herbage production.

Continuous grazing without adequate recovery periods following each grazing event over several years causes this site to depart from the Reference Plant Community. Species such as western wheatgrass, blue grama, inland saltgrass and forbs will initially increase. Prairie Junegrass, needle and thread will decrease in frequency and production. In time, heavy continuous grazing will likely cause blue grama and upland sedges to dominate the site. This plant community is relatively stable and the competitive advantage prevents other species from establishing. This plant community is less productive than the Reference Plant Community. Runoff increases and infiltration will decrease. Soil erosion will be minimal.

Within the natural disturbance regime, droughts of varying length and severity are common. Long- term drought reduces plant vigor, seed production and increases bare ground.

Extended periods of non-use and/or lack of fire results in a plant community with high litter levels, favoring an increase in exotic cool-season grasses such as Kentucky bluegrass, crested wheatgrass, and/or smooth bromegrass.

Due to a general invasion of cool-season exotic species and alterations in historic disturbance regimes (i.e. reduced fire frequency) across the MLRA, returning to the Western Wheatgrass-Needelgrasses-Blue Grama, Plant Community Phase 1.1, is not possible. Today, the Western

Wheatgrass-Needlegrasses-Blue grama, Plant Community Phase 2.1, most resembles the 1.1 Reference Plant Community Phase in appearance and function.

The plant community upon which interpretations are primarily based is the Reference Plant Community. The Reference Plant Community has been determined by study of rangeland relic areas, areas protected from excessive disturbance, and areas under long-term rotational grazing regimes.

Trends in plant community dynamics ranging from heavily grazed to lightly grazed areas, seasonal use pastures, and historical accounts also have been considered. Subclimax plant communities, states, transitional pathways, and thresholds have been determined through similar studies and experience.

State-and-Transition Models (STM) are ecological process-driven models. The ecological dynamics characterized by the STM reflect the functional changes in ecological drivers and feedback mechanisms (pathways), and the resulting changes in plant community composition (phases or states). The application of various management actions coupled with weather variables impact the ecological processes, drivers, and feedback mechanisms drive plant community composition changes. The pathway narratives describing the ecological dynamics of the site reference various management inputs (i.e., prescribed grazing, prescribed fire), however, it is the manager's responsibility to understand how these various management actions impact the ecological processes/drivers/feedback mechanisms.

Following the state and transition diagram are narratives for each of the described states and community phases. These may not represent every possibility, but they are the most prevalent and repeatable states/community phases. The plant composition tables shown below have been developed from the best available knowledge at the time of this revision. As more data are collected, some of these community phases and/or states may be revised or removed, and new ones may be added. The main purpose for including the descriptions here is to capture the current knowledge and experience at the time of this revision.

Plant Communities and Transitional Pathways

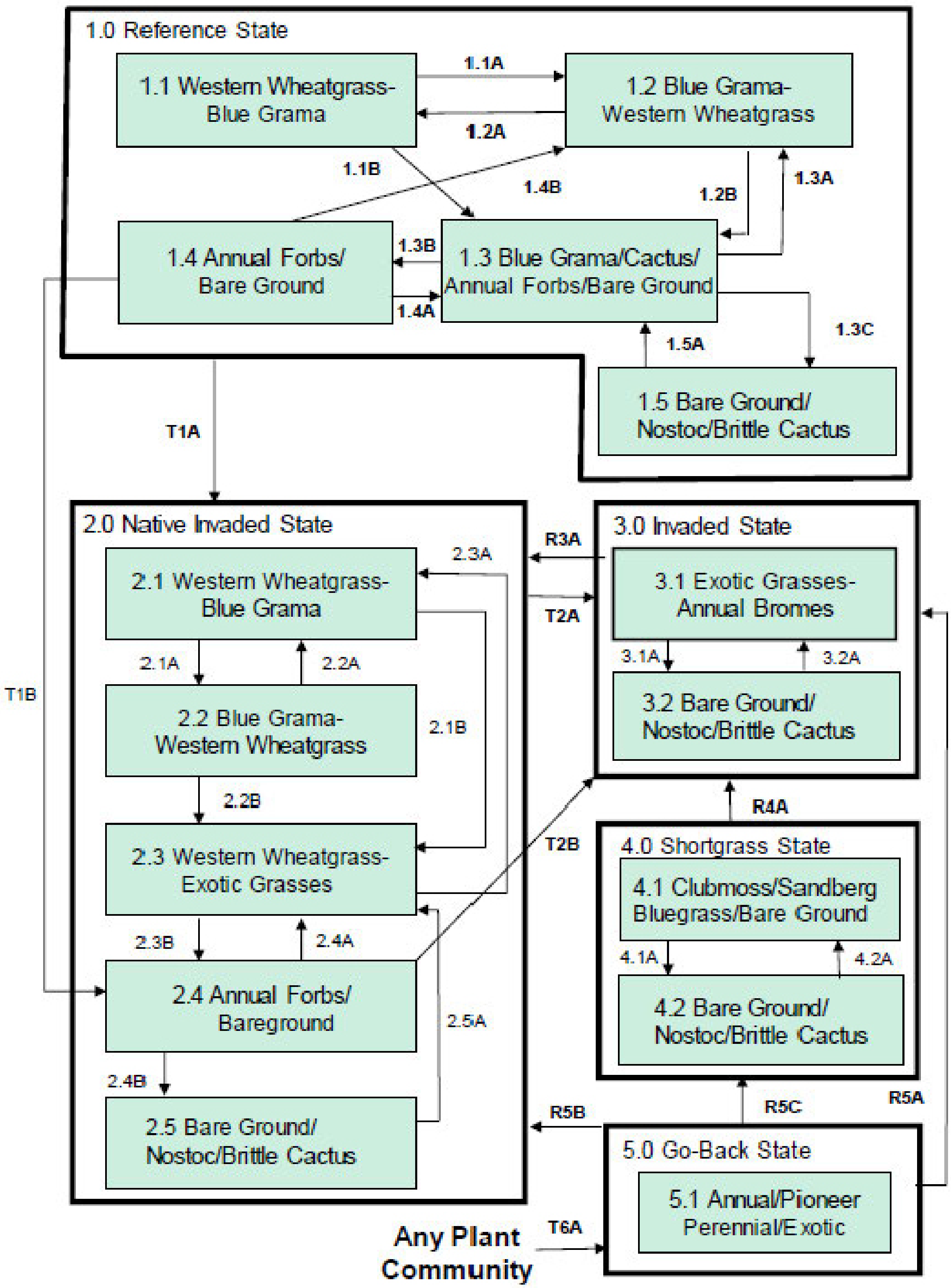


Diagram Legend — MLRA 54 Thin Claypan

	T1A	Introduction of exotic cool-season grasses
	T1B	Long-term prairie dog occupation coupled with introduction of exotic grasses and forbs
	T2A	Extended periods of non-use or very light grazing, no fire
	T2B	Removal of prairie dogs
	T6A	Cessation of annual cropping
	R3A	Long-term prescribed grazing and prescribed fire with possible reseeding
	R4A	Mechanical treatment (e.g. chiseling)
	R5A	Failed range seeding
	R5B	Successful range seeding with prescribed grazing and prescribed burning
	R5C	No management inputs
	CP 1.1 - 1.2 (1.1A)	Long-term drought with/without heavy, long-term grazing
	CP 1.1 - 1.3 (1.1B)	Introduction of prairie dogs
	CP 1.2 - 1.1 (1.2A)	Return to average growing conditions and reduced grazing pressure
	CP 1.2 - 1.3 (1.2B)	Introduction of prairie dogs
	CP 1.3 - 1.2 (1.3A)	Removal of prairie dogs
	CP 1.3 - 1.4 (1.3B)	Long-term prairie dog occupation
	CP 1.3 - 1.5 (1.3C)	Soil erosion
	CP 1.4 - 1.3 (1.4A)	Removal of prairie dogs, return to normal precipitation
	CP 1.4 - 1.2 (1.4B)	Removal of prairie dogs, return to normal precipitation
	CP 1.5 - 1.3 (1.5A)	Soil deposition
	CP 2.1 - 2.2 (2.1A)	Heavy continuous grazing with or without drought
	CP 2.1 - 2.3 (2.1B)	Light grazing, no fire
	CP 2.2 - 2.1 (2.2A)	Reduced grazing pressure and return to average precipitation
	CP 2.2 - 2.3 (2.2B)	Rest or light utilization, no fire
	CP 2.3 - 2.1 (2.3A)	Prescribed grazing, prescribed burning
	CP 2.3 - 2.4 (2.3B)	Introduction of prairie dogs
	CP 2.4 - 2.3 (2.4A)	Removal of prairie dogs
	CP 2.4 - 2.5 (2.4B)	Soil erosion
	CP 2.5 - 2.3 (2.5A)	Soil deposition
	CP 3.1 - 3.2 (3.1A)	Soil erosion
	CP 3.2 - 3.1 (3.2A)	Soil deposition
	CP 4.1 - 4.2 (4.1 A)	Soil erosion
	CP 4.2 - 4.1 (4.2A)	Soil deposition

Plant Community Composition and Group Annual Production

COMMON/GROUP NAME	SYMBOL	Group	1.1 Western Wheatgrass-Blue Grama lbs./acre		% Comp	
GRASSES & GRASS-LIKES			765 - 855		85 - 95	
		1	180	270	20	30
western wheatgrass	PASM	1	180	270	20	30
bearded wheatgrass	ELTRS	1	9	18	1	2
		2	180	270	20	30
blue grama	BOGR2	2	135	225	15	25
buffalograss	BUDA	2	9	45	1	5
		3	45	126	5	14
needle and thread	HECOC8	3	9	45	1	5
Sandberg bluegrass	POSE	3	9	45	1	5
prairie junegrass	KOMA	3	9	45	1	5
OTHER NATIVE GRASSES		4	18	45	2	5
plains reedgrass	CAMO	4	0	18	0	2
inland saltgrass	DISP	4	9	45	1	5
green needlegrass	NAVI4	4	0	18	0	2
tumblegrass	SCPA	4	0	18	0	2
dropseed	SPORO	4	0	18	0	2
other native perennial grasses	2GP	4	9	45	1	5
other native annual grasses	2GA	4	0	9	0	1
GRASS-LIKES		5	18	45	2	5
needleleaf sedge	CADU6	5	9	45	1	5
threadleaf sedge	CAFI	5	9	18	1	2
other grass-likes	2GL	5	0	27	0	3
FORBS		6	63 - 90		7 - 10	
cudweed sagewort	ARLU	6	0	9	0	1
heath aster	SYER	6	9	18	1	2
Hood's phlox	PHHO	6	0	9	0	1
Lambert crazyweed	OXLA3	6	9	18	1	2
Nuttall's violet	VINU2	6	9	9	1	1
prairie coneflower	RACO3	6	9	18	1	2
rose pussytoes	ANRO2	6	9	9	1	1
rush skeletonweed	LYJU	6	9	9	1	1
scarlet globemallow	SPCO	6	9	9	1	1
silverleaf scurfpea	PEAR6	6	9	18	1	2
sticky cinquefoil	POGL9	6	9	9	1	1
wavyleaf thistle	CIUN	6	0	9	0	1
western yarrow	ACMI2	6	9	18	1	2
wild onion	ALLIU	6	9	9	1	1
wild parsley	MUDI	6	9	9	1	1
woolly Indianwheat	PLPA2	6	9	9	1	1
native annual/biennial forbs	2FORB	6	0	18	0	2
native perennial forbs	2FP	6	0	18	0	2
SHRUBS		7	9 - 45		1 - 5	
brittle cactus	OPFR	7	9	18	1	2
broom snakeweed	GUSA2	7	9	9	1	1
fringed sagewort	ARFR4	7	9	18	1	2
Nuttall's saltbush	ATNU2	7	9	18	1	2
plains pricklypear	OPPO	7	0	18	0	2
purple pincushion	ESVIV	7	0	9	0	1
rubber rabbitbrush	ERNA10	7	0	9	0	1
silver sagebrush	ARCA13	7	0	9	0	1
winterfat	KRLA2	7	0	9	0	1
other shrubs	2SHRUB	7	0	18	0	2
CRYPTOGAMS		8	0 - 9		0 - 1	
clubmoss	SEDE2	8	0	9	0	1

Annual Production lbs./acre	LOW	RV	HIGH
GRASSES & GRASS-LIKES	435	792	-1045
FORBS	60	77	-95
SHRUBS	5	27	-50
CRYPTOGAMS	0	5	-10
TOTAL	500	900	1200

This list of plants and their relative proportions are based on near normal years. Fluctuations in species composition and relative production may change from year to year dependent upon precipitation or other climatic factors. RV = Representative Value.

Rhoades Pedon Description

Print Date: Feb. 17, 2023
Description Date: June 23, 2022
Describer: Wade Bott, John Kempenich
Site ID: S2022ND089002

Soil Survey Area: ND089 -- Stark County, North Dakota
5-DIC -- Dickinson, North Dakota
Pedon ID: S2022ND089002

Quad Name:
Lab Source ID: KSSL
Lab Pedon #: 22N0293

Country:
State: North Dakota
County: Stark
MLRA: 54 – Rolling Soft Shale Plain

Map Unit: E0515B -- RHOADES-DAGLUM COMPLEX, 2 TO 6 PERCENT SLOPES

Std Latitude: 46.9573370
Std Longitude: -103.1279400

User Transect ID:
Soil Name as Described/Sampled: Rhoades
Classification: Fine, smectitic, frigid Leptic Vertic Natrustolls
Soil Name as Correlated:
Classification:
Pedon Type: classifies to current taxon name, full description
Pedon Purpose: laboratory sampling site
Taxon Kind: series
Associated Soils:
Physiographic Division:
Physiographic Province:
Physiographic Section:
State Physiographic Area:

Local Physiographic Area:
Geomorphic Setting: microlow on footslope of hillslope on sedimentary plains
Upslope Shape: linear
Cross Slope Shape: linear

Particle Size Control Section: 10 to 60 cm.
Description origin: NASIS

Description database: KSSL

Primary Earth Cover: Grass/herbaceous cover
Secondary Earth Cover: Grassland rangeland
Vegetation:
Parent Material: slope alluvium derived from sedimentary rock
Bedrock Kind:
Bedrock Depth:
Bedrock Hardness:
Bedrock Fracture Interval:
Surface Fragments:

Diagnostic Features:

mollic epipedon 0 to 22 cm.
albic horizon 0 to 10 cm.
albic materials 0 to 10 cm.
argillic horizon 10 to 68 cm.
natric horizon 10 to 68 cm.
gypsum accumulations 22 to 214 cm.
secondary carbonates 35 to 214 cm.
salt accumulations 35 to 158 cm

Cont. Site ID: S2022ND089002

Pedon ID: S2022ND089002

Slope (%)	Elevation (meters)	Aspect (deg)	MAAT (C)	MSAT (C)	MWAT (C)	MAP (mm)	Frost-Free Days	Drainage Class	Slope Length (meters)	Upslope Length (meters)
0.0								Well drained		

E1--0 to 5 centimeters (0.0 to 2.0 inches); grayish brown (10YR 5/2) silt loam, very dark grayish brown (10YR 3/2), moist; 15 percent sand; 24 percent clay; weak very thin platy parts to weak fine granular structure; slightly sticky, slightly plastic; many fine roots throughout; many fine high-continuity dendritic tubular pores; noneffervescent; clear smooth boundary. Lab sample # 22N01277

E2--5 to 10 centimeters (2.0 to 3.9 inches); grayish brown (10YR 5/2) silt loam, very dark grayish brown (10YR 3/2), moist; 15 percent sand; 24 percent clay; moderate thin platy parts to weak fine granular structure; slightly sticky, slightly plastic; common fine roots throughout; common fine high-continuity dendritic tubular pores; 5 percent fine faint spherical 10YR 4/4), moist, masses of oxidized iron with diffuse boundaries In matrix; noneffervescent; clear smooth boundary. Lab sample # 22N01278

Btn--10 to 22 centimeters (3.9 to 8.7 inches); grayish brown (10YR 5/2) silty clay loam, very dark grayish brown (10YR 3/2), moist; 10 percent sand; 37 percent clay; strong coarse columnar parts to moderate medium subangular blocky structure; slightly sticky, moderately plastic; many fine roots throughout; common fine moderate-continuity dendritic tubular pores; 70 percent distinct 10YR 3/2), moist, clay films on all faces of peds; noneffervescent; clear wavy boundary. Lab sample # 22N01279

Btny--22 to 35 centimeters (8.7 to 13.8 inches); light brownish gray (10YR 6/2) silty clay, dark grayish brown (10YR 4/2), moist; 10 percent sand; 46 percent clay; moderate coarse prismatic parts to moderate medium angular blocky structure; slightly sticky, very plastic; common very fine roots throughout and common fine roots throughout; common very fine moderate-continuity dendritic tubular and common fine moderate-continuity dendritic tubular pores; 1 percent prominent 10YR 7/2), moist, gypsum coats on surfaces along pores and 1 percent prominent 10YR 7/2), moist, gypsum coats on surfaces along root channels and 65 percent distinct 10YR 3/2), moist, clay films on all faces of peds; 1 percent fine prominent spherical 10YR 7/2), moist, gypsum masses with sharp boundaries in matrix; noneffervescent; clear wavy boundary. Lab sample # 22N01280

Btnky--35 to 68 centimeters (13.8 to 26.8 inches); light brownish gray (10YR 6/2) silty clay, dark grayish brown (10YR 4/2), moist; 5 percent sand; 42 percent clay; moderate coarse prismatic parts to moderate medium angular blocky structure; slightly sticky, very plastic; common very fine roots throughout; many fine high-continuity dendritic tubular pores; 1 percent prominent 10YR 7/2), moist, gypsum coats on surfaces along root channels and 2 percent prominent 10YR 7/2), moist, gypsum coats on surfaces along pores and 55 percent distinct 10YR 4/2), moist, clay films on all faces of peds; carbonate, finely disseminated in matrix and 2 percent fine prominent spherical 10YR 7/2), moist, carbonate masses with sharp boundaries in matrix; slight effervescence; clear wavy boundary. Lab sample # 22N01281

Bky--68 to 158 centimeters (26.8 to 62.2 inches); light brownish gray (10YR 6/2) silty clay, dark grayish brown (10YR 4/2), moist; 3 percent sand; 42 percent clay; moderate coarse prismatic parts to moderate medium subangular blocky structure; slightly sticky, very plastic; common very fine roots throughout; common fine moderate-continuity dendritic tubular pores; 1 percent prominent 10YR 7/2), moist, gypsum coats on surfaces along pores and 1 percent prominent 10YR 7/2), moist, gypsum coats on surfaces along root channels; carbonate, finely disseminated in matrix and 1 percent fine prominent spherical 10YR 7/2), moist, carbonate masses with sharp boundaries in matrix; strong effervescence; gradual wavy boundary. Lab sample # 22N01282

C--158 to 214 centimeters (62.2 to 84.3 inches); light brownish gray (2.5Y 6/2) silty clay, dark grayish brown (10YR 4/2), moist; 3 percent sand; 50 percent clay; massive; slightly sticky, very plastic; common very fine roots throughout; common very fine moderate-continuity dendritic tubular pores; 1 percent prominent 10YR 7/2), moist, gypsum coats on surfaces along root channels and 2 percent prominent 10YR 7/2), moist, gypsum coats on surfaces along pores; carbonate, finely disseminated in matrix and 2 percent fine prominent spherical 10YR 7/2), moist, carbonate masses with sharp boundaries in matrix; violent effervescence. Lab sample # 22N01283

Rhoades Characterization Data

Pedon ID: S2022ND089002

Sampled Date: 6/2/2022

Series: Rhoades

Classification: Fine, smectitic, frigid Leptic Vertic Natrustoll

Particle Size Control Section: 10 - 60

Clay Weighted Average: 42

CEC Activity, CEC7/Clay, Weighted Average: 0.54

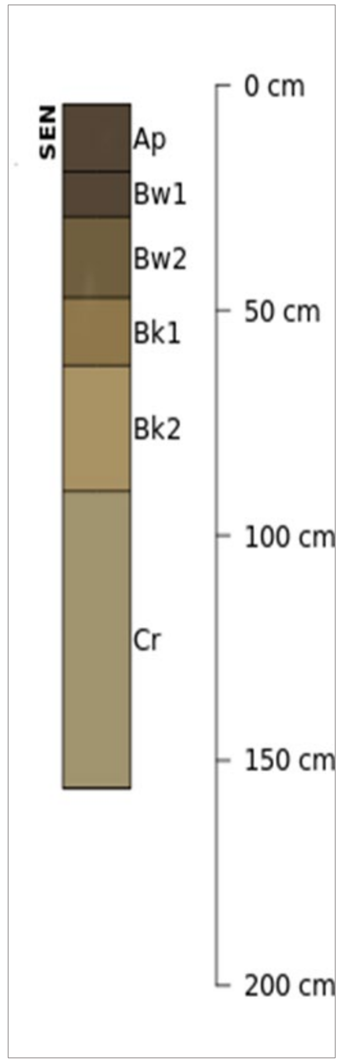
Horizon	Depth	Texture	Clay (%)	Silt (%)	Sand (%)	Core Db (g/cm-3)	Est. OC (%)	Fine Silt (%)	Coarse Silt (%)	V. Fine Sand (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	V. Coarse Sand (%)	Coarse Fragments (%)
E1	0-5	sicl	27.0	55.8	17.2	0.72	4.2	35.3	20.5	11.2	4.7	1.1	0.1	0.1	-
E2	5-10	sil	23.9	56.7	19.4	1.41	2.3	34.1	22.6	13.4	4.9	1.1	tr	-	-
Btn	10-22	sicl	36.5	50.7	12.8	1.42	1.6	30.2	20.5	9	3.4	0.4	tr	tr	-
Btny	22-35	sic	43.5	48.9	7.6	1.50	1.0	33.3	15.6	6.1	1.1	0.4	tr	tr	-
Btnky	35-68	sic	43.1	50.7	6.2	1.61	0.8	36.6	14.1	5.1	0.9	0.2	tr	-	-
Bky	68-165	sicl	32.1	54.4	13.5	1.44	0.4	34.5	19.9	11.8	1.6	0.1	tr	-	tr
C	158-214	sic	50.0	47.0	3.0	1.50	0.4	38.4	8.6	2.5	0.5	tr	-	-	-

Horizon	Depth	CEC7 (cmo/kg)	CEC7/Clay	Base Saturation	EC (dS/m)	ESP (%)	SAR	Ext. Ca (cmol/kg)	Ext. Mg (cmol/kg)	Ext. Na (cmol/kg)	Ext. Acidity (cmol/kg)	pH Water	CaCO3 (%)
E1	0-5	20.5	0.76	91	0.4	5	5	10.4	5.7	1.3	11.5	7.0	-
E2	5-10	14.9	0.62	99	1.1	7	7	8.4	4.1	1.6	6.1	7.6	-
Btn	10-22	23.0	0.63	100	1.0	23	12	8.3	10.0	6.2	4.1	8.2	-
Btny	22-35	22.7	0.52	100	6.3	20	15	35.4	16.6	9.8	-	8.3	2
Btnky	35-68	22.1	0.51	100	10.5	17	15	53.5	16.2	9.6	-	8.3	4
Bky	68-165	15.2	0.47	100	12.2	26	21	38.8	15.7	13.0	-	8.7	6
C	158-214	23.8	0.48	100	16.3	-	24	44.0	15.9	15.4	-	8.5	3

Sen Series Information

LOCATION SEN ND
Established Series
Rev. CJH
07/1999

Scan the QR code for the official series description.



SEN SERIES

The Sen series consists of well drained, moderately permeable soils that formed in calcareous siltstone or shale. They are moderately deep to soft bedrock. These soils are on upland plains and have slope of 0 to 25 percent. Mean annual air temperature is 42 degrees F, and mean annual precipitation is 15 inches.

TAXONOMIC CLASS: Fine-silty, mixed, superactive, frigid Typic Haplustolls

TYPICAL PEDON: Sen silt loam - on a northeast-facing slope of 4 percent in a cultivated field. (Colors are for dry soil unless otherwise stated)

Ap--0 to 6 inches; grayish brown (10YR 5/2) silt loam, very dark grayish brown (10YR 3/2) moist; moderate medium granular structure; slightly hard, friable, slightly sticky and nonplastic; common roots; neutral; abrupt smooth boundary. (5 to 8 inches thick)

Bw1--6 to 10 inches; grayish brown (10YR 5/2) silt loam, very dark grayish brown (10YR 3/2) moist; weak coarse prismatic structure parting to moderate coarse and medium subangular blocky; slightly hard, friable, slightly sticky and nonplastic; common roots; neutral; clear wavy boundary.

Bw2--10 to 17 inches; light yellowish brown (2.5Y 6/3) silt loam, olive brown (2.5Y 4/3) moist; moderate coarse prismatic structure parting to moderate medium subangular blocky; slightly hard, friable, sticky and slightly plastic; common roots; slightly alkaline; clear wavy boundary. (Combined Bw horizons 7 to 20 inches thick)

Bk1--17 to 23 inches; pale yellow (2.5Y 7/3) silt loam, light olive brown (2.5Y 5/4) moist; weak coarse prismatic structure parting to moderate medium subangular blocky; slightly hard, friable, sticky and slightly plastic; common roots; medium generally rounded masses of carbonates; violent effervescence; slightly alkaline; clear wavy boundary.

Bk2--23 to 34 inches; white (2.5Y 8/2) silt loam, light yellowish brown (2.5Y 6/4) moist; weak medium subangular blocky structure; slightly hard, friable, sticky and slightly plastic; common roots; many small iron concretions; strong effervescence; moderately alkaline; clear wavy boundary. (Combined Bk horizons 5 to 20 inches thick)

Cr--34 to 60 inches; pale yellow (5Y 7/3) and pale olive (5Y 6/3) soft stratified siltstone, pale olive (5Y 6/3) moist; slight effervescence.

TYPE LOCATION: Slope County, North Dakota; about 3 1/2 miles north of West Rainy Butte; 180 feet west and 1,990 feet north of the southeast corner of sec. 36, T. 139 N., R. 99 W.

RANGE IN CHARACTERISTICS: The depth to soft bedrock typically is 30 to 40 inches, but ranges from 20 to 40 inches. Depth to carbonates ranges from 10 to 30 inches. The 10- to 40-inch particle-size control section averages between 18 and 35 percent clay and less than 15 percent fine and coarser sand. Stony phases are recognized.

The A horizon has hue of 10YR, value of 3 to 5 and 2 or 3 moist, and chroma of 2 or 3. It is loam, silt loam or silty clay loam. It is neutral or slightly alkaline.

The Bw horizon has hue of 10YR or 2.5Y, value of 3 to 6 and 3 to 5 moist, and chroma of 2 to 4. It typically is silt loam, but some is loam or silty clay loam. It has weak or moderate prismatic structure that parts to weak or moderate, medium or coarse subangular blocky. It is neutral to moderately alkaline. Some pedons have BC horizons.

The Bk horizon has hue of 2.5Y or 5Y, value of 5 to 8 and 4 to 6 moist, and chroma of 2 to 4. It typically is silt loam or silty clay loam, but some is loam. Carbonates are both diffused and in soft accumulations. The Bk horizon contains 10 to 30 percent calcium carbonate equivalent. It is slightly alkaline or moderately alkaline.

The Cr horizon is soft bedrock that is massive or stratified siltstone or silty shale.

COMPETING SERIES: These are the Amsterdam, Bryant, Golva, Omio, Peritsa and Temvik series. Amsterdam soils contain significant quantities of glass shards and are in intermountain valleys. Bryant, Golva, Peritsa and Temvik soils do not have siltstone within depths of 40 inches. Omio soils do not have Bk horizons and formed in calcareous loess overlying soft siltstone.

GEOGRAPHIC SETTING: Sen soils are level to strongly sloping on upland plains. Slope gradients commonly are 3 to 8 percent but range from 0 to 25 percent. The soils formed in calcareous siltstone or sandstone. The climate is cool, semiarid. Mean annual air temperature ranges from about 39 F to 45 degrees F, and the mean annual precipitation is from 13 to 18 inches. Most of the precipitation comes in the spring and summer.

GEOGRAPHICALLY ASSOCIATED SOILS: These are the Amor, Cabba, Chama, Farland, Grail, Grassna, Morton and Savage soils. Amor soils are on nearby upland plains where the bedrock contains more sand. They are fine-loamy. Cabba soils are on the crests of hills and steep side slopes. They do not have Bw horizons and have siltstone within depths of 20 inches. Chama soils are on convex areas in the same landscape as the Sen soils. They have carbonates within depths of 10 inches. Farland soils are on nearly level terraces and Morton soils are on well drained uplands and in complex with Sen soils in some places. Both of these soils have an argillic horizon. In addition, Farland soils do not have siltstone within depths of 40 inches. Grail soils are in concave swales and fans and Savage soils are on nearly level terraces. Both these soils contain more than 35 percent clay in the particle-size control section and have argillic horizons. Grassna soils are in concave swales and on foot slopes. They have a mollic epipedon more than 16 inches thick and are very deep.

DRAINAGE AND PERMEABILITY: Well drained. Runoff is slow, medium, or rapid. Permeability is moderate.

USE AND VEGETATION: Soils are cropped to small grains in a crop-summer fallow rotation. Native vegetation is mid and short prairie grasses as green needlegrass, needleandthread, western wheatgrass, blue grama and a variety of forbs.

DISTRIBUTION AND EXTENT: Western North Dakota and possibly northwestern South Dakota, and eastern Montana. The series is of large extent.

MLRA SOIL SURVEY REGIONAL OFFICE (MO) RESPONSIBLE: Denver, Colorado

SERIES ESTABLISHED: Burleigh County, North Dakota, 1971.

REMARKS: Diagnostic horizons and features recognized in this pedon are: mollic epipedon - the zone from the surface of the soil to a depth of 10 inches (Ap and Bw1 horizons); cambic horizon - the zone from 10 to 17 inches (Bw2 horizon).

ADDITIONAL DATA: Laboratory data No. SU7OND-44-2. Other data, S58ND-17-1 and S59ND-17-1 in Soil Survey Investigations Report No. 2.

National Cooperative Soil Survey, U.S.A.

USDA NRCS, MLRA 54 — Loamy Ecological Site Description

Site stage: Approved

Site Name: Loamy

Site Type: Rangeland

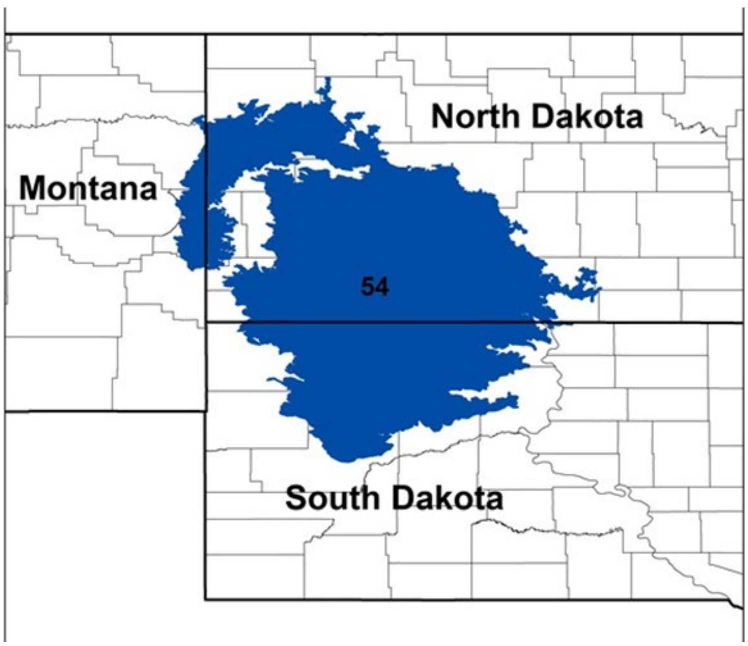
Site ID: R054XY031ND

Major Land Resource Area 54: Rolling Soft Shale Plain

For more information on MLRA's, refer to the following web site:

https://www.nrcs.usda.gov/resources/data-and-reports/major-land-resource-area-mlra

Scan the QR code for the full ecological site description.



Location of MLRA 54, Rolling Soft Shale Plain in North Dakota, South Dakota, and Montana

MLRA 54 covers 29,280 square miles and encompasses approximately 18.7 million acres. MLRA 54 spans three U.S. states, with 64 percent of it in North Dakota, 33 percent in South Dakota, and 3 percent in Montana. Most of MLRA 54 is underlain by soft, calcareous shale, siltstone, and sandstone of the Tertiary Fort Union Group and the Cretaceous Fox Hills and Hell Creek Formations. MLRA 54 is predominantly unglaciated, and the soils developed from residuum weathered in place. Along the eastern and northern edges of the MLRA where MLRA 54 transitions into the glaciated Missouri plateau, remnants of glacial till parent materials still remain on the high areas of the landscape. The MLRA 54 landscape is characterized by old, moderately dissected rolling plains with areas of local badlands, hills, and isolated buttes. The elevation is 1,650 feet (505 meters) on the eastern side of the MLRA with a gradual rise to 3,600 feet (1,100 meters) on the western side. The Missouri River runs along the north and east sides of MLRA 54. Most of the Standing Rock Indian Reservation, the northwest third of the Cheyenne River Indian Reservation, and the Grand River National Grasslands are in the southern part of this MLRA.

Ecological Site Concept

In the Loamy ecological site, soils are greater than 20 inches deep, and surface textures vary from loams to silt loams and form a ribbon less than 2 inches long. Subsoils range from silt loams to clay loams and form a ribbon less than 2 inches long. Slopes range from 0 to 35 percent. This site occurs on well drained uplands that are upslope from Loamy Terrace or Loamy Overflow sites and downslope from Limy Residual or Shallow Loamy sites. The dominant species are western wheatgrass, some green needlegrass, and blue grama with fringed sagewort and western snowberry.

Physiographic Features

This site occurs on level to moderately steep sedimentary uplands and areas of glacial till.

Landform: (1) Hillslopes
(2) Terraces

	Minimum	**Maximum**
Elevation (feet):	1,650	3,600
Slope (percent):	0	35
Water table depth (inches):	48	None
Flooding:	---	---
Frequency:	None	None
Ponding:	---	---
Frequency:	None	None
Runoff class:	Low	Medium
Aspect:	No influence on this site	

Representative Soil Features

The Loamy ESD in MLRA 54 is represented by moderately deep to very deep medium- textured soils with textural family classes that range from fine-loamy to fine-silty. Representative soils in MLRA 54 include the fine-loamy Amor, Shambo, Reeder, Farnuf, and Stady series and the fine-silty Morton, Sen, Farland, and Golva series. Slopes are 0 to 35 percent. The soils in this ecological site are well drained, and formed in soft siltstone, sandstone, mudstone, and alluvium. The surface layer is 5 to 12 inches thick, and surface textures range from loam to silt loam. The subsoils textures range from silt loam to clay loam. Saturated hydraulic conductivity is moderate in the surface horizons and moderate or moderately slow in the subsoil. Water flow patterns may be present, and there is a risk of rills and eventually gullies if vegetative cover is not adequate.

Cryptobiotic crusts are present, but their function is not well understood. Some pedestalling of plants may occur, but it is not very evident on casual observation and occurs on less than 5 percent of the plants. Water flow paths are broken and irregular in appearance or are discontinuous with numerous debris dams or vegetative barriers. The soil surface is stable and intact.

The following soil properties listed in the table below represent the soil profile above the sedimentary beds or to sand and gravel. Major soil series correlated to this ecological site can be found in Section II of the Natural Resources Conservation Service Field Office Technical Guide or the following web sites:

- http://soildatamart.nrcs.usda.gov/
- http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm

Parent materials
Kind: Residuum, slope alluvium
Origin: Mudstone, siltstone
Surface texture:
(1) Loam
(2) Silt loam
(3) Silty clay loam
Subsurface texture group: Loamy

	Minimum	Maximum
Surface fragments <=3" (% cover):	0	10
Surface fragments >3" (% cover):	0	5
Subsurface fragments <=3" (% volume):	0	35
Subsurface fragments >3" (% volume):	0	10
Drainage class: Well drained		
Permeability class: Moderately slow or moderate		

	Minimum	Maximum
Depth (inches):	20	80
Available water capacity (inches):	3.00	9.00
Electrical conductivity (mmhos/cm):	0	4
Sodium adsorption ratio:	0	5
Calcium carbonate equivalent (percent):	0	15
Soil reaction (1:1 water):	6.1	8.4

Plant Communities

Ecological Dynamics of the Site

The site developed under Northern Great Plains climatic conditions and included natural influence of large herding herbivores and frequent fire. Changes will occur in the plant communities due to weather fluctuations and/or management actions. Under adverse impacts, a slow decline in vegetative vigor and composition will occur. Under favorable conditions, the site has the potential to resemble the Reference Community Phase 1.1. The Reference State has been determined by study of rangeland relic areas, areas protected from excessive disturbance, and areas under long-term rotational grazing regimes. Trends in plant community dynamics ranging from heavily grazed to lightly grazed areas, seasonal use pastures, and historical accounts also have been considered. Community phases, community pathways, states, transitions, thresholds, and restoration pathways have been determined through similar studies and experience.

The natural disturbance regime consisted of frequent fires caused both by natural and Native American ignition sources. These fires occurred during any season of the year, but were concentrated in the spring and late summer or early fall. Lightning fires occurred most frequently in July and August while fires started by Native Americans occurred in April, September, and October. Large ungulate grazing was heavy and occurred often, but usually for short durations. Grazing may have been severe when occurring after a fire event, or in association with reliable water sources. The grazing and fire interaction, especially when coupled with drought events, set up the dynamics discussed and displayed in the following state-and-transition diagram and descriptions.

This ecological site has been grazed by domestic livestock since introduced into the area. The introduction of domestic livestock and the use of fencing and reliable water sources have radically changed the disturbance regime of this site. Heavy continuous grazing and/or continuous seasonal (spring) grazing, without adequate recovery periods following each grazing occurrence causes this site to depart from the Reference Plant Community Phase. Blue grama and introduced cool-season grasses, if present, will begin to increase. Western wheatgrass will increase initially and then begin to decrease. Green needlegrass will decrease in frequency and production (Community Phases 1.2 and 2.2). In time, heavy continuous grazing will likely cause upland sedges and blue grama and/or introduced cool-season grasses, if present, to dominate and pioneer perennials and annuals to increase (Community Phases 3.1 and 4.1). The resulting plant community is relatively stable and competitive advantage prevents other species from establishing. Extended periods of non-use and/or lack of fire will result in a plant community having high litter levels, which favors an increase in introduced cool-season grasses such as Kentucky bluegrass, crested wheatgrass, and/or smooth bromegrass. Shrubs such as western snowberry increase in this situation, especially in areas prone to snow accumulation and drift.

Due to a general invasion of exotic species (such as Kentucky bluegrass, crested wheatgrass and smooth bromegrass) across the MLRA within this site, returning to the

1.1 Western Wheatgrass/Green Needlegrass Plant Community Phase may not be possible. Today, the 2.1 Western Wheatgrass/Green Needlegrass Plant Community Phases most resembles the 1.1 Reference Plant Community Phase in appearance and function.

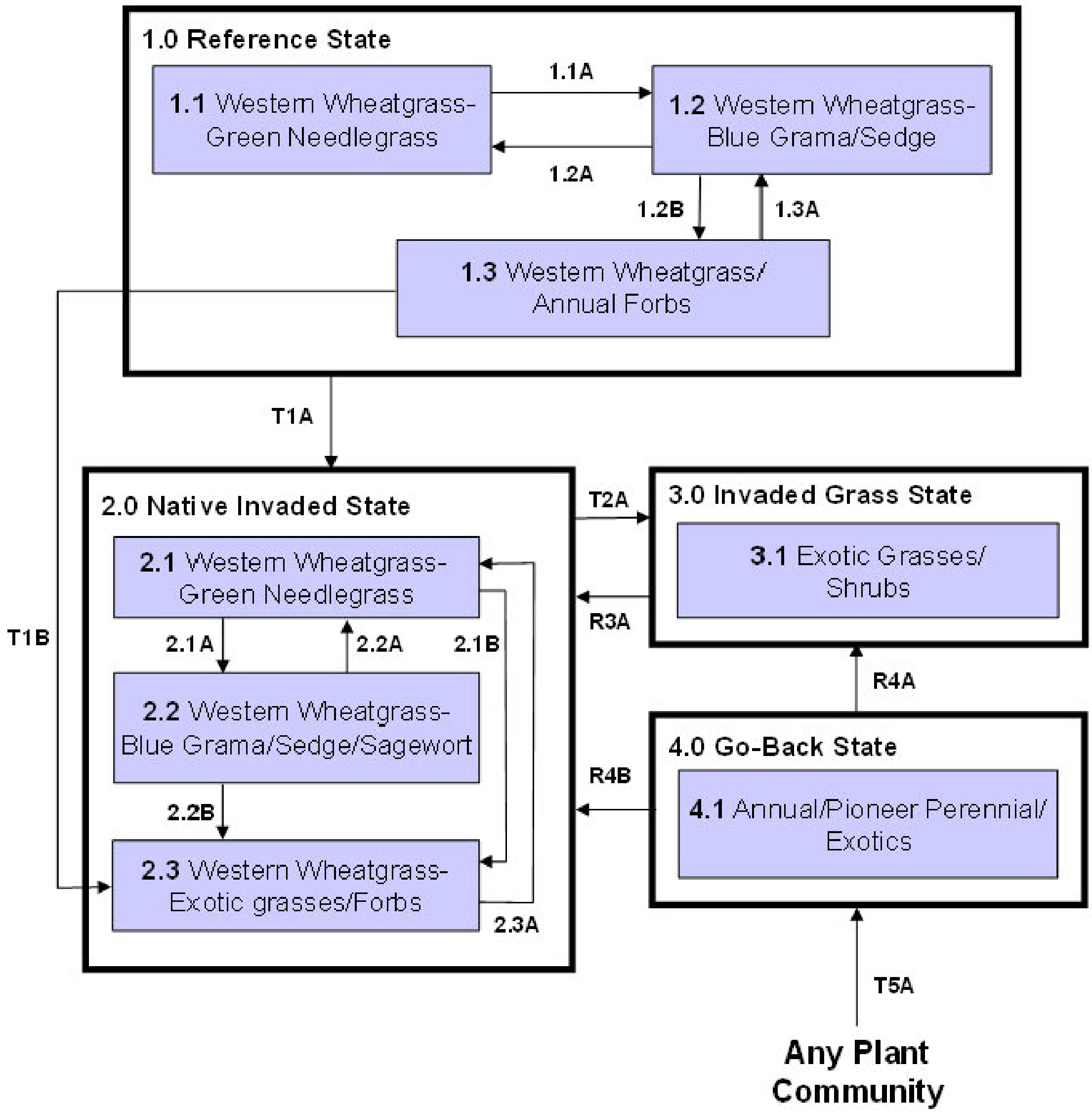
State-and-Transition Models (STM) are ecological process driven models. The ecological dynamics characterized by the STM reflect the functional changes in ecological drivers and feedback mechanisms (pathways), and the resulting changes in plant community composition (phases or states). The application of various management actions coupled with weather variables impact the ecological processes/drivers/feedback mechanisms drive plant community composition changes. The pathway narratives describing the ecological dynamics of the site reference various management inputs (i.e. prescribed grazing, prescribed fire), it is the manager's responsibility to understand how these various management actions impact the ecological processes/drivers/feedback mechanisms.

Plant Community and Vegetation State Narratives

Following are the narratives for each of the described plant communities. These plant communities may not represent every possibility, but they are the most prevalent and repeatable plant communities. The plant composition tables shown above have been developed from the best available knowledge at the time of this revision. As more data are collected, some of these plant communities may be revised or removed, and new ones may be added. None of these plant communities should necessarily be thought of as "Desired Plant Communities." According to the USDA NRCS National Range and Pasture Handbook, Desired Plant Communities (DPCs) will be determined by the decision-makers and will meet minimum quality criteria established by the NRCS. The main purpose for including any description of a plant community here is to capture the current knowledge and experience at the time of this revision.

Plant Community Phase 1.1

State-and-Transition Diagram



Western Wheatgrass/Green Needlegrass Plant Species Composition

Diagram Legend — MLRA 54 Loamy

T1A	Introduction of exotic cool-season grasses
T1B	Long-term prairie dog occupation coupled with introduction of exotic grasses and forbs
T2A	Extended periods of non-use or very light grazing, no fire
T5A	Cessation of annual cropping
R3A	Long term prescribed grazing with prescribed burning
R4A	Failed native seeding
R4B	Native seeding with prescribed grazing and prescribed fire
CP 1.1 - 1.2 (1.1A)	Long-term drought with/without heavy, long-term grazing
CP 1.2 - 1.1 (1.2A)	Return to average growing conditions and reduced grazing pressure
CP 1.2 - 1.3 (1.2B)	Long-term occupation by prairie dogs
CP 1.3 - 1.2 (1.3A)	Removal of prairie dogs
CP 2.1 - 2.2 (2.1A)	Heavy continuous grazing with or without drought
CP 2.1 - 2.3 (2.1B)	Prairie dog occupation
CP 2.2 - 2.1 (2.2A)	Reduced grazing pressure and return to average precipitation
CP 2.2 - 2.3 (2.2B)	Heavy continuous grazing coupled with long-term drought
CP 2.3 - 2.1 (2.3A)	Removal of prairie dogs

Annual Production (pounds per acre)

Group	Group name	Common name	Symbol	Scientific name	Low	High
1					960	1440
		blue grama	BOGR2	*Bouteloua gracilis*	120	240
		green needlegrass	NAVI4	*Nassella viridula*	360	480
		western wheatgrass	PASM	*Pascopyrum smithii*	480	720
2					120	240
		slender wheatgrass	ELTRS	*Elymus trachycaulus subsp. subsecundus*	24	120
		needle and thread	HECOC8	*Hesperostipa comata subsp. comata*	120	240
		porcupinegrass	HESP11	*Hesperostipa spartea*	48	168
3 -Other Native Grasses					24	240
		grasses, perennial	2GP		0	72
		big bluestem	ANGE	*Andropogon gerardii*	0	120

Annual Production (pounds per acre)

Group	Group name	Common name	Symbol	Scientific name	Low	High
		Fendler threeawn	ARPUL	*Aristida purpurea var. longiseta*	0	24
		sideoats grama	BOCU	*Bouteloua curtipendula*	0	120
		plains reedgrass	CAMO	*Calamagrostis montanensis*	24	120
		prairie Junegrass	KOMA	*Koeleria macrantha*	24	120
		Sandberg bluegrass	POSE	*Poa secunda*	24	120
4 -Grass-Likes					24	120
		grass-likes (not a true grass)	2GL		24	120
		needleleaf sedge	CADU6	*Carex duriuscula*	24	120
		threadleaf sedge	CAFI	*Carex filifolia*	24	120

Group	Forb				Annual Production (pounds per acre)	
Group	Group name	Common name	Symbol	Scientific name	Low	High
5 -Forbs					120	240
		forbs (herbaceous, not grass nor grass-like)	2FORB		0	72
		common yarrow	ACMI2	*Achillea millefolium*	24	48
		onion	ALLIU	*Allium*	0	24
		tarragon	ARDR4	*Artemisia dracunculus*	0	48
		white sagebrush	ARLU	*Artemisia ludoviciana*	24	48
		groundplum milkvetch	ASCR2	*Astragalus crassicarpus*	24	48
		purple prairie clover	DAPU5	*Dalea purpurea*	24	48
		blacksamson echinacea	ECAN2	*Echinacea angustifolia*	0	24
		old man's whiskers	GETR	*Geum triflorum*	0	24
		dotted blazing star	LIPU	*Liatris punctata*	0	48
		Rush skeletonplant	LYJU	*Lygodesmia juncea*	0	24
		silverleaf Indian breadroot	PEAR6	*Pediomelum argophyllum*	24	48
		prairie coneflower	RACO3	*Ratibida columnifera*	24	48
		Missouri goldenrod	SOMI2	*Solidago missouriensis*	0	48
		scarlet globemallow	SPCO	*Sphaeralcea coccinea*	0	24
		white heath aster	SYER	*Symphyotrichum ericoides*	24	48
		American vetch	VIAM	*Vicia americana*	24	48

Group	Shrub/Vine				Annual Production (pounds per acre)	
Group	Group name	Common name	Symbol	Scientific name	Low	High
6 -Shrubs					24	120
		subshrubs (<.5m)	2SUBS		0	48
		leadplant	AMCA6	*Amorpha canescens*	0	24
		dwarf sagebrush	ARCA13	*Artemisia cana*	0	48
		fringed sagewort	ARFR4	*Artemisia frigida*	24	48
		winterfat	KRLA2	*Krascheninnikovia lanata*	0	24
		prairie rose	ROAR3	*Rosa arkansana*	0	24
		western snowberry	SYOC	*Symphoricarpos occidentalis*	24	48

Sen Pedon Description

Print Date: Feb. 17, 2023
Description Date: June 24, 2022
Describer: Wade Bott, John Kempenich

Site ID: S2022ND089003

Soil Survey Area: ND089 -- Stark County, North Dakota 5-DIC -- Dickinson, North Dakota
Pedon ID: S2022ND089003

Quad Name:
Lab Source ID: KSSL

Lab Pedon #: 22N0294

Country:
State: North Dakota
MLRA: 54 -- Rolling Soft Shale Plain

Map Unit: E0515B --RHOADES-DAGLUM COMPLEX, 2 TO 6 PERCENT SLOPES

Std Latitude: 46.9562520
Std Longitude: -103.1272950

User Transect ID:
Soil Name as Described/Sampled: Unnamed, Belfield-like Classification: Fine-loamy, mixed, superactive, frigid Glossic Natrustolls Soil Name as Correlated:
Classification:
Pedon Type: not classified to current taxon name
Pedon Purpose: laboratory sampling site
Taxon Kind: family
Associated Soils:

Physiographic Division:
Physiographic Province:
Physiographic Section:

State Physiographic Area:
Local Physiographic Area:

Geomorphic Setting: microlow on shoulder of hillslope on sedimentary plains

Upslope Shape: concave
Cross Slope Shape: linear
Particle Size Control Section: 10 to 60 cm.

Description origin: NASIS

Primary Earth Cover: Grass/herbaceous cover

Secondary Earth Cover: Grassland rangeland

Vegetation:

Parent Material: slope alluvium derived from sedimentary rock

Bedrock Kind: Shale and siltstone
Bedrock Depth: 67 centimeters
Bedrock Hardness: very weakly coherent cemented
Bedrock Fracture Interval:

Surface Fragments:

Description database:

Diagnostic Features:

mollic epipedon 0 to 18 cm.
albic horizon 0 to 10 cm.
albic materials 0 to 18 cm.
argillic horizon 10 to 41 cm.
glossic horizon 10 to 18 cm.
natric horizon 18 to 41 cm.
secondary carbonates 41 to 115 cm.
gypsum accumulations 41 to 115 cm.
paralithic materials 67 to 115 cm.
paralithic contact 67 to cm.

Top Depth (cm)	Bottom Depth (cm)	Restriction Kind	Restriction Hardness
67	115	bedrock, paralithic	Very weakly coherent

Cont. Site ID: S2022ND089003 **Pedon ID:** S2022ND089003

Slope (%)	Elevation (meters)	Aspect (deg)	MAAT (C)	MSAT (C)	MWAT (C)	MAP (mm)	Frost-Free Days	Drainage Class	Slope Length (meters)	Upslope Length (meters)
3.0								Well drained		

E1--0 to 5 centimeters (0.0 to 2.0 inches); dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2), moist; 25 percent sand; 22 percent clay; weak very fine granular structure; friable, slightly sticky, slightly plastic; many fine roots throughout; common fine high-continuity dendritic tubular pores; noneffervescent; clear smooth boundary. Lab sample # 22N01284

E2--5 to 10 centimeters (2.0 to 3.9 inches); dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2), moist; 27 percent sand; 25 percent clay; weak thin platy parts to weak fine granular structure; friable, slightly sticky, slightly plastic; common very fine roots throughout and common fine roots throughout; common very fine high-continuity dendritic tubular and common fine high-continuity dendritic tubular pores; 10 percent fine distinct spherical 10YR 5/6), moist, masses of oxidized iron with clear boundaries Throughout; noneffervescent; clear wavy boundary. Lab sample # 22N01285

EBt--10 to 18 centimeters (3.9 to 7.1 inches); 30 percent dark grayish brown (10YR 4/2) and 70 percent brown (10YR 5/3) silt loam, 30 percent very dark grayish brown (10YR 3/2) and 70 percent brown (10YR 4/3), moist; 23 percent sand; 26 percent clay; weak medium platy parts to weak fine subangular blocky structure; friable, slightly sticky, slightly plastic; common very fine roots throughout and common fine roots throughout; common very fine high-continuity dendritic tubular and common fine high-continuity dendritic tubular pores; 30 percent faint

10YR 4/2), moist, clay films on all faces of peds; 2 percent fine prominent spherical 10YR 5/6), moist, masses of oxidized iron with clear boundaries Throughout; noneffervescent; clear wavy boundary. Lab sample # 22N01286

Btn--18 to 41 centimeters (7.1 to 16.1 inches); brown (10YR 5/3) silty clay loam, brown (10YR 4/3), moist; 12 percent sand; 31 percent clay; moderate coarse prismatic parts to moderate coarse subangular blocky structure; friable, moderately sticky, moderately plastic; common very fine roots throughout; common very fine high-continuity dendritic tubular and common fine high-continuity dendritic tubular pores; 50 percent faint 10YR 4/2), moist, clay films on all faces of peds; 5 percent medium prominent spherical 10YR 5/6), moist, masses of oxidized iron with clear boundaries Throughout; carbonate, finely disseminated in matrix and 2 percent fine prominent spherical 10YR 7/2), moist, gypsum masses with sharp boundaries in matrix and 1 percent fine prominent spherical 10YR 7/2), moist, carbonate masses with sharp boundaries in matrix; strong effervescence; clear wavy boundary. Lab sample # 22N01287

Bky--41 to 67 centimeters (16.1 to 26.4 inches); silt loam, grayish brown (10YR 5/2), moist; 17 percent sand; 25 percent clay; moderate coarse prismatic parts to moderate coarse subangular blocky structure; friable, slightly sticky, slightly plastic; common very fine roots throughout; common very fine high- continuity dendritic tubular and common fine high-continuity dendritic tubular pores; 1 percent prominent 10YR 7/2), moist, gypsum coats on surfaces along pores and 1 percent prominent 10YR 7/2), moist, gypsum coats on surfaces along root channels; 1 percent fine prominent spherical moderately coherent cemented 7.5YR 4/6), moist, ironstone nodules with sharp boundaries In matrix and 10 percent coarse prominent spherical 10YR 5/6) masses of oxidized iron with clear boundaries Throughout; 1 percent fine prominent spherical 10YR 7/1), moist, gypsum crystals, unspecified with sharp boundaries in cracks and 1 percent fine prominent spherical 10YR 7/2), moist, carbonate masses with sharp boundaries on surfaces along pores; noneffervescent; clear wavy boundary. Lab sample # 22N01288

2Cr--67 to 115 centimeters (26.4 to 45.3 inches); very weakly coherent cemented Shale and siltstone bedrock, 55 percent dark gray (10YR 4/1) and 45 percent light brownish gray (10YR 6/2), moist; massive; 1 percent prominent 10YR 7/2), moist, gypsum coats in cracks; 1 percent medium prominent spherical moderately coherent cemented 7.5YR 4/6), moist, ironstone nodules with sharp boundaries In cracks and 10 percent coarse prominent spherical 10YR 5/6) masses of oxidized iron with clear boundaries In cracks. Lab sample # 22N01289

Sen Characterization Data

Pedon ID: S2022ND089003

Sampled Date: 6/2/2022

Series: Sen

Sampled Classification: Fine-loamy, mixed, superactive, frigid Glossic Natrustoll

Particle Size Control Section: 25 - 67

Clay Weighted Average: 26

CEC Activity, CEC7/Clay, Weighted Average: 0.74

Horizon	Depth	Texture	Clay (%)	Silt (%)	Sand (%)	Core Db (g/cm-3)	Est. OC (%)	Fine Silt (%)	Coarse Silt (%)	V. Fine Sand (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	V. Coarse Sand (%)	Coarse Fragments (%)
E1	0-5	sicl	30.5	56.9	12.6	0.48	2.9	34.3	22.6	6	4.1	1.9	0.3	0.3	-
E2	5-10	sicl	30.5	59.3	10.2	1.31	2.0	35.1	24.2	4.3	3.6	1.5	0.3	0.5	-
EBt	10-18	sicl	32.4	55.2	12.4	1.39	1.8	34.7	20.5	5.3	4.4	2	0.4	0.3	tr
Btn	18-41	sicl	31.4	57.2	11.4	1.56	1.1	32.9	24.3	4.9	3.8	2	0.4	0.3	-
Bky	41-67	sil	22.3	68.2	9.5	1.45	0.4	28.8	39.4	7.6	0.9	0.7	0.2	0.1	-
2Cr	67-115	cl	36.0	40.8	23.2	1.63	0.3	39.7	1.1	21	0.9	0.5	0.4	0.4	-

Horizon	Depth	CEC7 (cmo/kg)	CEC7/Clay	Base Saturation (%)	EC (dS/m)	ESP (%)	SAR	Ext. Ca (cmol/kg)	Ext. Mg (cmol/kg)	Ext. Na (cmol/kg)	Ext. Acidity (cmol/kg)	pH Water	CaCO3 (%)
E1	0-5	22.7	0.74	89	-	tr	-	12.4	6.9	tr	9.6	6.7	-
E2	5-10	31.1	1.02	74	-	tr	-	13.6	8.5	tr	8.7	6.7	-
EBt	10-18	21.5	0.66	85	-	tr	-	11.1	6.4	tr	8.6	7.0	-
Btn	18-41	21.1	0.67	91	-	tr	-	11.0	7.7	tr	6.0	7.2	-
Bky	41-67	19.3	0.87	100	-	1	-	32.6	7.5	0.2	-	8.2	1
2Cr	67-115	18.8	0.52	100	5.59	6	5	74.1	15.4	3.1	2.8	7.8	4

Belfield Series Information

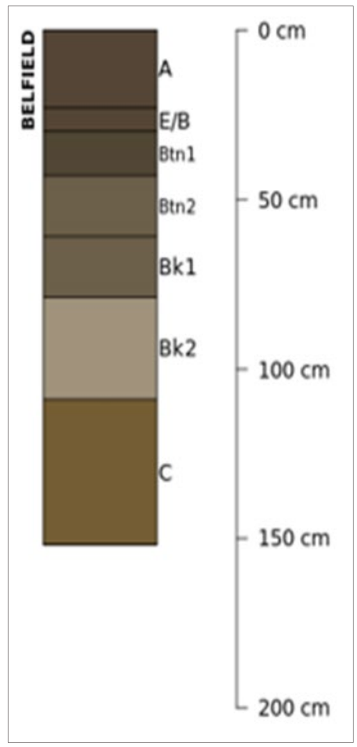
LOCATION BELFIELD ND+MT SD

Established Series

Rev. FWW-CJH

01/2023

Scan the QR code for the official series description.



BELFIELD SERIES

The Belfield series consists of deep and very deep, well or moderately well drained slowly permeable soils formed in alkaline, calcareous residuum or alluvium on uplands, flats, terraces and in swales. Slope ranges from 0 to 9 percent. Mean annual air temperature is 43 degrees F, and mean annual precipitation is 15 inches.

TAXONOMIC CLASS: Fine, smectitic, frigid Glossic Natrustolls

TYPICAL PEDON: Belfield silty clay loam with a 1 percent slope in native grassland. (Colors are for dry soil unless otherwise stated)

A--0 to 9 inches; grayish brown (10YR 5/2) silty clay loam, very dark grayish brown (10YR 3/2) moist; moderate medium prismatic structure parting to moderate very fine subangular blocky; very hard, friable; many roots; many very fine pores; common uncoated sand grains on faces of peds; slightly acid; clear wavy boundary. (5 to 15 inches thick)

E/B--9 to 12 inches; light brownish gray (2.5Y 6/2) silty clay loam, very dark grayish brown (10YR 3/2) moist; moderate medium prismatic structure parting to weak medium platy which parts to strong very fine subangular blocky; very hard, friable; many roots; many very fine pores; thin light gray (10YR 7/1) uncoated sand grains on top of plates and discontinuous on bottom of plates; slightly acid; clear smooth boundary. (Combined E, E/B, and B/E horizons 2 to 6 inches thick)

Btn1--12 to 17 inches; grayish brown (2.5Y 5/2) silty clay, very dark grayish brown (2.5Y 3/2) moist; strong medium prismatic structure parting to strong medium and fine angular blocky; extremely hard, friable; common roots; many very fine pores; faint continuous clay films on faces of peds; common uncoated sand grains in the upper part and few in the lower part; neutral; clear wavy boundary.

Btn2--17 to 24 inches; light olive brown (2.5Y 5/4) silty clay loam, dark grayish brown (2.5Y 4/2) moist; moderate medium prismatic structure parting to moderate medium and fine subangular blocky; very hard, friable; few roots; many fine pores; faint clay films of olive brown (2.5Y 4/3) moist; slightly alkaline; clear wavy boundary. (Combined Btn horizons 6 to 24 inches thick)

Bk1--24 to 31 inches; grayish brown (2.5Y 5/2) silty clay loam, dark grayish brown (2.5Y 4/2) moist; moderate medium prismatic structure parting to weak medium subangular blocky; very hard, friable; few roots; many fine and very fine pores; common threads and masses of carbonates; strong effervescence; moderately alkaline; clear wavy boundary.

Bk2--31 to 43 inches; light brownish gray (2.5Y 6/2) and pale yellow (2.5Y 8/2) silty clay loam, dark grayish brown (2.5Y 4/2) and light brownish gray (2.5Y 6/2) moist; weak medium prismatic structure parting to moderate medium subangular blocky; very hard, friable; many fine pores; many threads and masses of carbonates; violent effervescence; moderately alkaline; gradual wavy boundary. (Combined Bk horizons 0 to 36 inches thick)

C--43 to 60 inches; light olive brown (2.5Y 5/4) clay loam, olive brown (2.5Y 4/4) moist; massive; very hard, friable; many fine pores; violent effervescence; moderately alkaline.

TYPE LOCATION: Stark County, North Dakota; 2320 feet east and 235 feet north of the southwest corner, sec. 36, T. 137 N., R. 98 W.

RANGE IN CHARACTERISTICS: The mollic epipedon ranges from 7 to 30 inches in thickness and in many pedons includes all or part of the Btn horizon. The depth to carbonates ranges from 15 to 55 inches. The substratum, below depths of 36 inches, typically is alkaline local alluvium or partially weathered soft siltstone, shale or sandstone. Saline phases are recognized.

The A horizon has hue of 10YR, value of 3 to 5 and 2 or 3 moist, and chroma of 2 or 3. It commonly is silt loam or silty clay loam, but some is loam or clay loam. It is slightly acid or neutral.

The E/B horizon has hue of 10YR, 2.5Y or 5Y, value of 3 to 7 and 2 to 5 moist, and chroma of 1 to 3. It is sandy loam to silty clay. It is neutral or slightly acid. Some pedons have E or B/E horizons with the same properties as the E/B horizon.

The Btn horizon has hue of 10YR or 2.5Y, value of 3 to 7 and 2 to 5 moist, and chroma of 2 to 4. It is silty clay, silty clay loam, clay or clay loam averaging 35 to 45 percent clay. Clay films are faint and distinct on faces of peds. It is neutral to moderately alkaline. Some pedons have Btkn horizons.

The Bk horizon has hue of 2.5Y or 5Y, value of 5 to 8 and 4 to 7 moist, and chroma of 1 to 4. It is loam, clay loam, silty clay loam or silty clay. It is slightly alkaline to strongly alkaline. Some pedons have BCk or BC horizons. Some pedons have Bky or Bkz horizons below a depth of 20 inches.

The C horizon has hue of 2.5Y or 5Y, value of 5 to 8 and 4 to 7 moist, and chroma of 1 to 4. It typically is silty clay loam or clay loam, but some are loam, clay, or silty clay. Some pedons are fine sandy loam below 40 inches. It is moderately or strongly alkaline.

COMPETING SERIES: This is the Lennep series. Lennep soils have Btn horizons that average 50 to 60 percent clay.

GEOGRAPHIC SETTING: Belfield soils are on level and nearly level terraces, flats and upland swales and on nearly level to moderately sloping uplands. Slopes from 1 to 4 percent are most common, but slope ranges from 0 to 9 percent. The soils formed in alkaline, calcareous residuum, or alluvium mainly of tertiary origin. Mean annual precipitation ranges from 13 to 18 inches, and mean annual air temperature ranges from 39 to 45 degrees F.

GEOGRAPHICALLY ASSOCIATED SOILS: These are the Amor, Daglum, Farland, Grail, Lawther, Moreau, Morton, Regent, Rhoades, Wyola, Sen and Shambo soils. None of the associated soils, except Daglum and Rhoades soils, have natric horizons. Amor, Moreau, Morton, Regent and Sen soils are adjacent to Belfield soils on uplands. Farland, Wyola and Shambo soils are adjacent to Belfield soils on terraces. Grail and Lawther soils are adjacent to Belfield soils in upland swales. Daglum and Rhoades soils occupy similar positions as Belfield soils. They have strong columnar structure. In addition, Rhoades soils have visible salts or gypsum within a depth of 16 inches.

DRAINAGE AND PERMEABILITY: Well drained or moderately well drained. Runoff is negligible to medium depending on slope and surface texture. Permeability is slow. A seasonal high water table is at a depth of 3.5 to 5.0 feet at some time during the period of April through June in the moderately well drained phase. It is at a depth of 4 to more than 6 feet during the same period in the well drained phase.

USE AND VEGETATION: Most areas are cropped to small grains. Some are used for hay or pasture. Native vegetation is mid and short prairie grasses such as western wheatgrass, blue grama, and green needlegrass.

DISTRIBUTION AND EXTENT: Southwestern North Dakota, northwestern South Dakota, and eastern Montana. The soil is extensive.

MLRA SOIL SURVEY REGIONAL OFFICE (MO) RESPONSIBLE: Salina, Kansas

SERIES ESTABLISHED: Stark County, North Dakota, 1965.

REMARKS: Revised 4/95.

Diagnostic horizons and features recognized in this pedon are: mollic epipedon - the zone from the surface of the soil to a depth of 9 inches (A horizon); glossic characteristics - E/B horizon and uncoated sand grains in upper Btn1 horizon; natric horizon - the zone from 12 to 24 inches (Btn1 and Btn2 horizons).

ADDITIONAL DATA: North Dakota Agricultural Station Laboratory Data Nos. S61ND-45-1, S61ND-45-4, S61ND-45-5, and S61ND-45-9.

National Cooperative Soil Survey

U.S.A.

Additional Ecological Site Descriptions

USDA NRCS, MLRA 54 – Clayey Ecological Site Description

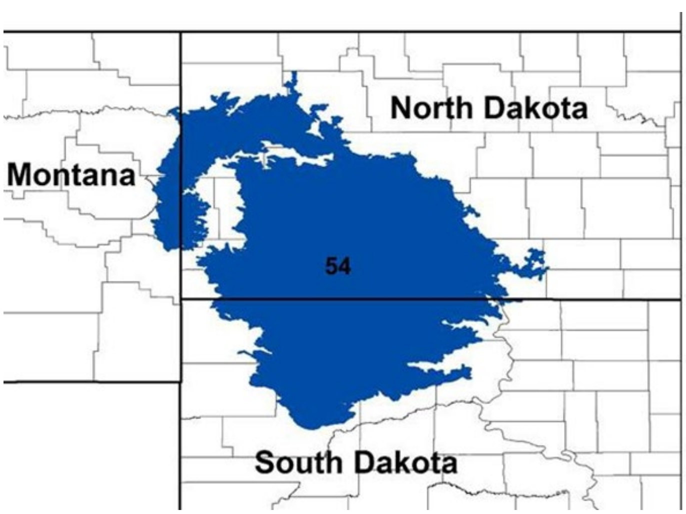
Site stage: Provisional-Draft

Provisional: an ecological site description (ESD) at the provisional status represents the lowest tier of documentation that is releasable to the public. It contains a grouping of soil units that respond similarly to ecological processes. The ESD contains 1) enough information to distinguish it from similar and associated ecological sites and 2) a draft state and transition model capturing the ecological processes and vegetative states and community phases as they are currently conceptualized. The provisional ESD has undergone both quality control and quality assurance protocols. It is expected that the provisional ESD will continue refinement towards an approved status.

Scan the QR code for the provisional ESD.

Site Name: Clayey
Site Type: Rangeland
Site ID: R054XY020ND
Major Land Resource Area (MLRA): 054-Rolling Soft Shale Plain

For more information on MLRAs, refer to the following web site:
https://www.nrcs.usda.gov/resources/data-and-reports/major-land-resource-area-mlra



Location of MLRA 54, Rolling Soft Shale Plain in North Dakota, South Dakota, and Montana

MLRA 54 covers 29,280 square miles and encompasses approximately 18.7 million acres. MLRA 54 spans three states with 64 percent of it in North Dakota, 33 percent in South Dakota, and 3 percent in Montana. Most of MLRA 54 is underlain by soft, calcareous shale, siltstone, and sandstone of the Tertiary Fort Union Group and the Cretaceous Fox Hills and Hell Creek Formations. Most of the soils in MLRA 54 developed from residuum weathered in place. Along the eastern and northern edges of the MLRA where MLRA 54 transitions into the glaciated Missouri plateau, remnants of glacial till parent materials still remain on the high areas of the landscape. The MLRA 54 landscape is characterized by old, moderately dissected rolling plains with areas of local badlands, hills, and isolated buttes. Elevation is 1,650 feet (505 meters) on the eastern side of the MLRA with a gradual rise to 3,600 feet (1,100 meters) on the western side. The Missouri River runs along the north and east side of MLRA 54. Most of the Standing Rock Indian Reservation, the northwest third of the Cheyenne River Indian Reservation, and the Grand River National Grasslands are in the southern part of the MLRA.

Ecological Site Concept

The Clayey ecological site is primarily located on backslopes, flats, and swales on level to moderately steep landforms on uplands (sedimentary plains and till plains). Soils on this site are moderately deep to very deep, fine-textured soils with greater than 18 percent clay in the surface horizon and greater than 35 percent clay in the subsoil (forms a ribbon >2 inches long). The surface soil is typically very dark grayish brown color to a depth of 7 to more than 20 inches; however, on terraces, the surface layer may be grayish brown. Slopes range from 0 to 25 percent. On the landscape, Shallow Clayey, Shallow Loamy, and Very Shallow ecological sites occur higher and Loamy Terrace and Thin Claypan sites occur lower. Claypan and Loamy sites occur on similar landscape positions. The Claypan site has a dense, sodic, root-restrictive subsoil. Soils on the Loamy site form a ribbon 1 to 2 inches long.

Physiographic Features

The Clayey ecological site is primarily located on backslopes, flats, and swales on level to moderately steep landforms on uplands (sedimentary plains and till plains). It can also occur on terraces. Parent materials are weathered residuum (siltstone, shale), alluvium from residuum, or glacial till. Slope ranges from 0 to 25 percent.

Landform: sedimentary plain, till plain, terraces

	Minimum	Maximum
Elevation:	1,650	3,600
Slope (percent):	0	25
Water Table Depth (inches):	42	> 80
Flooding:		
Frequency:	None	None
Ponding:		
Depth (inches):	0	0
Frequency:	None	None
Runoff Class:	Low	Very High
Aspect:	No influence on this site	No influence on this site

Representative Soil Features

Soils associated with the Clayey ES are in the Mollisol, Entisol, and Vertisol orders. The Mollisols are classified further as Glossic Natrustolls, Pachic Vertic Argiustolls, Pachic Vertic Haplustolls, Vertic Argiustolls, and Vertic Haplustolls. The Entisols are classified further as Vertic Ustifluvents. The Vertisols are classified further as Leptic Haplusterts, Leptic Udic Haplusterts, and Typic Haplusterts. These soils were developed under prairie vegetation. Most formed in clayey residuum (typically soft sedimentary shale or siltstone) or clayey alluvium derived from residuum. A few soils developed from glacial till. The soils on this site are moderately deep to very deep. They are well drained or moderately well drained.

The common feature of soils in this site is a fine-textured subsoil (forms a ribbon >2 inches long), but it is not so dense as to be root-restrictive. The subsoil is clay, silty clay, clay loam, or silty clay loam (if clay loam or silty clay loam, clay content exceeds 35%). The surface soil is typically dark-colored to a depth of 7 to more than 20 inches; however, on terraces, the surface layer may be grayish brown (non-mollic). Surface textures are commonly silty clay loam, silty clay, clay or clay loam. Surface textures also may be silt loam or loam - particularly in Glossic Natrustolls where claypan horizons affect but do not restrict root development. In some soils, bedrock is present below a depth of 20 inches which affects or restricts root growth (e.g., bedded shale).

Soil reaction typically is slightly acid to moderately alkaline (pH 6.1 to 8.4); however, it ranges from moderately acid (pH 5.6) to strongly alkaline (pH 9.0). Soil salinity is none or very slight (E.C. < 4) to a depth greater than 20 inches, however slight salinity (E.C. < 8) is allowable within that depth. Sodicity is commonly none to low (SAR < 5); however, soils with claypan layers can have SAR values as high as 15 in the subsoil. Calcium carbonate content, typically, is less than 15 percent, but ranges to 30 percent in the lower subsoil.

When dry, these soils can crack; when wet, surface compaction can occur with heavy traffic. This site should show slight to no evidence of rills, wind-scoured areas, or pedestalled plants. Water flow paths are broken, irregular in appearance, or discontinuous with numerous debris dams or vegetative barriers. The soil surface is stable and intact. Soil layers within a depth of 20 inches are non-restrictive to water movement and root penetration.

These soils are mainly susceptible to water erosion. The hazard of water erosion increases on slopes greater than about 5 percent. Loss of the soil surface layer can result in a shift in species composition and/or production.

The major soil series which characterize the Clayey ecological site in MLRA 54 are Barkof, Belfield, Grail, Lawther, Moreau, Niobell, Regent, and Savage.

Access Web Soil Survey (https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx) for specific local soils information.

Parent Material Kind: residuum, alluvium, till

Parent Material Origin: residuum, till

Surface Texture: silty clay loam, silty clay, clay, silt loam, clay loam

Surface Texture Modifier: none

Subsurface Texture Group: Clayey

Surface Fragments < 3" (% Cover): 0

Surface Fragments > 3" (%Cover): 0-3

Subsurface Fragments < 3" (% Volume): 0-13

Subsurface Fragments > 3" (% Volume): 0-1

	Minimum	**Maximum**
Drainage Class:	Moderately well drained	Well drained
Permeability Class:	Very slow	Moderately slow
Depth to first restrictive layer (inches):	20	>80
Electrical Conductivity (dS/m)*:	0	8
Sodium Absorption Ratio**:	0	15
Soil Reaction (1:1 Water)**:	5.6	9.0
Soil Reaction (0.1M CaCl2):	NA	NA
Available Water Capacity (inches)**:	3.00	8.50
Calcium Carbonate Equivalent (percent)**:	0	30

*This attribute represents from 0 to 20 inches.

** These attributes represent from 0 to 40 inches or the first restrictive layer.

Plant Communities

Ecological Dynamics of the Site:

This ecological site description is based on nonequilibrium ecology and resilience theory and utilizes a State-and-Transition Model (STM) diagram to organize and communicate information about ecosystem change as a basis for management. The ecological dynamics characterized by the STM diagram reflect how changes in ecological drivers, feedback mechanisms, and controlling variables can maintain or induce changes in plant community composition (phases and/or states). The application of various management actions, combined with weather variables, impact the ecological processes which influence the competitive interactions, thereby maintaining or altering plant community structure.

Prior to European influence, the historical disturbance regime for MLRA 54 included frequent fires, both anthropogenic and natural in origin. Most fires, however, were anthropogenic fires set by Native Americans. Native Americans set fires in all months except perhaps January. These fires occurred in two peak periods, one from March-May with the peak in April and another from July-November with the peak occurring in October. Most of these fires were scattered and of small extent and duration. The grazing history would have involved grazing and browsing by large herbivores such as American bison, elk, and whitetail deer. Herbivory by small mammals, insects, nematodes and other invertebrates are also important factors influencing the production and composition of the communities. Grazing and fire interaction, particularly when coupled with drought events, influenced the dynamics discussed and displayed in the following state and transition diagram and descriptions.

Following European influence, this ecological site generally has had a history of grazing by domestic livestock, particularly cattle, which along with other related activities (e.g., fencing, water development, fire suppression) has changed the disturbance regime of the site. Changes will occur in the plant communities due to these and other factors.

Weather fluctuations coupled with managerial factors may lead to changes in the plant communities, and may, under adverse impacts, result in a slow decline in vegetative vigor and composition. However, under favorable conditions the botanical composition may resemble that prior to European influence.

Four vegetative states have been identified for the site (Reference, Native/Invaded, Invaded, and Go-Back). Within each state one or more community phases have been identified. These community phases are named based on the more dominant and visually conspicuous species; they have been determined by study of historical documents, relict areas, scientific studies, and ecological aspects of plant species and plant communities. Transitional pathways and thresholds have been determined through similar methods.

Plant Communities and Transitional Pathways

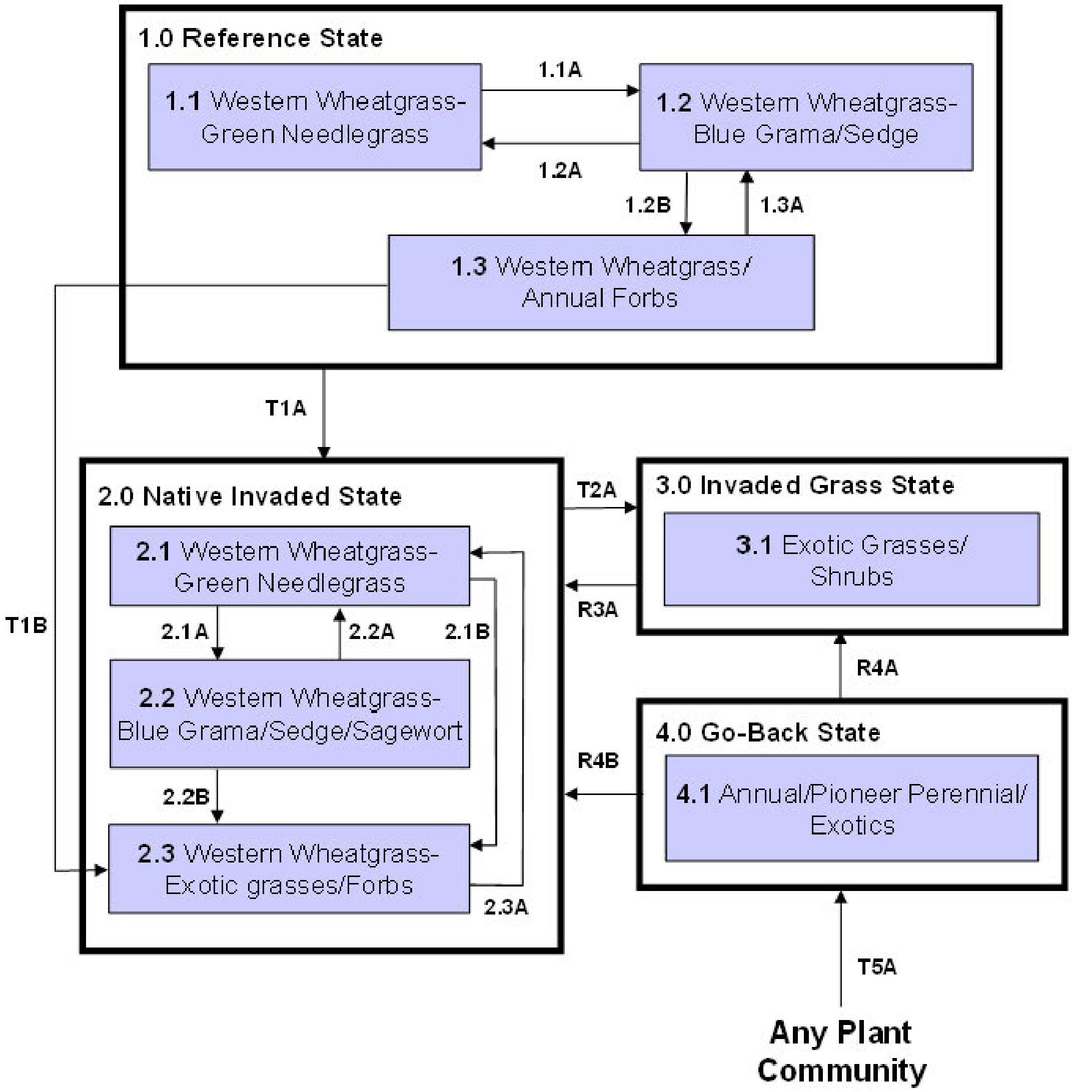


Diagram Legend — MLRA 54 Clayey

T1A	Introduction of exotic cool-season grasses
T2A	Extended periods of non-use or very light grazing, no fire
T5A	Cessation of annual cropping
R3A	Long term prescribed grazing with prescribed burning
R4A	Successful range planting
R4B	Failed range planting
CP 1.1 - 1.2 (1.1A)	Long-term drought with/without heavy, long-term grazing
CP 1.2 - 1.1 (1.2A)	Return to average precipitation and reduced grazing pressure
CP 1.2 - 1.3 (1.2B)	Long-term occupation by prairie dogs
CP 1.3 - 1.2 (1.3A)	Abandonment of prairie dogs
CP 2.1 - 2.2 (2.1A)	Heavy grazing pressure with or without drought
CP 2.1 - 2.3 (2.1B)	Extended periods of non-use or very light grazing, no fire
CP 2.2 - 2.1 (2.2A)	Return to average precipitaiton, prescribed grazing with prescribed burning
CP 2.2 - 2.3 (2.2B)	Extended periods of non-use or very light grazing, no fire
CP 2.2 - 2.4 (2.2C)	Long-term occupation by prairie dogs
CP 2.3 - 2.2 (2.3A)	Long-term drought and/or heavy season-long grazing pressure
CP 2.3 - 2.1 (2.3B)	Long term prescribed grazing with prescribed burning
CP 2.4 - 2.2 (2.4A)	Removal/abandonment of prairie dogs

Plant Community Composition and Group Annual Production

COMMON/GROUP NAME	SYMBOL	Group	lbs./acre	% Comp
		1.1 Western Wheatgrass-Green Needlegrass		
GRASSES & GRASS-LIKES			*1785 - 1890*	*85 - 90*
WHEATGRASS		**1**	**525 - 840**	**25 - 40**
western wheatgrass	PASM	1	525 - 840	25 - 40
thickspike wheatgrass	ELLA3	1	0 - 210	0 - 10
NEEDLEGRASS		**2**	**420 - 630**	**20 - 30**
green needlegrass	NAVI4	2	315 - 525	15 - 25
porcupinegrass	HESP11	2	0 - 63	0 - 3
SHORT WARM-SEASON		**3**	**105 - 210**	**5 - 10**
blue grama	BOGR2	3	105 - 210	5 - 10
buffalograss	BUDA	3	21 - 105	1 - 5
NATIVE COOL-SEASON		**4**	**21 - 105**	**1 - 5**
needle and thread	HECO26	4	21 - 105	1 - 5
prairie Junegrass	KOMA	4	21 - 63	1 - 3
plains reedgrass	CAMO	4	21 - 63	1 - 3
slender wheatgrass	ELTRT	4	21 - 63	1 - 3
Sandberg bluegrass	POSE	4	21 - 42	1 - 2
sedge	CAREX	4	21 - 42	1 - 2
OTHER NATIVE GRASSES		**5**	**21 - 105**	**1 - 5**
big bluestem	ANGE	5	0 - 105	0 - 5
sideoats grama	BOCU	5	0 - 105	0 - 5
plains muhly	MUCU3	5	0 - 42	0 - 2
saltgrass	DISP	5	0 - 21	0 - 1
other perennial grasses	2GP	5	21 - 105	1 - 5
FORBS		*6*	*42 - 147*	*2 - 7*
common yarrow	ACMI2	6	21 - 42	1 - 2
tarragon	ARDR4	6	21 - 42	1 - 2
white sagebrush	ARLU	6	21 - 42	1 - 2
blazing star	LIATR	6	21 - 42	1 - 2
leafy wildparsley	MUDI	6	21 - 42	1 - 2
scarlet beeblossom	OESU3	6	21 - 42	1 - 2
purple locoweed	OXLA3	6	21 - 42	1 - 2
scurfpea	PSORA2	6	21 - 42	1 - 2
upright prairie coneflower	RACO3	6	21 - 42	1 - 2
goldenrod	SOLID	6	21 - 42	1 - 2
scarlet globemallow	SPCO	6	21 - 42	1 - 2
white heath aster	SYER	6	21 - 42	1 - 2
prairie thermopsis	THRH	6	21 - 42	1 - 2
wavyleaf thistle	CIUN	6	21 - 21	1 - 1
pussytoes	ANTEN	6	0 - 21	0 - 1
larkspur	DELPH	6	0 - 21	0 - 1
blacksamson echinacea	ECAN2	6	0 - 21	0 - 1
rush skeletonweed	LYJU	6	0 - 21	0 - 1
spiny phlox	PHHO	6	0 - 21	0 - 1
white prairie aster	SYFA	6	0 - 21	0 - 1
prairie onion	ALST	6	2 - 21	0.1 - 1
false boneset	BREU	6	2 - 21	0.1 - 1
old man's whiskers	GETR	6	2 - 21	0.1 - 1
desertparsley	LOMAT	6	2 - 21	0.1 - 1
American vetch	VIAM	6	2 - 21	0.1 - 1
other perennial forbs	2FP	6	0 - 42	0 - 2
other annual forbs	2FA	6	0 - 21	0 - 1
SHRUBS		*7*	*21 - 63*	*1 - 3*
prairie sagewort	ARFR4	7	21 - 42	1 - 2
prairie rose	ROAR3	7	21 - 42	1 - 2
western snowberry	SYOC	7	21 - 42	1 - 2
silver sagebrush	ARCA13	7	0 - 21	0 - 1
winterfat	KRLA2	7	0 - 21	0 - 1
western pricklypear	OPPO	7	0 - 21	0 - 1
other shrubs	2SHRUB	7	0 - 21	0 - 1

Annual Production lbs./acre	LOW	RV	HIGH
GRASSES & GRASS-LIKES	1240	1964	2885
FORBS	40	95	150
SHRUBS	20	42	65
TOTAL	1300	2100	3100

This list of plants and their relative proportions are based on near normal years. Fluctuations in species composition and relative produ may change from year to year dependent upon precipitation or other climatic factors. RV = Representative Value.

USDA NRCS, Northern Rolling Plains, Northeastern Part, Perennial Riparian Complex (Valley Type VIII, C5 Stream Type) — 058CY001ND

ECOLOGICAL SITE DESCRIPTION

Scan the QR code for the full ecological site description.

GENERAL SITE INFORMATION

Site Type	Lotic Riparian Complex
Site ID	058CY001ND
Site Name	Northern Rolling Plains, Northeastern Part, Perennial Riparian Complex (Valley Type VIII, C5Stream Type)

Major Land Resource Area(s)

Number	Name
58C	Northern Rolling Plains, Northeastern Part

Site Concept	This site covers the lotic riparian complexes of plant community components along reaches of the Little Missouri River in MLRA 58C. This is a perennial stream that drains a relatively small sized watershed and empties into the Missouri River (Lake Sakakawea) in the northeast portion of Dunn County. The site concepts are based on the C5 stream type (predominantly sandy channel materials) and fluvial surfaces including a floodplain (with a plant community component of stable, bank holding obligate vegetation), a primary floodplain step plant community (with a community component of willows and grasses) that can dissipate energy and trap sediments during high flow events, a secondary floodplain step plant community where woody recruitment is taking place, and a low terrace (dominated by Eastern Cottonwood and Western wheatgrass). This site also has a high terrace that is disconnected from the floodplain and is characterized by a silver sagebrush/ western wheatgrass plant community.

Original Site Description Approval

Site Date	11/2014
Site Approval	John Warner
Site Authors	M. Meehan, J. Printz, K. Sedivec
Site Contributors	J. Kempenich, J. Dahl, G. Petik, G. Sandness, M. Ell, P. Olson
Site Reviewers	J. Repp, M. Moseley
Approval Date	03-23-15

REPRESENTATIVE PHYSIOGRAPHIC FEATURES

Narrative	This site occurs within the Little Missouri River Watershed, located in the Badlands portion of the Northwestern Great Plains Region of North Dakota (Severson and Sieg 2006). The landscape of the Unglaciated Plains is classified as a semiarid rolling plain of shale and sandstone with areas of buttes and badlands. The Little Missouri River flows through a landscape that remained untouched by recent glacial active. The valley of the Little Missouri River follows a route cut by the Pleistocene glaciers through the soft silts and clays of the Sentinel Butte and Bullion Creek Formations. The valley's dimensions are a function of geologic substrate; the valley is deep and constrained by the badlands (Bluemle 1973). The surrounding landscape is highly erosive leading to the entrenchment of the river and the formations of multiple terraces. The floodplain is composed primarily of sands with silts and clays present in the banks.

	Minimum	Maximum
Elevation (feet)	1875	2800
Valley Slope (percent)	0.5	2.5

Fluvial Surface/Landform 1 [1/]	Floodplain	
	Minimum	**Maximum**
Water Table Depth (inches)	surface	18
Water Table Duration (days) [2/]	365	365
Water Table Frequency (months) [3/]	January	December
Flooding Frequency	Very Frequent	Very Frequent
Flooding Duration	Long	Very Long
Ponding Depth (inches)	None	None
Ponding Frequency	None	none
Ponding Duration	None	none
Runoff Class	Negligible	Negligible

[1/] Landforms are numbered as they change laterally away from the channel.
[2/] Enter the number of days the water table is above 6 ft depth.
[3/] Enter the beginning and ending month of elevated water table (above 6 ft depth).

Fluvial Surface/Landform 2 [1/]	Primary Floodplain Step	
	Minimum	**Maximum**
Water Table Depth (inches)	surface	72
Water Table Duration (days) [2/]	365	365
Water Table Frequency (months) [3/]	January	December
Flooding Frequency	Frequent	Frequent
Flooding Duration	Brief	Long
Ponding Depth (inches)	None	None
Ponding Frequency	None	None
Ponding Duration	None	None
Runoff Class	Negligible	Negligible

[1/] Landforms are numbered as they change laterally away from the channel.
[2/] Enter the number of days the water table is above 6 ft depth.
[3/] Enter the beginning and ending month of elevated water table (above 6 ft depth).

Fluvial Surface/Landform 3 [1/]	Secondary Floodplain Step	
	Minimum	**Maximum**
Water Table Depth (inches)	surface	>72
Water Table Duration (days) [2/]	0	270
Water Table Frequency (months) [3/]	March	November
Flooding Frequency	Frequent	Frequent
Flooding Duration	Brief	Brief
Ponding Depth (inches)	None	None
Ponding Frequency	None	None
Ponding Duration	None	None
Runoff Class	Negligible	Negligible

[1/] *Landforms are numbered as they change laterally away from the channel.*
[2/] *Enter the number of days the water table is above 6 ft depth.*
[3/] *Enter the beginning and ending month of elevated water table (above 6 ft depth).*

Fluvial Surface/Landform 4 [1/]	Low Terrace	
	Minimum	**Maximum**
Water Table Depth (inches)	surface	>72
Water Table Duration (days) [2/]	0	120
Water Table Frequency (months) [3/]	April	July
Flooding Frequency	Occasional	Occasional
Flooding Duration	Very brief	Brief
Ponding Depth (inches)	None	none
Ponding Frequency	None	none
Ponding Duration	None	none
Runoff Class	Very Low	Very Low

[1/] *Landforms are numbered as they change laterally away from the channel.*
[2/] *Enter the number of days the water table is above 6 ft depth.*
[3/] *Enter the beginning and ending month of elevated water table (above 6 ft depth).*

Fluvial Surface/Landform 5 1/	High Terrace	
	Minimum	**Maximum**
Water Table Depth (inches)	>72	---
Water Table Duration (days) 2/	0	0
Water Table Frequency (months) 3/	---	---
Flooding Frequency	Rare	Rare
Flooding Duration	Extremely Brief	Very Brief
Ponding Depth (inches)	None	None
Ponding Frequency	None	None
Ponding Duration	None	None
Runoff Class	Very Low	Low

1/ Landforms are numbered as they change laterally away from the channel.
2/ Enter the number of days the water table is above 6 ft depth.
3/ Enter the beginning and ending month of elevated water table (above 6 ft depth).

INFLUENCING WATER FEATURES

Narrative	This site is a lotic, fluvial system that includes the area influenced by the stream and its associated ground water on very low gradients (< 2%) that include adjacent floodplains and terraces. The stream occurs in alluvial valley fill and sediments supplied are sandy and clayey materials from adjacent badlands and prairie landscapes. The potential natural channel is the expression that has the best combinations of energy dissipation, sediment transfer, floodplain development and the associated high quality values associated with the system. It is rarely found in this site due to past disturbances and the extreme level of entrenchment and widening of the stream system.

Level II Rosgen Stream Type Classification

Valley Type(s)	Valley Type VIII: Wide, gentle valley slope with well-developed floodplain adjacent to river terraces. Valley Type VIII is most readily identified by the presence of multiple river terraces positioned laterally along broad valleys with gentle, down-valley elevation relief. Alluvial terraces and floodplains are the predominant depositional landforms which produce a high sediment supply. Soils are developed predominantly over alluvium originating from combined riverine and lacustrine depositional processes. Stream types "C" or "E," which have slightly entrenched, meandering channels that develop a riffle/pool bed-form, are normally seen in the Type VIII valley. However, "F," and "G" stream types can also be found, depending on local stream and riparian conditions.
Reference Stream Type	The C5 stream types are systems with moderate to high sinuosities, gentle to moderately steep channel gradients, and moderate to high channel width/depth ratios. The C5 stream type is a riffle/pool stream found in valleys with well-developed floodplains. The C5 stream channels within this site are found in valley type VIII.
Channel Material(s)	Sand dominated bed with smaller accumulations of gravel and occasional silt/clay. Streambanks comprised of sandy/silt/clay mixture with dense root mat.
Stream Succession Scenario[1/]	C5→Gc5 →F5 →Bc →C5
Channel Evolution Stage[1/]	I → II → III → IV → V

Delineative Criteria	Low	High
Entrenchment Ratio (floodprone width / bankfull width)[2/]	2.2	200
Width/Depth Ratio (bankfull width / bankfull depth at riffle)[2/]	10	60
Sinuosity (stream length / valley length) [2/]	1.1	1.6
Slope Range[2/]	0.004	0.02
Channel Materials D_{50} (particle size index, mm)	0.07	0.56
Channel Materials D_{84} (particle size index, mm)	0.45	2.4

Information from Rosgen, 1996 and modified as needed for site description. Delineative criteria are for the stream type and may represent a larger range of values than exists for the reference channel.

[1/] Describe succession of channel types and their associated channel evolution stage (I – V)

[2/] Expressed as ft/ft.

REPRESENTATIVE SOIL FEATURES

Narrative	The soils in MLRA 58C of the Little Missouri River floodplain are deposits of several different geological formations. In the southern part the deposits are from Upper Cretaceous sediments of the Hell Creek and Fox Hills formations. In the central part the deposits are from a mixture of the Paleocene Epoch sediments in the Fort Union Group (Ludlow, Slope, Bullion Creek, Sentinel Butte Formations). In the northeastern part of the MLRA the river has been modified by past glaciation. The modified pattern of the river has caused extensive down cutting through glacial drift and sedimentary bedrock of the Sentinel Butte and Bullion Creek Formations (Bluemle 2000). This change in the river pattern has also caused extensive erosion throughout MLRA 58C. During periods of snow melt and heavy rains the exposed sediments of the badland areas are easily eroded . The sediments are all concentrated into the tributaries and the Little Missouri River, which cause a heavy sediment load during these periods that have influenced the development of soils on the floodplain. When the sediments keep burying the surface layer, the soil development process needs to start over. These soils are classified as Entisols soil order, which describes the beginning processes of soil development. The soils of the flood plain have also been influenced from the sediments of the geological formations listed above., and other geological sediments that are further south of MLRA 58C. Typically the sediments and soils of the river system consist of a mixture of sediments (sands, silts, clays, and gravels) due to the flow events of the river. There is no soil development on the edge of the river channel (floodplain) due to constant re-working of the sediments, time has not allowed soil development; this zone is considered a miscellaneous land type called “Riverwash”. As you increase in elevation from the channel edge, the soils on the primary and secondary steps are Typic or Aeric Fluvaqents and typically the particle size family class is Sandy, Coarse-Loamy or Loamy. There are stratified thin layers of sediments that range from sand to clay loams throughout the soil profile. The soils are frequently flooded, and the water table will fluctuate with the depth of water in the river channel. The soils on the low terraces are Oxyaquic Ustifluvents and the particle size family class is Sandy. The parent material does have stratified thin layers of sediments that range from sands to loams. These soils are occasionally flooded, and the water table will also fluctuate with the depth of water in the river channel. The soils of the high terraces are Ardic Ustifluvents, and the particle size family class is Coarse-Loamy or Loamy. These soils are rarely flooded and do not have a water table, it is noted that faint relic mottles are present in the soil profile, indicating that water had a role in the soil development. The soils on the high terraces have been on a stable landform for many years and are developing mollic colors in the surface layer.

Fluvial Surface/Landform 1	Floodplain
Soil Features Narrative	This component of the floodplain is a Miscellaneous Area called "Riverwash". Areas of Riverwash consist of Sand, Silt, Clay, and Gravel which are unstable due to the frequency of flooding that continually re-works the sediment.
Parent Materials - Kind	Alluvium
Bedrock - Kind	
Typical Surface Texture (<2mm)	Sand
Surface Texture Modifier	Extremely Gravelly

	Minimum	**Maximum**
Surface Fragments ≤10" (% cover)	25	90
% Coarse Fragments >2mm (% volume in 10–20" layer)	10	90
Drainage Class	Very poorly drained	Poorly drained
Saturated Hydraulic Conductivity Class	1.417 in/hr	100.00 in/hr
Depth to Bedrock (inches)	Variable	Variable
Depth to Redoximorphic Features (inches)	0	0
Depth of Fine Roots (1-2mm)	None	None
Electrical Conductivity (mmhos/cm)	0	4
Sodium Adsorption Ratio within 16" Depth	0	0
Calcium Carbonate Equivalent within Surface 10"	0	0
Soil Reaction within Surface 4 Inches	6.1	7.8
Available Water Capacity (inches)	.03	.04

Fluvial Surface/Landform 2	Primary Floodplain Step
Soil Features Narrative	This soil component is a coarse-loamy, mixed, superactive, calcareous, frigid Aeric Fluvaquent. There is no named soil series for this component in this MLRA. The soils on this landform have minimal development (AC and C horizons) due to flooding frequency. A water table will fluctuate with the water depth of the river throughout the year. Recent sediment deposition from 2011 spring flooding and buried horizons was noted during the field investigation. Sand and gravel deposits occurred at 140 cm. at the site.
Parent Materials - Kind	Alluvium
Bedrock - Kind	
Typical Surface Texture (<2mm)	Sandy Loam to Sand
Surface Texture Modifier	Fine to Very Gravelly

	Minimum	**Maximum**
Surface Fragments ≤10" (% cover)	none	60
% Coarse Fragments >2mm (% volume in 10–20" layer)	none	60
Drainage Class	Poorly drained	Somewhat poorly drained
Saturated Hydraulic Conductivity Class	1.417 in/hr	100.00 in/hr
Depth to Bedrock (inches)	>60	-
Depth to Redoximorphic Features (inches)	0	1
Depth of Fine Roots (1-2mm)	0	3
Electrical Conductivity (mmhos/cm)	0	4
Sodium Adsorption Ratio within 16" Depth	0	0
Calcium Carbonate Equivalent within Surface 10"	0	25
Soil Reaction within Surface 4 Inches	6.6	8.4
Available Water Capacity (inches)	.03	.19

Fluvial Surface/Landform 3	Secondary Floodplain Step
Soil Features Narrative	The soil component on this landform is similar to the Primary step soil. It classifies as a fine-loamy, mixed, superactive, calcareous, frigid Aeric Fluvaquent at the site investigated. There is no named soil series for this component in this MLRA. The soils on this landform have minimal development (A and C horizons) due to flooding frequency. A water table will fluctuate with the water depth of the river throughout the year. Recent sediment deposition from 2011 spring flooding and buried horizons were noted during the field investigation. Sand and gravel deposits occurred at 120 cm. at the site.
Parent Materials - Kind	Alluvium
Bedrock - Kind	
Typical Surface Texture (<2mm)	Sandy Loam or Loamy Sand
Surface Texture Modifier	Fine

	Minimum	**Maximum**
Surface Fragments ≤10" (% cover)	10	70
% Coarse Fragments >2mm (% volume in 10–20" layer)	none	40
Drainage Class	Poorly drained	Somewhat Poorly drained
Saturated Hydraulic Conductivity Class	1.417 in/hr.	100.00 in/hr.
Depth to Bedrock (inches)	>60	-
Depth to Redoximorphic Features (inches)	0	1
Depth of Fine Roots (1-2mm)	0	9
Electrical Conductivity (mmhos/cm)	0	4
Sodium Adsorption Ratio within 16" Depth	0	0
Calcium Carbonate Equivalent within Surface 10"	0	25
Soil Reaction within Surface 4 Inches	6.6	8.4
Available Water Capacity (inches)	.05	.17

Fluvial Surface/Landform 4	Low Terrace
Soil Features Narrative	The soil component on this landform is similar to Hanly series. Hanly is a sandy floodplain soil with a varying range of surface and subsurface textures, but is in the Sandy family class. The range of the surface textures are listed below. The soil observed in the field would be saturated during flooding events and has a fluctuating water table that is associated with the depth of the river water throughout the year. This soil classified as a Sandy, mixed, frigid Aquic Ustifluvents. Sediment deposition from the spring flood of 2011 ranged from ½ to 2 inches was noted during the field investigation on this landform. Buried horizons and stratified layers of loams to sands were noted in the subsurface during the field investigation. Drainage class; due to the water table it is moderately well to somewhat poorly drained, if no water table existed it would be the Hanly soil series which is somewhat excessive to excessively drained.
Parent Materials - Kind	Alluvium
Bedrock - Kind	
Typical Surface Texture (<2mm)	Sandy Loam or Loamy Sand
Surface Texture Modifier	Fine

	Minimum	**Maximum**
Surface Fragments ≤10” (% cover)	0	1
% Coarse Fragments >2mm (% volume in 10–20” layer)	0	10
Drainage Class	Somewhat Poorly drained	Moderately Well drained
Saturated Hydraulic Conductivity Class	1.417 in/hr	100.00 in/hr
Depth to Bedrock (inches)	>60	-
Depth to Redoximorphic Features (inches)	2	12
Depth of Fine Roots (1-2mm)	0	24
Electrical Conductivity (mmhos/cm)	0	0
Sodium Adsorption Ratio within 16” Depth	0	0
Calcium Carbonate Equivalent within Surface 10”	0	15

	Minimum	Maximum
Soil Reaction within Surface 4 Inches	6.6	8.4
Available Water Capacity (inches)	.05	.14

Fluvial Surface/Landform 5	High Terrace
Soil Features Narrative	The soil component on this landform is Glendive. Glendive is a coarse-loamy floodplain soil with a varying range of surface and subsurface textures. The most common surface textures are listed below. One of the sites described during the soils investigation had an organic duff layer (Oe horizon) from the woodlands that were present. Surface textures on the investigated sites ranged from loam to very fine sandy loam. No sediment deposition was noted on this landform. There was a thin layer of sediment deposited in the lower areas of this landform, from the spring flood of 2011. Hanly soils do occur as inclusions on this landform. Relic mottles occurred at 45 inches, which indicate that water has influenced the development of the soil.
Parent Materials - Kind	Alluvium
Bedrock - Kind	
Typical Surface Texture (<2mm)	Sandy Loam, Loamy Sand, or Loam
Surface Texture Modifier	Fine

	Minimum	Maximum
Surface Fragments ≤10” (% cover)	0	0
% Coarse Fragments >2mm (% volume in 10–20” layer)	0	15
Drainage Class	Well drained	Somewhat Excessive drained
Saturated Hydraulic Conductivity Class	1.417 in/hr	14.17 in/hr
Depth to Bedrock (inches)	>60	-
Depth to Redoximorphic Features (inches)	relict mottles at 45	>60
Depth of Fine Roots (1-2mm)	0	36 inches
Electrical Conductivity (mmhos/cm)	0	0

COMMUNITY PHASE INFORMATION

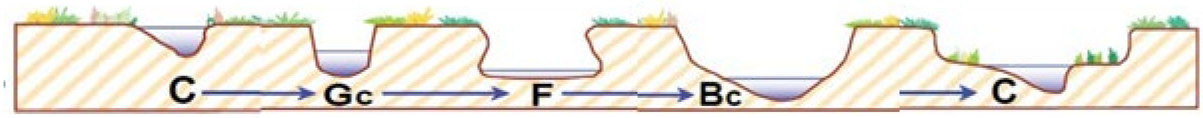
Fluvial Geomorphology, Channel Evolution, and Stream Type Succession of the Site

The site has a potential C5 channel type in an alluvial valley with a broad floodplain, floodplain step, and low terrace fluvial surfaces. The site has a succession scenario (channel evolution) of C5 > Gc5 > F5 > Bc > C5 (similar to Rosgen scenario #9 with the addition of a Bc channel type in the stable analogue state).

The state-and-transition model includes these channel types as phases and depicts the characteristics of potential stream types (C5 in alluvial valleys). The phases are arranged in the order of channel evolution and are grouped by their inherent stability. State 1 is the potential natural channel and has the best expression of vegetative communities, stability, habitat, and resilience. State 2 is the most unstable and apt to change quickly. The Gc channel phase depicted may not always be present in the evolution of the channel when bed materials prevent vertical stability, or with looser materials, it will exist only for a short period before widening into the more characteristic F channel. State 3 phases are considered stable analogues; they have inherent stability, although with a more limited ability to form floodplains and terraces due to the entrenchment of the stream. There is a natural progression from the B5c to the C5 channel. Proper management of the uplands is critical to this progression.

Transition 1A occurs in response to severe flooding combined with disturbance to the riparian vegetation that reduce resistance and resilience, allowing the channel to widen and/or deepen resulting in the loss of beneficial and stabilizing banks vegetation (PCC1 is usually completely gone after this transition). Transition 2A occurs when management and conditions facilitate the development of floodplains, raising of the water table, and return of beneficial bank vegetation. The channel bottom changes from flat to parabolic and the entire stream is more capable of transporting water, sediments, and nutrients and is more capable of dispersing energy from high flows. There is also a significant increase in water storage in the adjacent soils.

The end point of channel evolution is the entrenched C5 channel with floodplains, floodplain step, and low terrace with appropriate plant community components. The phase has high stability (if bank vegetation is maintained) and is in balance with energy, water, and sediment supplied by the catchment. Transition 3A is similar to 1A where the stable analogue is destabilized as a result of disturbance and at risk of channel scour during high flow events; resulting in a further entrenched version of the phases in state 2. Removal of disturbances and reestablishment of beneficial vegetation will facilitate the transition back to state 3 and the development of stable channels through the community pathways.



Ecological Dynamics of the Site

The site occurs on low gradient, alluvial valleys, with sandy channel materials on the Little Missouri River and other perennial reaches of streams within MLRA 58C. The potential (or reference) reach consists of a C5 channel with a broad relatively flat floodplain that has a low terrace that supports a riparian forest component. The potential channel is slightly entrenched (entrenchment ratio 4-10, considerably more floodplain than stream bankfull width), has a wide and shallow channel (width/depth ratio >12), moderate to high sinuosity. Channel materials are predominately sands with a small amount of gravels.

The entire system has experienced historic and anthropogenic disturbances (drought, flood, fire, overgrazing, crop production, and energy development). These disturbances resulted in the system becoming entrenched, thus true reference areas cannot be located. The best examples of what this site used to be are found in the stable analogues of C5 channels that are moderately confined, but adequately express the plant community components.

Plant Communities and Fluvial Surfaces:

The site exhibits 3-5 plant community components. There is no significant instream plant community associated with these streams. The first plant community is a herbaceous community associated with the floodplain. The floodplain step, low terraces, and high terraces support plant communities comprised of trees, shrubs, and herbaceous plants.

PCC1: The greenline plant community, which occurs at the water's edge (PCC1) is a graminoid-shrub dominated community that is characterized by common threesquare (Schoenoplectus pungens), and dwarf spikerush (Eleocharis parvula) with an overstory of sandbar willow (Salix interior). The greenline community generally occurs within the bankfull elevation (or slightly higher) and is maintained by seasonal flows and a local water table. Considerable scouring occurs in this portion of the floodplain on an annual basis so the plants in this community are adapted to this frequent disturbance and function to protect and stabilize banks. Sandbar willow and common threesquare have deep roots that bind bank materials and maintain bank stability in most high flow events.

This plant community is subject to damage by natural forces that include extreme flooding and ice jams. In addition to the natural forces, these communities are often compromised by anthropogenic actions including channel modification (bridges, fords, crossings, straightening, etc.), overgrazing, crop production, and energy development. Disturbance can result in the plant community being replaced by shallow rooted upland species that are not capable of protecting and stabilizing banks; resulting in the formation of tensile cracks, bank sloughing, accelerated lateral and vertical movement (unstable state). In the unstable channel phases PCC1 has been lost and the stream is subject to extreme bank and bed erosion.

PCC2: The next plant community component (moving away from the channel) occurs on a floodplain step and consists of shrub dominated community that is characterized by sandbar willow. Recruitment of woody species is common in this community and regeneration (seedlings) of eastern cottonwood (Populus deltoids) and willow species is common. The understory of this willow dominated community is characterized by prairie cordgrass (Spartina pectinata), Canada wildrye (Elymus canadensis), and American licorice (Glycyrrhiza lepidota). This community is subject to scouring in high flow events and sediment deposition. The plant species in this community have adaptations to withstand high flow events that dissipate energy and trap sediments.

This plant community is also susceptible to flooding, ice jams, channel modification (bridges, fords, crossings, straightening, ect.), overgrazing, crop production, and energy development. Similarly, disturbance can result in the plant community being replaced by shallow rooted upland species. The loss of PCC2 leaves the floodplain step vulnerable to scouring and avulsion because the new plant community has a diminished capacity to dissipate energy and trap sediments during high flow events. In unstable channels phases (2.1 and 2.2) PCC2 is either severely reduced in size or eliminated.

PCC3: Wider portions of the valley bottom allow for the formation of a secondary floodplain step that support young cottonwood and patches of silver buffalo berry (Shepherdia argentea) with a graminoid component characterized by prairie sandreed (Calamovilfa longifolia) and western wheatgrass (Pascopyrum smithii). This component is not continuous and tends to occur in patches and stringers along portions of the stream where the valley is not as constrained and disturbances have not removed woody species (woody species can be sheared off during ice jams and are subject to grazing by livestock and wildlife resulting in them being lost over time). This community is subject to high flow events; however, it is not subject to annual events.

PCC4: Low terraces that support mature stands of cottonwood are common throughout the valley. Similar to PCC3 the understory of this community is characterized by prairie sandreed and western wheatgrass. This plant community is subject to flooding, but only during 20 year events.

PCC5: This component is actually PCC4 that is no longer connected to the stream as a result of massive erosion and the subsequent entrenchment of the stream. These high terraces occur where there has been significant entrenchment of the stream channel. The majority of this entrenchment happened within the last 100 years. On many high terraces there are old cottonwoods, a remnant from when the community was still part of the active floodplain. This community is now dominated by silver sagebrush (Artemisia cana) and western wheatgrass and has been described as a Loamy Terrace ecological site, or dominated by silver sagebrush and prairie sandreed and has been described as a Sandy Terrace ecological site. It may be incorporated into the riparian complex or left as an associated site that was formerly part of the riparian complex.

These disconnected components now have their own states, phases, and transitions and function an independent ecological site. In time the old cottonwoods will die and only the remaining alluvial soils will testify to the former floodplain attributes.

Disturbances: The site has endured many disturbances that have altered the form and function of the stream. Historic records do not describe local conditions well but there is evidence that years of drought followed by above-average rainfall caused extreme entrenchment of the stream channel: in many cases the former nature of the gradually sloping, highly sinuous C type stream was replaced by deep, actively eroding gullies that widened and flattened over time. Several reaches of this site exhibit the almost gorge-like aspect of wide and deep channels. In some places, rehabilitation of the stream has rebuilt floodplains and low terraces that support cottonwoods within the wider gorges.

The absence of fire from the adjacent ecosystem has also altered the natural fire frequency. The riparian areas probably burned less often than the surrounding uplands but fire was undoubtedly a factor in creating and maintaining the plant communities.

Decades of improper livestock grazing have denuded streambanks and led to the entrenchment of several reaches and the total replacement of critical riparian species within the floodplain that are necessary for maintaining the integrity of the banks, trapping sediments, and reducing the energy of high flows. Overgrazing or long term exclusion of grazing tends to facilitate the invasion of Kentucky bluegrass, a shallow rooted upland species, resulting in decreased bank stality and increased erosion and runoff.

Recently, oil and gas drilling and development have had a major impact on many of these watersheds that include this ecological site. Hard stream crossings and the increase in miles of road have affected channels and sediment supplies. There is also the potential of discharges from the well pads that could adversely affect water quality as well as aquatic and terrestrial wildlife.

Hydrologic Modifications: Most of the direct hydrologic alteration has come from roads, livestock grazing and oil and gas development. There are some reaches that have been disturbed by channel straightening, bridge, and concrete crossing construction. There are very few instances of irrigation water withdrawals in the lower portions of the watersheds. Changes to the upland vegetation have probably disrupted the hydrology of the watersheds: invasions of smooth brome, Kentucky bluegrass, and crested wheatgrass on rangelands and increased woody cover due to lack of fire are likely causes. The effects of climate change are unknown but should be monitored in the future.

Invasive Species: PCC1 is not prone to a domination by invasive species. However, invasive species were observed in the remaining plant community components. Invasive species observed within this site include: leafy spurge (Euphorbia esula), quackgrass (Elymus repens), smooth brome (Bromus inermis), Kentucky bluegrass (Poa pratensis), and spotted knapweed (Centaurea stoebe).

Water Quality: The waters associated with this site should have superior water quality and moderate sediment loads. Sediment loads are naturally high due to the erodibility of the surrounding badlands landscapes. At times when sediments enter the system from breached beaver dams or from background bank erosion they will be occluded but should clear up rapidly if the downstream beaver dams are in place where they can trap the sediments. Where agriculture is present runoff can add contaminants to the stream, increases nutrient loads, pesticide residues, and fertilizers. Animal waste can be a problem where animals are allowed unrestricted access to the stream. Besides wastes entering the waters, livestock can break down banks (especially where the stabilizing bank vegetation has been removed) and cause excess erosion and increased sediment loads. Another concern to water quality within the watershed are disturbances induced by energy development such as increased traffic on bridges and crossing causing increased sediment loads and the potential hazards associated with a spill.

The primary beneficial uses identified in the State's water quality standards are aquatic life and recreation. Protection for aquatic life means surface waters should be suitable for the propagation and support of fish and other aquatic biota, including aquatic macroinvertebrates, and that contaminants will not adversely affect wildlife in the area. Protection of surface waters for recreation means waters should be suitable for direct body contact activities such as bathing and swimming and for secondary contact activities such as boating, fishing, and wading. Other beneficial uses identified in the State's water quality standards are municipal and domestic water (e.g., water suitable for drinking after appropriate treatment), agriculture (e.g., stock watering and irrigation), and industrial (e.g., washing and cooling). These uses apply to all classified rivers, streams, lakes, and reservoirs.

Based on the 2012 Section 303(d) List of Impaired Waters Needing Total Maximum Daily Loads (TMDLs), the North Dakota Department of Health (NDDoH) has identified a 124 mile segment of the Little Missouri River from its confluence with Little Beaver Creek downstream to its confluence with Andrew's Creek as impaired for recreational uses due to excessive bacteria concentrations and an 83 mile segment of the Little Missouri River from its confluence with Beaver Creek downstream to its confluence with Cherry Creek as impaired for recreational uses due to excessive E. coli bacteria concentrations. The primary sources of the bacteria contamination are run off from unconfined animal feeding operations and from livestock grazing in riparian areas. Other stressors negatively affecting the water quality of the Little Missouri River are riparian habitat degradation and siltation.

Plant Communities and Transitional Pathways (Narrative)

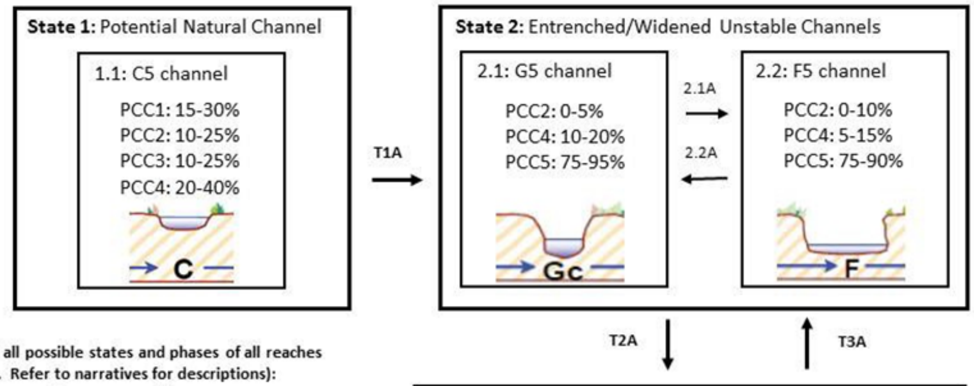
A state-and-transition Model (STM) for the Northern Rolling Plains, Northeastern Part Riparian Complex C5 ecological site (058CY001ND) is depicted below. Thorough descriptions of each state, transition, plant community, and pathway follow the model. This model is based on available experimental research, field observations, and interpretations by experts. It is likely to change as knowledge increases.

The plant communities will differ across the MLRA due to the naturally occurring variability in the extent of fluvial surfaces, soils, and influence of surface water and ground water in the hyporheic zone. The biological processes on this site are complex; therefore, representative values are presented in a land management context. The species lists are representative and are not botanical descriptions of all species occurring, or potentially occurring, on this site. They are not intended to cover every situation or the full range of conditions, species, and responses for the site.

Both percent species composition by weight and percent canopy or foliar cover are used in this ESD. Most observers find it easier to visualize or estimate percent canopy for woody species (trees and shrubs). Species composition by dry weight remains an important descriptor of the herbaceous community and of the community as a whole. Woody species are included in species composition for the site.

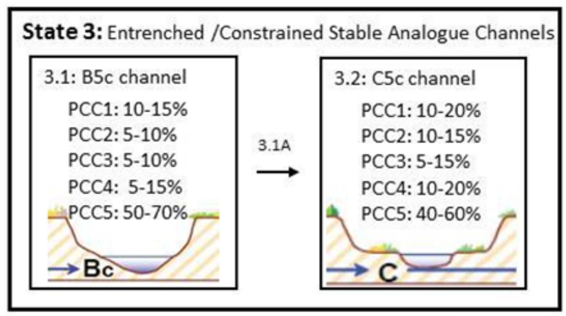
This STM includes only native communities and states. The converted communities are described in the Ecological Dynamics section above.

Northern Rolling High Plains, Northeastern Part, Perennial Riparian Complex (C5 Stream Type)



Notes (not all possible states and phases of all reaches are shown. Refer to narratives for descriptions):

- Phase 1.1 is rarely encountered due to past entrenchment of the entire system.
- Phase 2.1 is occasionally observed: 2.2 begins to form immediately due to instability of bed & bank materials.
- Reaches in states 2 & 3 can have invasive and introduced species within the plant community components.
- PCC5 is the early 20th century floodplain (now high terrace that is disconnected due to entrenchment.



I.D.	Plant Association	Fluvial Surface/Landform
1	Sandbar willow/Common threesquare	Floodplain
2	Sandbar willow/ Prairie cordgrass	Primary Floodplain Step
3	Plains cottonwood/Silver buffaloberry	Secondary Floodplain Step
4	Plains cottonwood/Western wheatgrass	Low Terrace
5	Silver sagebrush/Western wheatgrass or Silver sagebrush/ Prairie Sandreed	High Terrace

Draft 2: 11/2014

STATE 1 SECTION

State Number	1
State Name	Potential Natural Channel
State Narrative	This state includes the phase and plant community components believed to be the potential natural channel and incorporates the natural channel for the gradient and valley fill materials (C5) and fluvial surfaces that are freshened intermittently in order to produce the characteristic types of vegetation. This state is rarely found in this site due to past disturbances and the extreme level of entrenchment and widening of the stream system. This stream type is suited to handle the energy, water, and sediments supplied by the watershed and promote the plant community components that provide stability to the system. If undisturbed, this phase can supply the highest benefits and services from the riparian complex including, but not limited to: diverse, resilient plant community components that can withstand high flow events, significant fish and wildlife habitat, resistance to invasion by introduced species, highest potential water quality and quantity, and ground water recharge and release. The natural disturbance regime within this state would have included grazing by native ungulates, frequent drought for variable lengths of time, infrequent fires usually associated with periods drought. Due to the fire tolerant nature of the plant species occupying these sites, these events served to replace old growth with new, vigorous sprouts and remove non-sprouting species (e.g. Rocky Mountain juniper - which may have been introduced to the site from neighboring upland ecological sites). Fire frequency would have been less on these sites as compared to the adjoining upland ecological sites due to increased fuel moisture associated with the greener vegetation; grazing by native herbivores which would have been attracted to these areas by the greener vegetation and reliable water supply, especially during periods of below normal precipitation or late summer months when upland vegetation is less palatable.

Photo 1.—Characteristic C5 channel type for the site. Due to decades of disturbances to this system, the best references were found in state 3, phase 3.2.

Photo 2.—Sandbar willows occupy the floodplain steps that receive water and sediments from bankfull events.

Photo 3.—Bankfull events create favorable conditions for cottonwood establishment on the floodplain steps (PCC2 and PCC3).

Photo 4.—Young cottonwoods on the secondary floodplain step.

Photo 5.—Buffoloberry resprouting after being sheared off during a spring flood event (PCC3).

Photo 6.— Cottonwood gallery of the low terrace (PCC4). The wide valleys of this site support the formation of low

Photo 7.—Beaver activity helps development of favorable.

State 1 Community Phases

Community Phase Number	1.1
Community Phase Name	C5 Potential Natural Channel
Community Phase Narrative	This channel and its associated fluvial surfaces and plant community components represent the highest expression of functioning and ecological services of the site. The stream meanders through sediment eroded from the adjacent badlands creating fresh fluvial surfaces (at a fine scale) for vegetation development. Streambanks have high percentages of stabilizing vegetation and channels are relatively deep with continuous flow connecting to downstream sites. Habitat for amphibians and fish is very good. There are generally four major fluvial surfaces with distinct plant community components (PCC1, PCC2, PCC3, and PCC4) on each. Floodplains have willows and herbaceous, stabilizing vegetation and are mostly under the bankfull area. Floodplain steps (generally between bankfull and floodprone elevations) are dominated by willows (PCC2), cottonwoods (PCC3), and some grasses and forbs. Above the flood prone area are wide, relatively flat terraces with riparian forest and grasses.

Plant Community Components

PCC	Plant Association	Fluvial Surface/Landform[1/]	Composition (%)
1	Sandbar willow/Common threesquare	Floodplain	15-30
2	Sandbar willow/ Prairie cordgrass	Primary Floodplain Step	10-25
3	Eastern cottonwood/ Silver buffaloberry/ Prairie sandreed	Secondary Floodplain Step	10-25
4	Eastern cottonwood/ Western wheatgrass	Low Terrace	20-40

[1/] Corresponds to fluvial surfaces/landforms in the Physiographic Features and Representative Soil Features sections.

T1A Transition to Entrenched/Widened Unstable Channels State (State 2) from Reference State (State 1)

Entrenchment of C channel due to loss of riparian vegetation (obligate and facultative wet plant functional groups), increased bank erosion, and down cutting. This transition is often associated with an extended period of drought followed by a high flow event. This transition may be initiated by drought and/or improper grazing, resulting in the loss of riparian vegetation.

STATE 2 SECTION

State Number	2
State Name	Entrenched and/or Widened, Unstable Channels
State Narrative	This state represents a set of degraded channels (G5c – F5) that have crossed a threshold by becoming vertically and laterally unstable resulting in moderately deep entrenchment and loss of floodplain and floodplain step connectivity and vegetation. There are unfavorable changes to these plant community components from depression of the local water table, influencing plant vigor, competition, and composition. This may also provide an advantage to invasive plant species to invade the stressed site. They are difficult, if not impossible to restore without changing profile, pattern, and dimension of the stream.

2.1 A Community Phase Change 2.2

Lateral movement with significant bank erosion, increased sediment load and increase in width/depth ratio. This pathway happens almost immediately; the G5 channel cannot resist widening due to sandy bank materials.

2.2 A Community Phase Change to 2.1

Increased vertical instability and entrenchment from further loss of vegetation (similar to T1A). This may be caused by disturbances that remove stabilizing vegetation, natural flooding, ice or beaver dam failure. Significant increase in bank erosion although some stabilizing vegetation may increase.

Photo 1.—Aerial view of F5 channel, phase 2.2, showing the arrangement of community components.

Photo 2.—F5 channel has flat bottom and near vertical sides: these channels are actively eroding.

Photo 3.—The lack of bank stabilizing vegetation results in bank failures causing stable channels to transition into state 2.

Photo 4.—The entrenchment of the stream that occurs in state 2 results in the formation of a high terrace that is disconnected from the channel.

State 2 Community Phases

Community Phase Number	2.1
Community Phase Name	G5 Channel (active entrenchment)
Community Phase Narrative	This channel phase is the result of loss of floodplain connectivity and vegetation (PCC1 and PCC3 and possibly PCC2) resulting in rapid vertical instability and deep entrenchment. Due to the loose, sandy bed and bank materials, this phase is transitory. The forces which cause the entrenchment to continue to shape the channel into the next phase (F5) through bank sloughing and accelerated lateral movement.

Plant Community Components

PCC	Plant Association	Fluvial Surface/Landform[1/]	Composition (%)
2	Sandbar willow/ Prairie cordgrass	Primary Floodplain Step	0-5
4	Eastern cottonwood/ Western wheatgrass	Low Terrace	10-20
5	Silver sagebrush/ Western wheatgrass Silver sagebrush/ Praire sandreed	High Terrace (disconnected)	75-95

[1/] Corresponds to fluvial surfaces/landforms in the Physiographic Features and Representative Soil Features sections.

Community Phase Number	2.2
Community Phase Name	F5 Channel (Entrenched/ Widened)
Community Phase Narrative	This channel continues the lateral expansion of phase 2.1 resulting in an F5 channel. These channels are highly unstable and further disturbances can force these to quickly transform back into vertically unstable G5c channels. These channels are generally disconnected from the floodplain except for during extreme flooding events. As a result, PCC1 is non-existent and water tables in terraces are further lowered. Fish and wildlife habitat and water quality values are significantly lowered or absent. If carefully managed, these channels can begin to build new floodplains; allowing for increased sinuosity and the re-establish floodplain vegetative communities, both of which help dissipate energy.

Plant Community Components

PCC	Plant Association	Fluvial Surface/Landform[1/]	Composition (%)
2	Sandbar willow/ Prairie cordgrass	Primary Floodplain Step	0-10
4	Eastern cottonwood/ Western wheatgrass	Low Terrace	5-15
5	Silver sagebrush/ Western wheatgrass Silver sagebrush/ Praire sandreed	High Terrace (disconnected)	75-90

[1/] Corresponds to fluvial surfaces/landforms in the Physiographic Features and Representative Soil Features sections.

T2A Transition to Entrenched/Constrained Stable Analogue Channels State (State 3) from Entrenched/Widened Unstable Channels State (State 2)

Rehabilitation of entrenchment with stabilizing herbaceous vegetation (increased connectivity and/or formation of new flood plain and return to better energy and sediment balance). Multiple plant community components present on fluvial surfaces. May be significant decreases in bank height ratios (<1.2).

T3A Transition to Entrenched/Widened Unstable Channels State (State 2) from Entrenched/Constrained Stable Analogue Channels State (State 3)

Disturbance results in entrenchment of C channel due to loss of vegetation (obligate and facultative wet plant functional groups), increased bank erosion, and down cutting.

STATE 3 SECTION

State Number	3
State Name	Entrenched / Constrained Stable Analogue Channels
State Narrative	This state includes channels that, after experiencing vertical and lateral instability and entrenchment, develop new floodplains within the entrenchment. Floodplain plant community components return to the incipient floodplains and streams develop new connectivity. Channel forming processes at bankfull are better able to handle the energy, flow, and sediments. Channels begin as B5c channels and with careful management, are able to develop C5 morphology with associated (although truncated) floodplains and terraces. Water tables are elevated and expand laterally. There is increased connectivity of upstream and

	downstream habitats resulting in improved fish and wildlife habitat and enhanced water quality. Some streams that have had the riparian vegetation removed and/or significantly changed may not develop the native plant community components. Where invasive species now dominant the floodplain marginal bank stabilization will occur.

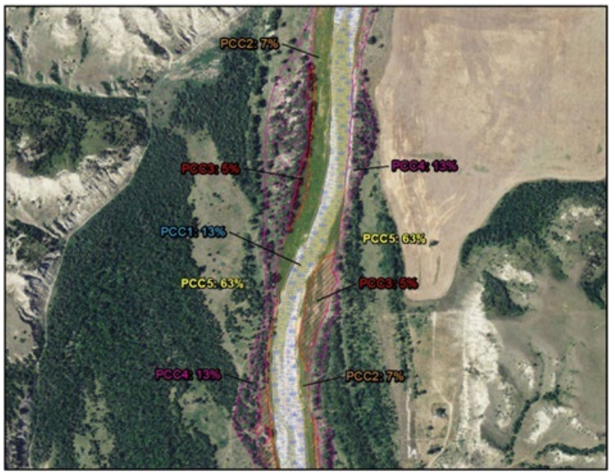


Photo 1.—Aerial view of B5c channel, phase 3.1, showing the arrangement of community components.

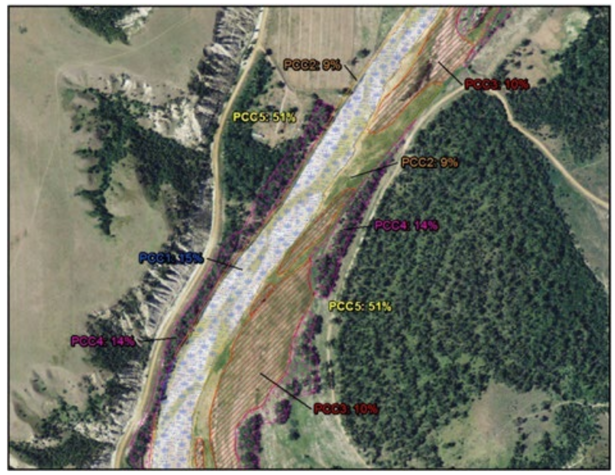


Photo 2.—Aerial view of C5 channel (phase 3.2), showing the arrangement of community components.

Photo 3.—B5c channel, phase 3.1, is the most prevalent stable analogue for the site.

Photo 4.—In phase 3.1 a new floodplain is established and PCC1 is reestablished.

3.1 A Community Phase Change to 3.5

The B5c channel will eventually (with proper management that increases bank stabilizing vegetation and normal flow variability) develop a small floodplain within the entrenched area, forming sand bars and slight cut banks. Increase of desirable greenline vegetation, sediment trapping, expansion of water table, and widening of flood plain (increased sinuosity, energy, and sediment transport balance). This pathway may require particularly long time periods to complete due to the stability of phase 3.1.

State 3 Community Phases

Community Phase Number	3.1
Community Phase Name	Entrenched / Constrained B5c (stable analogue)
community Phase Narrative	This phase represents the channel evolution from F5 to B5c resulting from a reduction in the near vertical, unstable banks associated with the F5 channel to somewhat more stable, parabolic shaped B5c channel. This phase represents the initial re-establishment of stream connectivity to its floodplain. Narrow floodplains are established where desirable bank stabilizing vegetation can grow. Local water tables are raised creating better conditions for terrace vegetation as well. The limited floodplain and associated stabilizing vegetation make this phase unstable “At-Risk” phase which can quickly transition to the F5 channel via transitional pathway T3A. Further rehabilitation of this phase may be limited by energy development, inappropriate livestock grazing, invasive species, or other disturbances (drought, large floods). If the native vegetation is not present or sources are not locally available, the phase is considered to be at-risk of crossing a threshold (T3A) to state 2.

Plant Community Components

PCC	Plant Association	Fluvial Surface/Landform[1/]	Composition (%)
1	Sandbar willow/Common threesquare	Floodplain	10-15
2	Sandbar willow/ Prairie cordgrass	Primary Floodplain Step	5-10
3	Eastern cottonwood/ Silver buffaloberry/ Prairie sandreed	Secondary Floodplain Step	5-10
4	Eastern cottonwood/ Western wheatgrass	Low Terrace	5-15
5	Silver sagebrush/ Western wheatgrass Silver sagebrush/ Praire sandreed	High Terrace (disconnected)	50-70

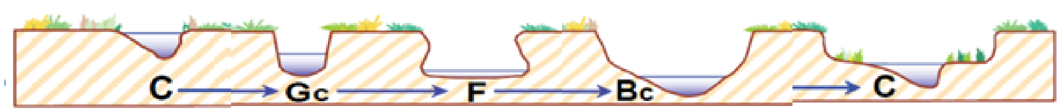
Community Phase Number	3.2
Community Phase Name	Entrenched / Constrained C5 (stable analogue)
Community Phase Narrative	This phase represents the best possible combination of attributes and values possible after the original C5 channel and floodplain have been altered by entrenchment and accelerated lateral movement. This phase represents the development of a new floodplain, through lateral movement that creates cut banks, and deposits new sand bars on the insides of bends. The original plant community components of the floodplain are rehabilitated, although constrained by the entrenchment, limiting their lateral extension. The local water table is able to rise and extend the groundwater influence laterally to the terraces. Incipient vegetation which does not have superior bank holding attributes makes can make this an "At-Risk" channel. This rehabilitated channel is probably not possible without careful management of livestock grazing, control of invasive species, and limiting water diversions. Disturbances that remove vegetation and affect bank stability (i.e. excessive trampling, fire, ice, energy development, and prolonged flood) can result in a transition to one of the phases in State 2.

Plant Community Components

PCC	Plant Association	Fluvial Surface/Landform[1/]	Composition (%)
1	Sandbar willow/Common threesquare	Floodplain	10-20
2	Sandbar willow/ Prairie cordgrass	Primary Floodplain Step	10-15
3	Eastern cottonwood/ Silver buffaloberry/ Prairie sandreed	Secondary Floodplain Step	5-15
4	Eastern cottonwood/ Western wheatgrass	Low Terrace	10-20
5	Silver sagebrush/ Western wheatgrass Silver sagebrush/ Praire sandreed	High Terrace (disconnected)	40-60

[1/] *Corresponds to fluvial surfaces/landforms in the Physiographic Features and Representative Soil Features sections.*

Community Phase Comparisons – Geomorphic Evaluation Criteria

Narrative	Little Missouri River (and other local perennial stream reaches) comparison of states and phases. C > G > F > Bc > C succession scenario (phases 1.1, 2.1, 2.2, 3.1, 3.2, and 3.3). Phase 1.1 is the reference.  The metric in the table below demonstrates the degree of departure from reference condition (Phase 1.1) for each phase and is designed to aid in the identification of threshold. *Generalizations were made for the metrics of phases 1.1 and 2.1 for stream type within MLRA 58C since these phases have not been observed in the field.

Phase	ER	Degree of Channel Incision (BHR)		W/D Ratio State (W/D / W/Dref)			Degree of Confinement (MWR / MWRref)			Bank Erosion Hazard Index (BEHI)	
		BHR	Rating	W/D	Ratio	Rating	MWR	Ratio	Rating	Score	Rating
1.1*	4	1.0	Stable	50	1.0	Stable	30.0	1.0	Un-confined	10	Low
2.1*	1.0	2.0	Deeply Incised	110	0.45	Highly Unstable	1.0	0.03	Severely Confined	48	Extreme
2.2	1.1	1.8	Deeply Incised	180	0.28	Highly Unstable	3.3	0.11	Confined	46	Extreme
3.1	2.1	1.3	Slightly Incised	70	1.4	Mod. Unstable	10.2	0.34	Mod. Confined	24	Moderate
3.2	3.5	1.1	Stable	55	1.1	Stable	25.0	0.83	Un-confined	10	Low

Enchanted Highway

The Enchanted Highway begins at Exit 72 on I-94 near Gladstone, North Dakota, and ends 32 miles south at the Enchanted Castle in the small town of Regent, North Dakota. Beginning with "Geese in Flight" at Exit 72 along I-94, large metal sculptures sit along the two-lane highway that passes through scenic farm country between Gladstone and Regent. Except for the "Geese in Flight" sculpture which is viewable from I-94, each sculpture has a parking area and an information kiosk, and several have picnic shelters.

The "Geese in Flight" sculpture is 110 ft tall and 154 ft wide and weighs more than 70 tons. It is recognized by the Guinness Book of World Records as the largest scrap metal sculpture in the world (photo courtesy of North Dakota Tourism).

Local artist Gary Greff envisioned the project as an attempt to attract tourists and rejuvenate the economy of his hometown of Regent, North Dakota. Inspired by local wildlife and historical figures, Greff began building the massive metal sculptures in 1989 out of scrap metal recycled from oil well tanks and well pipe. Greff has finished seven sculptures with two more currently in progress. Each sculpture takes roughly six years to complete and requires constant maintenance due to North Dakota's strong winds and harsh winters.

Constructed as a reminder of the risks of farming in the Northern Great Plains, the "Grasshoppers" sculpture symbolizes the devastation of wheat crops and homesteads by plagues of these insects in the early 1900s. This sculpture is made up of one 60 ft long grasshopper with several smaller grasshoppers in a wheat field (photo by Krista Bryan).

"Pheasants on the Prairie" includes a 40 ft tall rooster, a 35 ft tall hen, and three chicks to honor the game bird and its importance to the economy in southwest North Dakota (photo courtesy of North Dakota Tourism).

Wednesday, July 12th Materials

2023 NCSS Field Tour

Mine land reclaimed landscapes near Underwood, North Dakota

USDA-ARS Northern Great Plains Research Lab Campus in Mandan, North Dakota

Field Tour Schedule — Group 1

Wednesday July 12, 2023 **(CENTRAL TIME)**

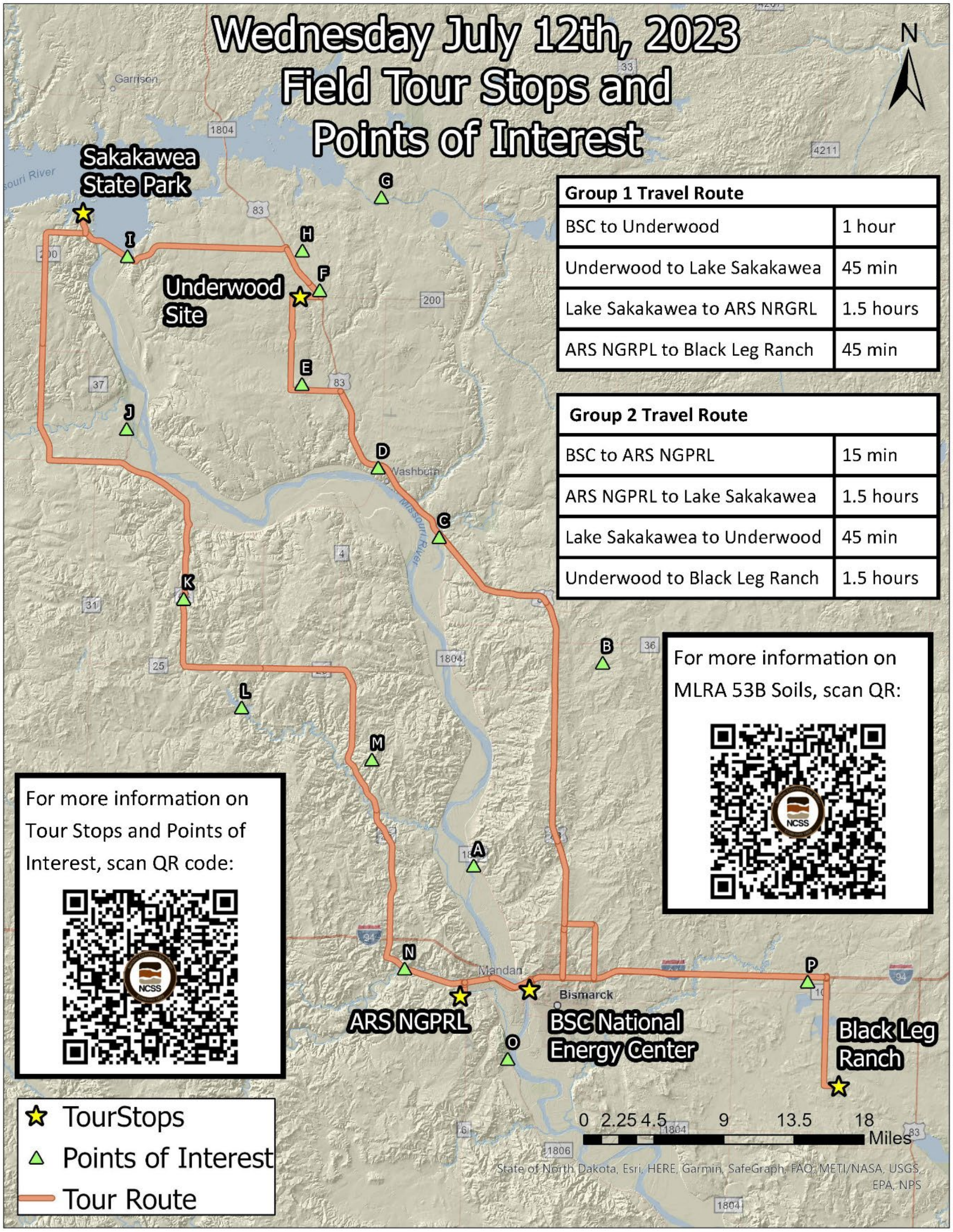
Time	Activity
6:45 a.m.	Load buses in the parking lot on the north side of the National Energy Center of Excellence (NECE) building
7:00 a.m.	Travel from Bismarck to the Underwood field site
8:00 a.m.	Arrive at Underwood field site and unload the buses
8:15 a.m.	Divide into 4 groups and rotate between 4 discussion sites concurrently: • Site A: Reclaimed Coal Mine Soil Pit • Site B: Unmined Soil Pit • Site C: Perspectives on Farming Reclaimed Mine Land • Site D: Reclamation Methods Groups will spend 20 minutes at each site and then rotate to the next with 10 minutes transition time. Water and snacks will be available.
10:15 a.m.	Load buses
10:30 a.m.	Travel to Lake Sakakawea State Park
11:15 a.m.	Unload buses
11:30 a.m.	Lunch at Lake Sakakawea State Park
12:15 p.m.	Load buses
12:30 p.m.	Travel to USDA ARS Northern Great Plains Research Laboratory **Bus 1 will travel to Site A; Bus 2 will travel to Site B.**
2:00 p.m.	Unload buses
2:15 p.m.	Divide into 2 groups and rotate between discussion sites concurrently: • Site A1: National Ecological Observatory Network (NEON) • Site A2: Multispecies Grazing and Burning (MSGAB) **Load and unload buses for transition between A and B sites.** • Site B1: I2 and I3 fields with soil pit and field instruments • Site B2: Eddy Flux and wind erosion towers Groups will spend 20 minutes at each site and then rotate to the next with 10 minutes transition time.
4:30 p.m.	Load buses
4:45 p.m.	Travel to Black Leg Ranch
5:30 p.m.	Unload buses
6:00 p.m.	NCSS Awards Banquet and Catered Supper
8:30 p.m.	Early bus departs for NECE
9:00 p.m.	Late bus departs for NECE

Field Tour Schedule — Group 2

Wednesday July 12, 2023 **(CENTRAL TIME)**

Time	Activity
6:45 a.m.	Load buses in the parking lot on the north side of the National Energy Center of Excellence (NECE) building
7:00 a.m.	Travel to USDA ARS Northern Great Plains Research Laboratory
7:15 a.m.	Unload buses
7:30 a.m.	Divide into 2 groups and rotate between discussion sites concurrently. • Site A1: National Ecological Observatory Network (NEON) to NEON Staff • Site A2: Multispecies Grazing and Burning (MSGAB) to ARS Staff **Load and unload buses for transition between A and B sites.** • Site B1: I2 and I3 fields with soil pit and field instruments • Site B2: Eddy Flux and wind erosion towers Groups will spend 20 minutes at each site and then rotate to the next with 10 minutes transition time.
9:45 a.m.	Load buses (snacks and refreshments available)
10:00 a.m.	Travel to Lake Sakakawea State Park
12:00 p.m.	Unload buses
12:15 p.m.	Lunch at Lake Sakakawea State Park
1:00 p.m.	Load buses
1:15 p.m.	Travel to the Underwood field site
2:30 p.m.	Arrive at Underwood field site and unload the buses
2:45 p.m.	Divide into 4 groups and rotate between 4 discussion sites concurrently: • Site A: Reclaimed Coal Mine Soil Pit • Site B: Unmined Soil Pit • Site C: Perspectives on Farming Reclaimed Mine Land • Site D: Reclamation Methods to Falkirk Mine Representative Groups will spend 20 minutes at each site and then rotate to the next with 10 minutes transition time
4:30 p.m.	Load buses
4:45 p.m.	Travel to Black Leg Ranch
5:45 p.m.	Unload buses
6:00 p.m.	NCSS Awards Banquet and Catered Supper
8:30 p.m.	Early bus departs for NECE
9:00 p.m.	Late bus departs for NECE

Field Tour Map

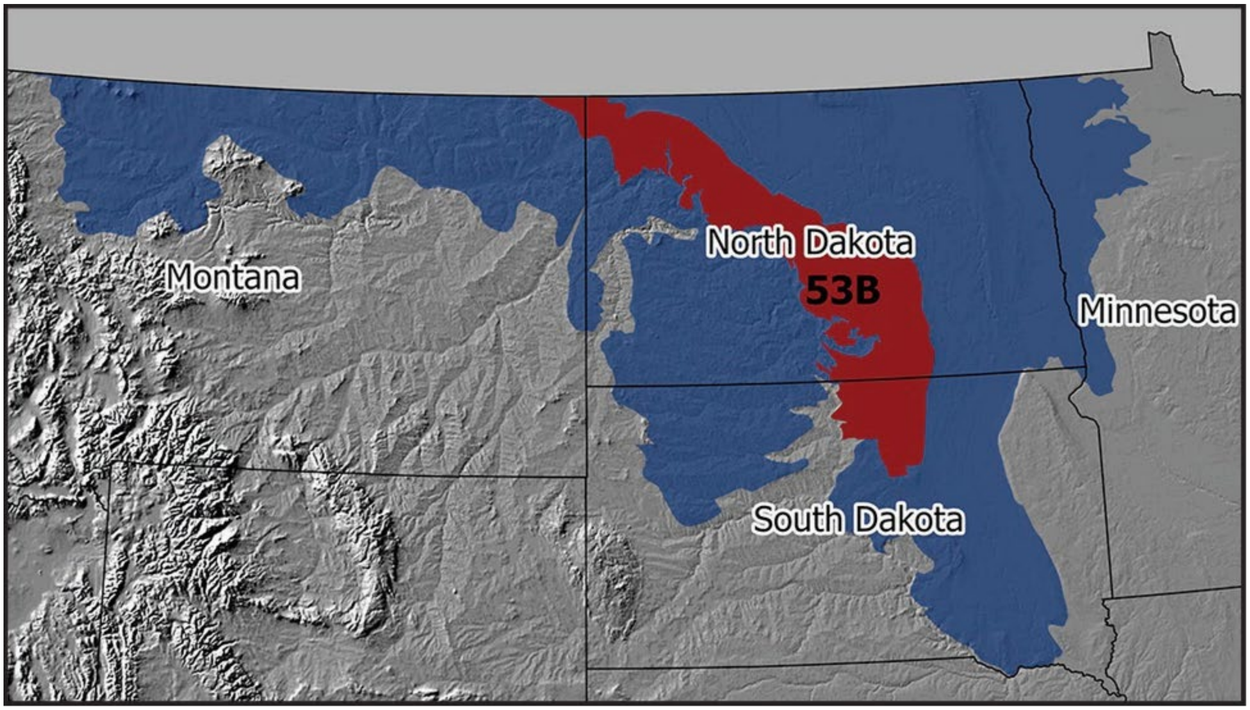


Wednesday Tour Points of Interest

A	Double Ditch Indian Village
B	Wilton Wind Farm
C	Painted Woods Creek
D	Lewis and Clark Interpretive Center
E	Rainbow Energy Coal Creek Station
F	Falkirk Open Pit Mine
G	McClusky Canal
H	Elevated Ice-walled lake plain
I	Garrison Dam and Lake Sakakawea
J	Knife River Indian Village
K	Scientific Center of North America
L	Nelson Lake
M	Glacial Deposits
N	Landslides
O	Fort Abraham Lincoln
P	Glacial Lake McKenzie

MLRA 53B Overview

53—Central Dark Brown Glaciated Plains



Source: USDA NRCS, Agriculture Handbook 296

MLRA 53B covers approximately 12,109,800 acres in parts of North Dakota, South Dakota, and Montana. This area marks the boundary of the western limits of glaciation in North Dakota and north-central South Dakota. Almost the entire MLRA is in the Missouri Coteau portion of the Missouri Plateau. The Missouri Coteau lies west of the Drift Prairie and is separated from the main portion of the Missouri Plateau to the west by the Missouri River. It is bordered by MLRAs 53B, 55A, and 55B; along this boundary, the moisture regime transitions from ustic to udic.

The characteristic pothole topography of the Missouri Coteau resulted from the collapse of glacial sediments that overlay a sheet of ice. The hummocky, undulating rolling hills of the Missouri Coteau dramatically rise 150 to 300 feet above the Drift Prairie. The near level to rolling till plains in this MLRA include kettle holes, kames, moraines, and small glacial lakes. This area has numerous closed-basin potholes with little integrated drainage. Numerous remnant and existing lacustrine sediments, typically occurring as stable and collapsed ice-walled lake plains are found in the MLRA. Glacial outwash deposits are along the margins of steep moraines leading to large glacial outwash plains. The glacial deposits of the western portion of the MLRA are generally from older glacial advances and are thinner, more weathered with moderate to gradual sloping till, and have more open drainage to the Missouri River watershed.

Typical rolling till plain of the Missouri Coteau (photo by Ben Romans, Ducks Unlimited).

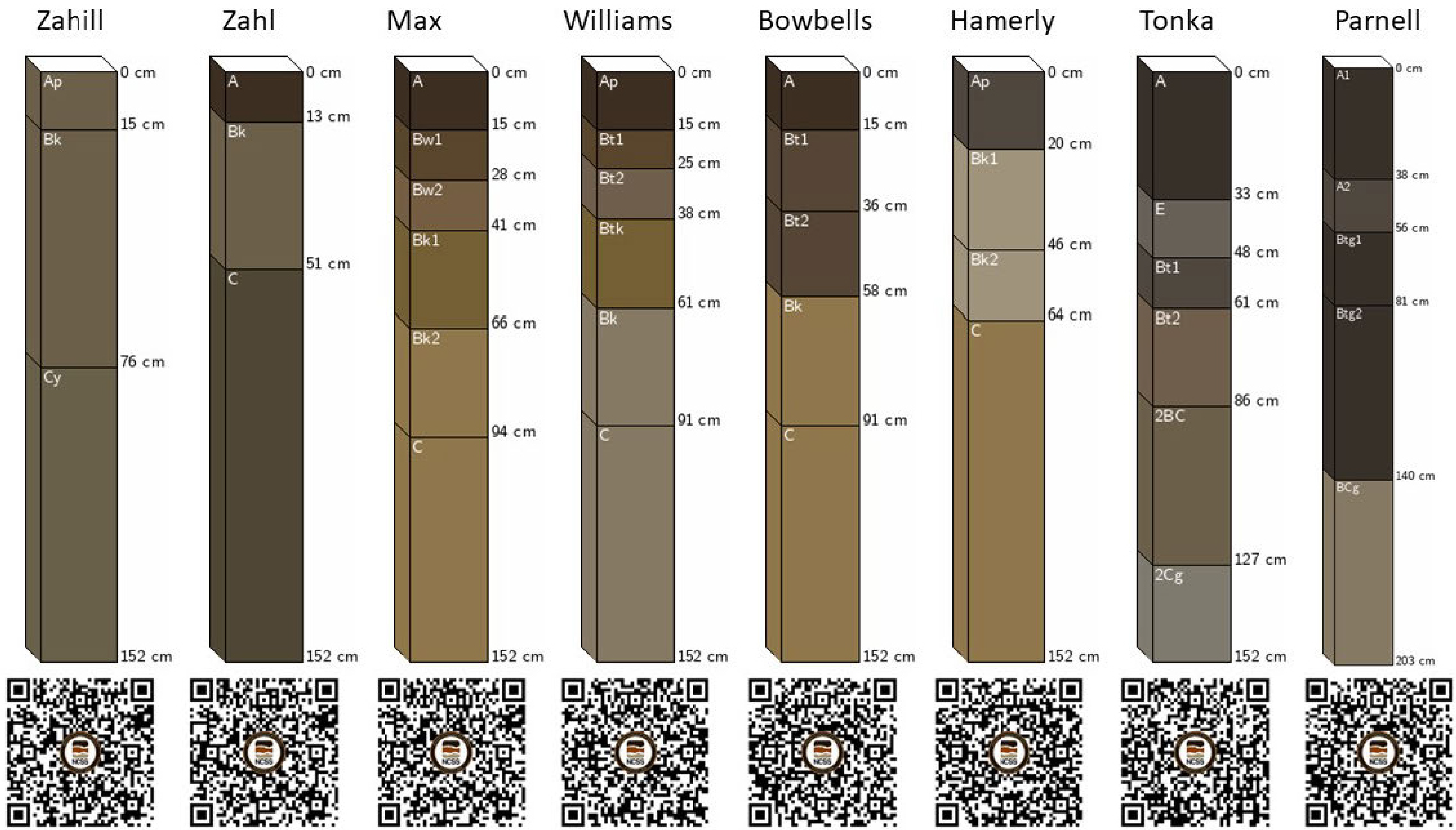
The average annual precipitation is 13 to 21 inches (335 to 541 millimeters). About 75 percent of the rainfall comes from high-intensity, convective thunderstorms during the growing season. Winter precipitation is typically snow. The annual snowfall is 25 to 50 inches (635 to 1,270 millimeters). The average annual temperature is 39 to 45 degrees F (4 to 7 degrees C). The freeze-free period averages 135 days and ranges from 110 to 140 days. Precipitation is the primary source of moisture for crops. In most years, moisture is inadequate for maximum crop production. Only small areas close to the Missouri River and to Lake Sakakawea are irrigated.

Mollisols are the dominant soil order in this MLRA. The soils in the area dominantly have a frigid temperature regime. They have an ustic or aquic moisture regime and mixed or smectitic mineralogy. They generally are very deep, well drained to very poorly drained, and clayey or loamy.

Native vegetation was dominated by tall-grass prairie species. Vegetation is characterized by western wheatgrass, needle and thread, green needlegrass, and big bluestem. Little bluestem is an important species on the more sloping and shallower soils. Prairie cordgrass, northern reedgrass, and slim sedge are important species on wet soils. Western snowberry, stiff goldenrod, echinacea, and prairie rose are commonly interspersed throughout the area.

Most of this area is in farms and ranches. Slightly more than one-half of the area is cropland. Crops are grown for sale or livestock feed. The principal crops are wheat, corn, soybeans, alfalfa, and oats. The more sloping soils support native grasses and are used as rangeland. Recreational hunting and fishing are important uses of the many natural wetlands.

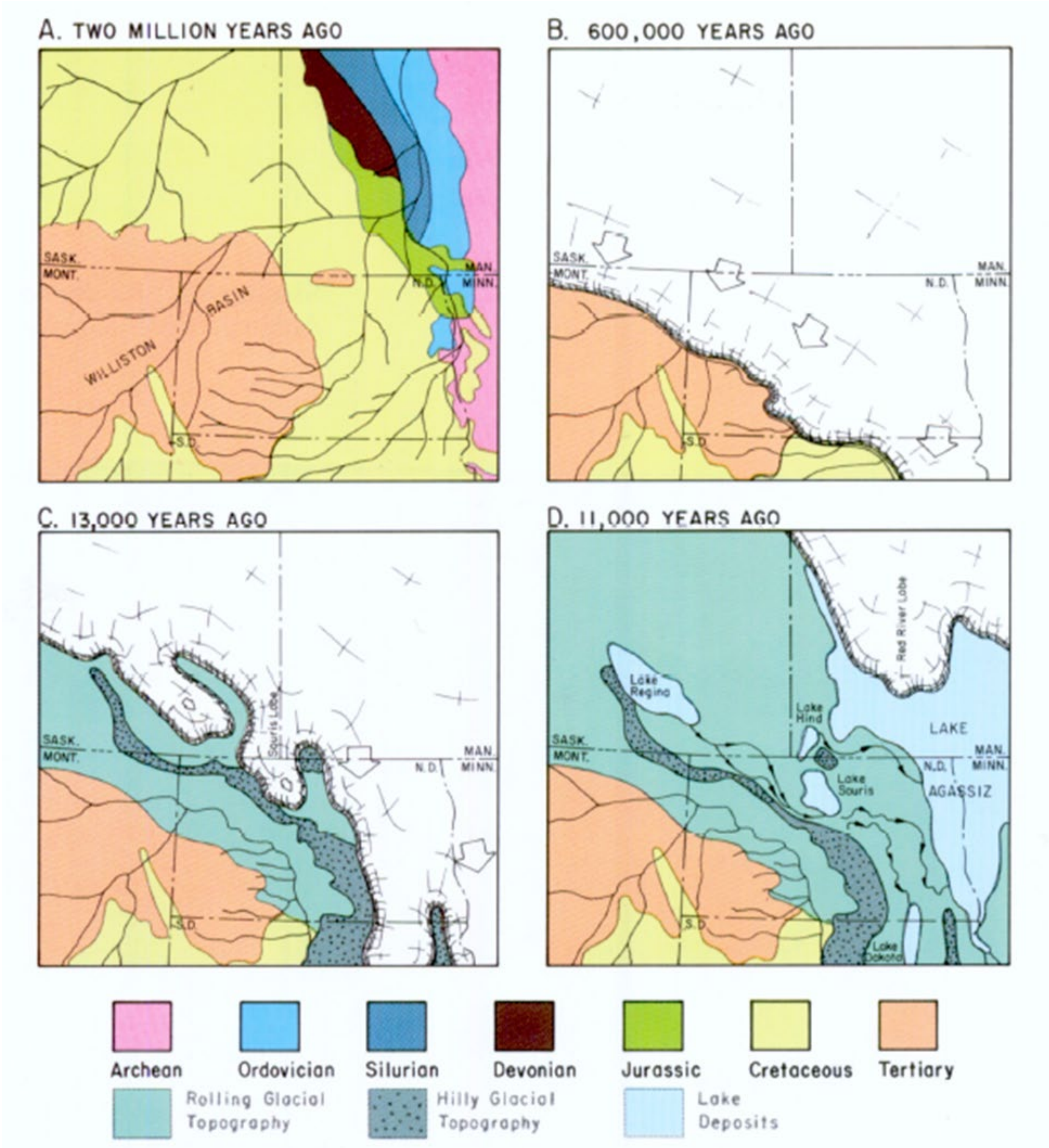
Common Soils of the Missouri Coteau



Scan QR codes for Official Series Descriptions for each Soil Series.

Pleistocene History of North Dakota

Text and image adapted from North Dakota Geologic Survey Roadside Geology Map



Source: North Dakota Geologic Survey

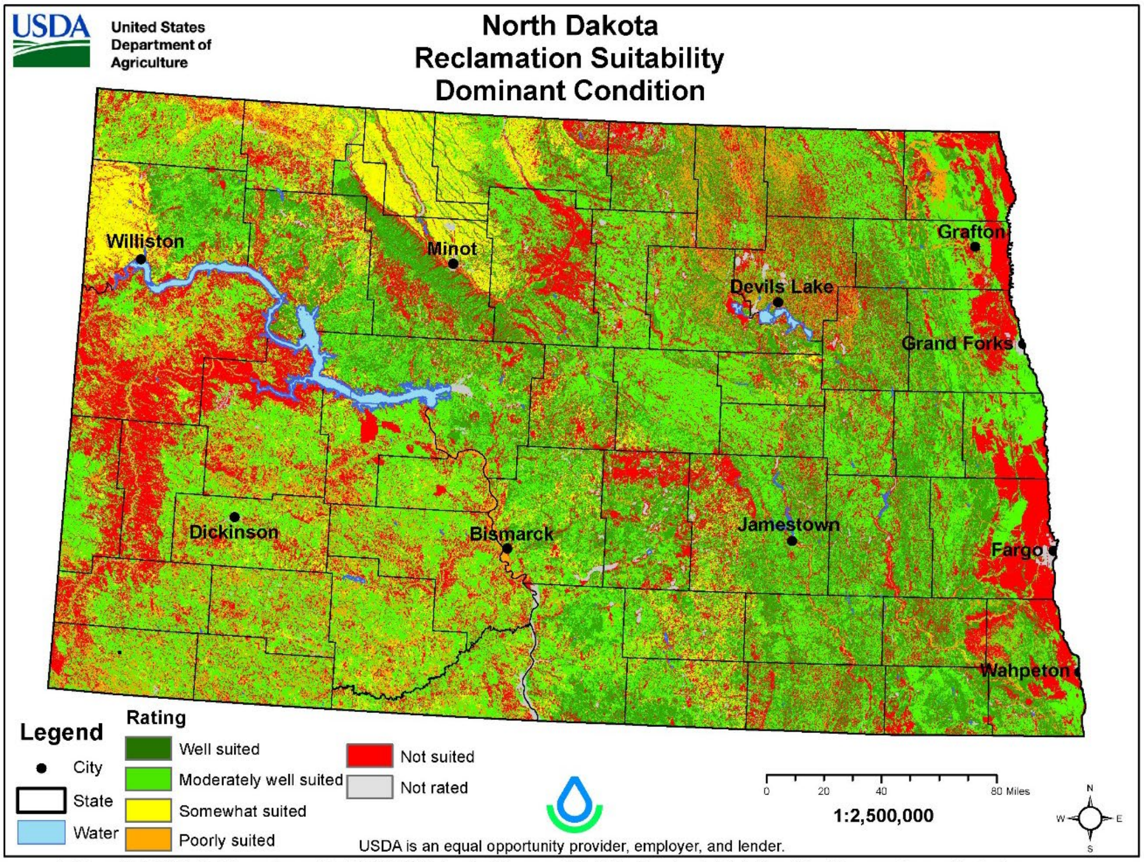
The previous diagrams show how glaciers affected areas around North Dakota during the Pleistocene Epoch. Diagram A shows conditions prior to the earliest glacial advances. Before glaciation, the area was a gently sloping plain northwards towards Hudson Bay. Drainage throughout the area was through extensive river systems that flowed north and east. During the Pleistocene, the area was most likely glaciated several times.

Diagram B shows the hypothetical extent of one of the earliest glacial advances. As a result of this and other advances, the northern route of river channels were blocked, causing them to cut new channels to the south and east along the margin of the ice sheet. As a result of the newer, steeper channel the Little Missouri River began eroding the badlands in western North Dakota. Each time the glaciers advanced they reshaped existing drainage patterns and established new ones. Evidence of glaciation in the southwestern portion of North Dakota is through the presence of glacial erratics and thin, mostly eroded till sediments.

Diagram C shows when the ice was melting for the last time. Active glacial sheets had melted from the central and northwestern portions of the state. The glacial ice was thinner than earlier glaciers and could not flow over higher areas such as the Missouri Coteau, Turtle Mountains, or Prairie Coteau. Large portions of the glacier that had been flowing over these high areas became covered with debris and stagnated, taking longer to melt that the nearby lowlands, creating the hummocky dead ice moraine common in these high areas.

Diagram D shows as the glaciers continued to melt, lakes formed along the southern boundary of the glacial ice. The largest of these Lake Agassiz covered portions of North Dakota, Minnesota, and Manitoba. Other smaller lakes such as Souris, Regina, and Dakota were also present at that time.

Reclaimed Soil Pit Information



Soil Survey Staff. Gridded Soil Survey Geographic (gSSURGO) Database for State name. United States Department of Agriculture, Natural Resources Conservation Service. Available online at https://gdg.sc.egov.usda.gov/. 10, 31,2022 (FY2023 official release)

Reclamation Suitability (ND)

The Reclamation Suitability (ND) interpretation provides a relative ranking of soils based on their resilience and ability to maintain or resume function after being drastically disturbed. Typical disturbances include temporary (approximately, but not limited to 25 years) change in land use or disturbance for the installation of infrastructure such as pipelines, oil well pads, access roads, evaporation ponds, pits, or mines.

The soil features considered are slope, slope aspect, seasonal high water table, ponding, flooding, surface fragments, mean annual precipitation minus potential evapotranspiration, available water capacity, organic matter, rooting depth, clay content, coarse fragment content, electrical conductivity, sodium adsorption ratio, pH, and calcium carbonate equivalent.

Preparation and planning are essential to reclamation success. This set of interpretive rules is intended to identify those soils that are least suited for reclamation activities so that their disturbance may be avoided, or appropriate management practices can be implemented in the planning process to increase reclamation success.

The separation of the topsoil layer from subsoil layers, as site disturbance is initiated, is critical to reclamation success. A key component to past successful reclamations has been the storage of the topsoil layer and its subsequent use as the top dressing in the reclamation area(s).

Wind and water erosion present a formidable barrier to successful reclamation on nearly all North Dakota landscapes. This is especially true in the southwestern portion of the state where soils are derived from sedimentary parent materials. Installation of erosion control practices such as mulch, erosion control blankets, fiber rolls, etc. can reduce sediment, slow water runoff, prevent soil loss, surface water pollution, and wildlife habitat loss, and also increases the potential for a successful reclamation.

The results of this interpretation are not designed or intended to be used in a regulatory manner.

Falkirk Mine

The Falkirk Mining Company began production in 1978. The company mines approximately 600 acres of land a year. With an annual production of approximately 8 million tons of lignite coal, Falkirk provides fuel to generate low-cost electricity for Minnesota. Through sound reclamation and environmental practices, Falkirk strives to return the land to a high-quality, diverse, and productive landscape. Falkirk continues to be a leader in developing clean, efficient, and environmentally friendly coal technologies.

Reclamation Process

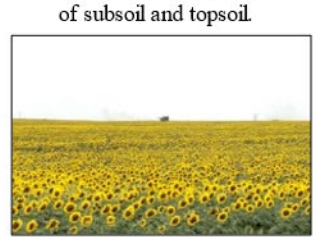
Topsoil and subsoil are removed and respread in two separate lifts.

Overburden (spoil) is piled and the coal is mined.

Overburden spoil is replaced, then reshaped and graded. This is followed by respread of subsoil and topsoil.

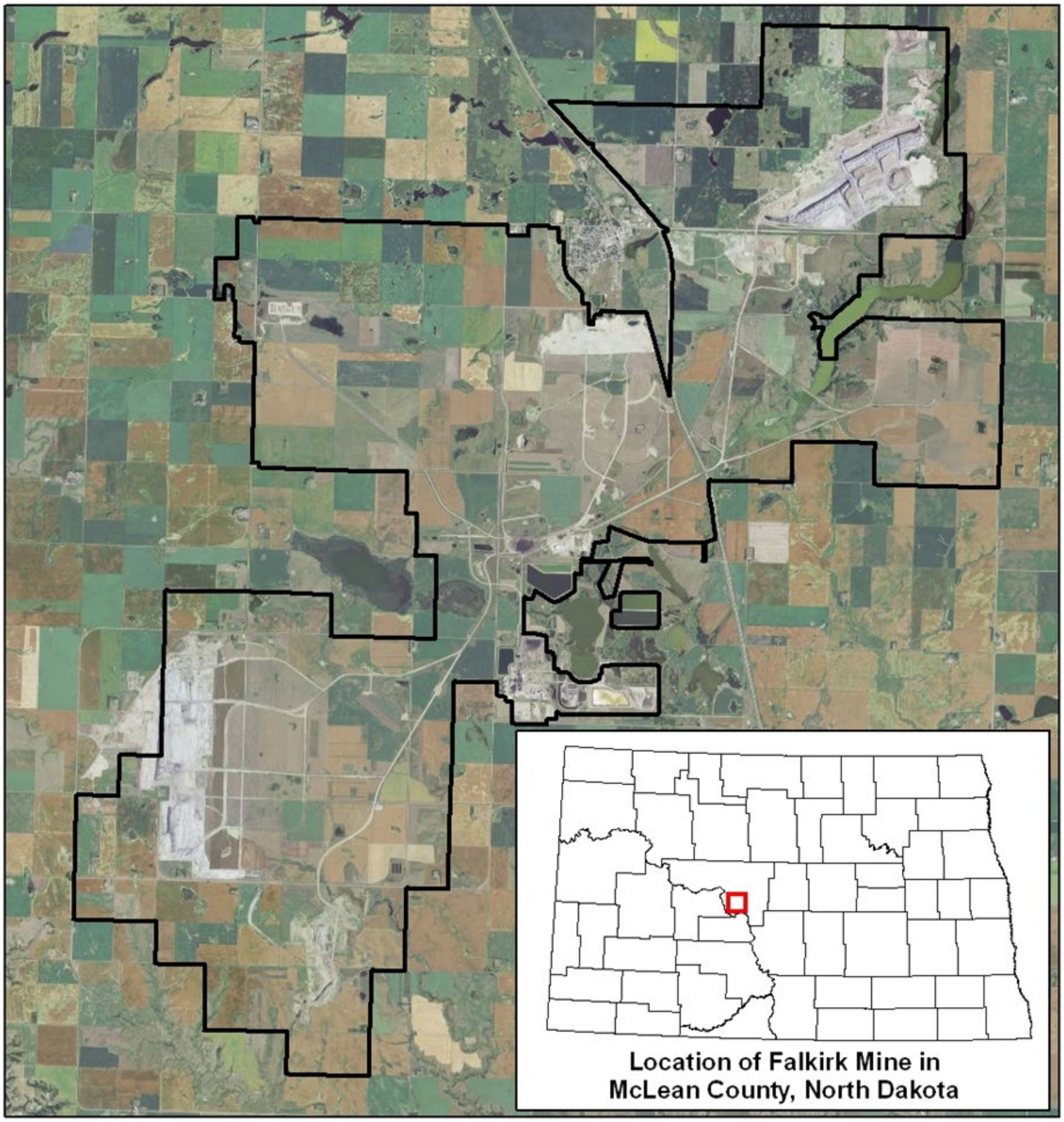
Wetlands and wildlife habitat are restored.

Areas are seeded to a pre-crop seed mixture.



Land is returned to its pre - mine level of productivity.

Soil Survey of Reclaimed Mine Lands at the Falkirk Mine



Mapping Procedure

Mapping of reclaimed areas presented a unique opportunity to investigate human altered soils. In a native setting, there is a relationship between the landscape and the formation of the soil. This relationship is the foundation for the development of soil map units. In the reclaimed areas there is no such relationship. Establishing soil series and map units was very similar. Both were based on the thickness of the respread topsoil and subsoil over the spoil.

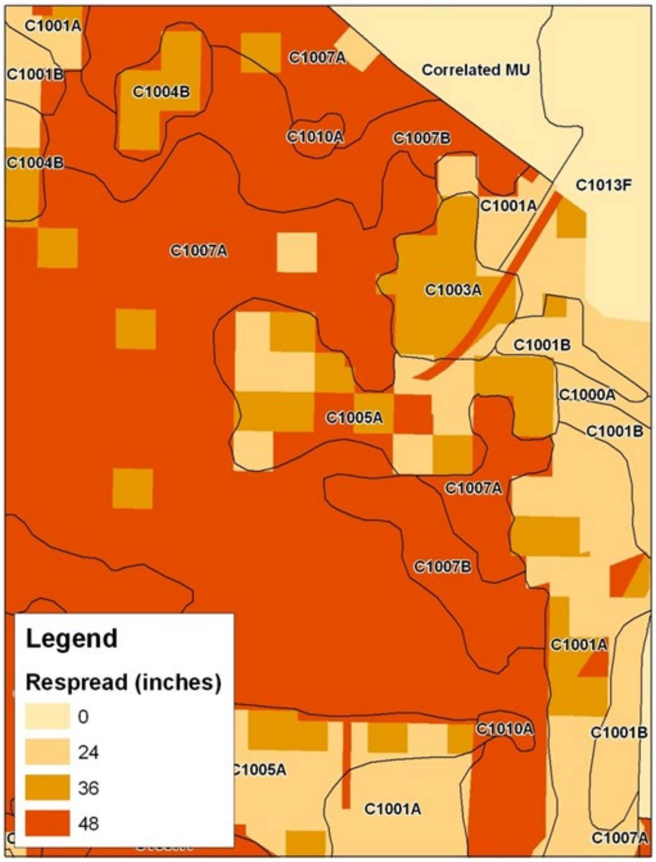
The Falkirk Mining Company has very good data available on the respread depths of the topsoil and the subsoil. This data along with a post mining elevation and curvature data were used to make the initial map of the area.

In creating the soil survey, a scale of 1:20,000 was used to delineate the map units. This was the standard for completed surveys throughout North Dakota. This scale limited the minimum size of delineations to 3 acres. Any areas smaller than 3 acres was considered an inclusion in the surrounding map units.

The first step in the mapping procedure was to use the re-spread data to pull out the soil series. Both complex and consociation map units were delineated based on the respread soil series data. Dragline is the hydric soil series developed for the project and was used in all restored wetlands. These map units were delineated using restored wetlands data provided by the Falkirk Mine and through review of ortho photography. Soil map delineations were further separated based on slope. Post mine elevation data provided by the Falkirk Mine was used to create a classified dataset. Six slope classes were developed to separate the delineations.

Review of ortho photos was completed on the map unit delineations to delineate active mines, disturbed areas, and any areas where there was no disturbance. The active mines have a distinct photo signature and include the pits and spoil piles. Disturbed areas include spoil piles, scraped areas, haul roads. Additionally, the mining infrastructure was delineated. In many places throughout the area, there was minimal disturbance and the original soil delineations were maintained.

The final step in the mapping process was field checking the map unit delineations. Field checks were intended to review the placement of the soil lines and the slope groups. Through the field review process, some of the delineations were combined.



Example of map unit type and respread depth.

Soil Series Development

Soils at the Falkirk Mine have been constructed though the placement of the spoil, the subsoil, and the topsoil. The construction of the soil has led to differences that allowed for the development of the soil series. In setting up the series, the primary distinguishing feature was the thickness of the respread. This information was provided by the North Dakota Public Service Commission (PSC) and the Falkirk Mining Company. The thickness of the respread is determined by the quality of the spoil it covers. A better-quality spoil receives a thinner cover of topsoil and subsoil, while a lower quality spoil will receive a thicker covering. The PSC has completed extensive sampling of the spoil at the Falkirk mine. The quality of the spoil is controlled by several factors, but primarily it is determined by salinity, sodicity, and texture. Table 1 below highlights the values that control the thickness of the respread. In addition to respread depth, drainage class was used to setup the soil series. Using the re-spread depth and drainage class 5 soil series were developed. These are the Boxcut, Coleharbor, Square Butte, Kniferiver, and Dragline series.

Generalized PSC Spoil Properties for Respread Thickness.

Respread Thickness (inches)	Soil Properties		
	SAR	Texture	EC
24	<12	Medium or finer	<8
36	12 - 20	All textures	<8
36	Any	Coarse (VFSL or coarser)	<8
48	>20	All textures	>8

Horizons

Anthropogenic soils can be simple in the separation of their horizons. This was true in the case of the soil series for the Falkirk Mine. Horizons were based on the deposition of the spoil, the subsoil, and the topsoil. The soil at the mine was all constructed in a similar manner. Therefore, they all have the same horizonation, the only difference being the thickness of the topsoil and subsoil respread.

Each of the lifts had to meet certain characteristics to be used in the reclamation process. These characteristics are legal requirements required by the state of North Dakota. The main requirements are organic matter (OM) percentage, SAR, and EC. To qualify as topsoil, the material must be from the original A or B horizons, and have greater than 1 percent OM. Additionally, it must have an SAR of less than 4 and an EC of less than 2. Textures for the topsoil are usually loam or clay loam. The subsoil must meet certain chemical restrictions as well. The EC must be less than 4 and the SAR value must be less than 10. There are no textural requirements for the subsoil, but it is usually a loam or clay loam. Typically, this material comes from the original B, C, or Cr horizons. Due to the glaciated history of the area surrounding the Falkirk Mine there is a layer of glacial till at the surface over sedimentary bedrock. The glacial till along with the bedrock are what compose the spoil.

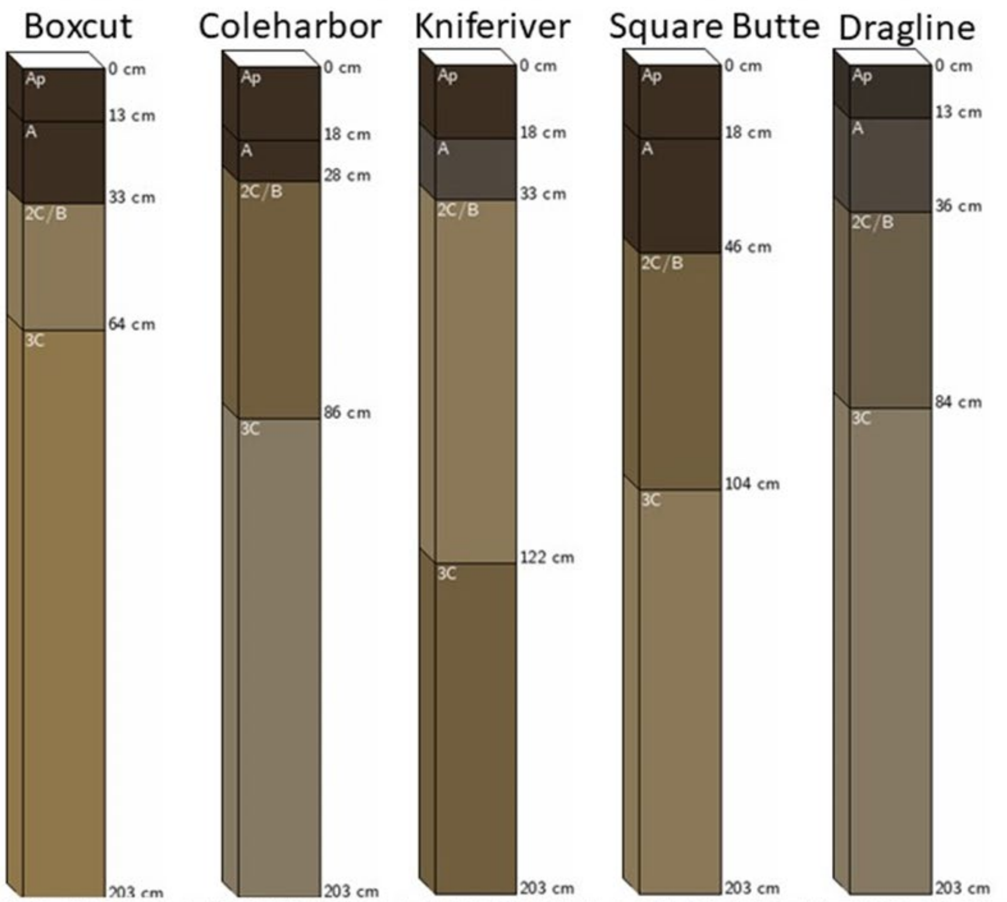
Horizons in the series are an ^Ap, ^A, ^2C/B, and ^3C. The Ap and A horizons represent the respread of the topsoil. The subsoil is represented by the ^2C/B horizon. The C/B designation was selected to account for the mixing of the original B and C horizons. It was felt that the identifiable B horizon material was enough to use the C/B, but that the C horizon material was more dominant. The ^3C horizon represents the spoil.

All the newly established soil series have essentially the same soil profile, with the primary difference being the thickness of the horizons. The thickness of the horizons as mentioned previously was determined by the quality of the spoil. To determine horizon depths and thickness, data collected by the PSC was analyzed. This data contained the depth of the topsoil and the subsoil for each of the respread depths. This analysis showed that the average thickness of the topsoil for all the series was close to 12 inches. There was some variation in thickness of the topsoil between the soil series. Square Butte was different than the other four soils. This series was used in areas of reclamation prior to 1973 reclamation laws. This caused some variability in the thickness of the topsoil. The rest of the cover over the spoil was the subsoil material. In areas of a 24" respread there was 12" of subsoil, in 36" of respread 24" of subsoil, and in 48" respread there is 36" of subsoil. Figure 5 below is an illustration of the representative pedon for each of the 5 new soil series established at the Falkirk Mine. In addition to the data review, pedon descriptions and transects were completed to verify the series horizons. The field checks correlated with the findings of the PSC data.

While completing the pedon descriptions and transects, some densic horizons were found in all the new soil series. It was typically found within the ^3C horizon. It formed during the construction of these soils due to compaction cause by the equipment used. This horizon was not common throughout the area; it accounted for about 10 percent of the pedons described.

As part of the project, data for reclaimed soil was compiled to populate the horizons for the series. The data came from North Dakota State University (NDSU), Agricultural Research Service (ARS), Public Service Commission (PSC) and covered soils at the Falkirk Mine and other mines. It contained information of the physical and chemical characteristics of the topsoil, subsoil, and the spoil. In all, the data spanned over 30 years.

Reclaimed Soils at the Falkirk Mine



Scan the QR codes for the official series descriptions for each soil series.

Classification of Reclaimed Soils During Initial Survey

Taxonomic Classification from 2011, Keys to Soil Taxonomy eleventh edition

Component	Taxonomic Class
Boxcut	Fine-loamy, mixed, superactive, nonacid, frigid Haplic Ustarents
Coleharbor	Fine-loamy, mixed, superactive, nonacid, frigid Haplic Ustarents
Dragline	Fine-loamy, mixed, superactive, nonacid, frigid Mollic Endoaquents
Kniferiver	Fine-loamy, mixed, superactive, nonacid, frigid Haplic Ustarents
Square Butte	Fine-loamy, mixed, superactive, nonacid, frigid Haplic Ustarents

Spoil quality determined the thickness of the respread, but in some cases the same thickness of respread was used on different types of spoil. This was done for the Coleharbor and the Dragline series. The Coleharbor series was set up to be on coarse-textured or sodic substratum's. To account for the sodic substratum a phase was used. Dragline was established to cover the wet areas of the reclaimed lands. The wet areas occurred above all types of spoil; therefore, it was necessary to create a phase with a sodic substratum. The sodic substratum did cause a few changes on the interpretations. For instance, the PI was slightly lower in the sodic phases.

Consistency in constructing the soils can be hard to accomplish. In some places the topsoil was spread thicker than others. These thicker areas were observed in the transects completed by the SSO and the PSC. To account for these areas a thick surface phase was developed for the Coleharbor, Kniferiver and Boxcut series. The thick surface did not require large changes in the data populated in comparison to the original series. The interpretations did change some, for example the PI increased for this phase.

Taxonomic Classification, Keys to Soil Taxonomy thirteenth edition

Entisols

Component	Taxonomic Class
Boxcut	Fine-loamy, spolic, mixed, superactive, nonacid, frigid Anthroportic Ustorthent
Coleharbor	Fine-loamy, spolic, mixed, superactive, nonacid, frigid Anthroportic Ustorthent
Dragline	Fine-loamy, mixed, superactive, nonacid, frigid Mollic Endoaquents
Kniferiver	Fine-loamy, spolic, mixed, superactive, nonacid, frigid Anthroportic Ustorthent
Square Butte	Fine-loamy, spolic, mixed, superactive, nonacid, frigid Anthroportic Ustorthent

Mollisols

Component	Taxonomic Class
Boxcut	Fine-loamy, spolic, mixed, superactive, nonacid, frigid Entic Haplustolls
Coleharbor	Fine-loamy, spolic, mixed, superactive, nonacid, frigid Entic Haplustolls
Dragline	Fine-loamy, mixed, superactive, nonacid, frigid Mollic Endoaquents
Kniferiver	Fine-loamy, spolic, mixed, superactive, nonacid, frigid Entic Haplustolls
Square Butte	Fine-loamy, spolic, mixed, superactive, nonacid, frigid Entic Haplustolls

Artesols – Proposed Soil Order and Classification

Component	Taxonomic Class
Boxcut	Fine-loamy, spolic, mixed, superactive, nonacid, frigid Typic Restortharts
Coleharbor	Fine-loamy, spolic, mixed, superactive, nonacid, frigid Typic Restortharts
Dragline	Fine-loamy, mixed, superactive, nonacid, frigid Typic Endoaquart
Kniferiver	Fine-loamy, spolic, mixed, superactive, nonacid, frigid Typic Restortharts
Square Butte	Fine-loamy, spolic, mixed, superactive, nonacid, frigid Typic Restortharts

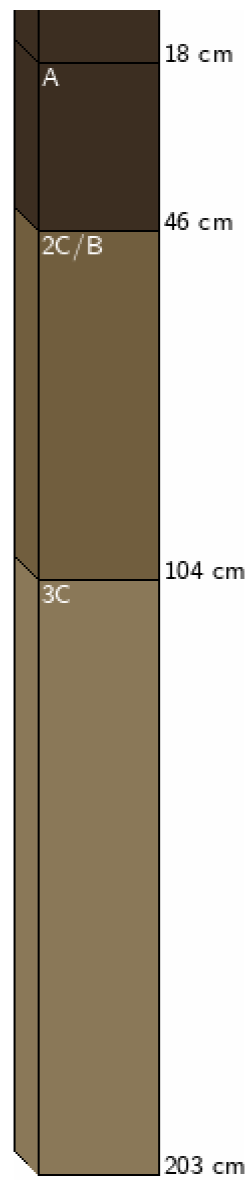
LOCATION SQUARE BUTTE ND

Established Series
PFS, MGU
12/2013

Scan the QR code for the official soil series description.

SQUARE BUTTE SERIES

The Square Butte series consists of very deep, well drained soils on surface mined areas. Saturated hydraulic conductivity is moderately low. These soils formed in materials that have been excavated and reclaimed during surface mining operations. Slopes range from 0 to 15 percent. Mean annual temperature is about 4 degrees C, and mean annual precipitation is about 36 centimeters.



TAXONOMIC CLASS: Fine-loamy, mixed, superactive, nonacid, frigid Haplic Ustarents

TYPICAL PEDON: Square Butte loam - with a 2 percent convex slope in a cultivated field. (Colors are for dry soil unless otherwise stated.)

Ap--0 to 18 centimeters; dark gray (10YR 4/1) loam, very dark brown (10YR 2/2) moist; moderate coarse and medium subangular blocky structure parting to moderate fine and medium subangular blocky structure; friable, moderately hard; slightly sticky and moderately plastic; common very fine and fine roots throughout; few very fine low-continuity tubular pores; noneffervescent; abrupt smooth boundary.

A--18 to 46 centimeters; dark grayish brown (10YR 4/2) loam, very dark brown (10YR 2/2) moist; moderate fine and medium subangular blocky structure; friable, moderately hard; slightly sticky and moderately plastic; common very fine and fine roots throughout; few very fine low-continuity tubular pores; noneffervescent; 1% of Bk material mixed in A horizon; abrupt smooth boundary. (Ap and A horizon 38 to 61 centimeters thick)

2C/B--46 to 104 centimeters; light olive brown (2.5Y5/3) clay loam, olive brown (2.5Y 4/3) moist; 1 percent fine prominent irregular dark yellowish brown (10YR 4/6) relict concentrations; moderate medium and coarse cloddy structure; friable, moderately hard; moderately sticky and moderately plastic; common very fine and fine roots throughout; few very fine low-continuity tubular pores; strong effervescence; 5% soft masses of lime from original Bk horizon; abrupt smooth boundary. (2C/B horizon 38 to 114 centimeters thick)

3C--104 to 203 centimeters; dark grayish brown (2.5Y 4/2) clay loam, light olive brown (2.5Y 5/3) moist; 1 percent fine prominent irregular yellowish brown (10YR 5/6) relict concentrations; massive; firm, hard; moderately sticky and moderately plastic; few very fine roots in cracks; slight effervescence; 3% lignite fragments.

TYPE LOCATION: McLean County, North Dakota; about 2 miles southwest of Underwood; 302 meters south and 201 meters west of the northeast corner of Sec. 31, T. 146 N., R. 82 W.

RANGE IN CHARACTERISTICS: Depth to carbonates ranges from 0 to 24 inches, but typically are found at a depth greater than 25 centimeters. The soil contains 1 to 10 percent rock fragments but ranges up to 15 percent. The rock fragments are dominantly gravel, but a few cobbles and stones are present in most pedons and occur at random depth, spacing, and orientation. Shale fragment content ranges from 0 to 5 percent. The clay content in the control section averages between 20 to 35 percent clay. Depth to 3C horizon (spoil material) ranges from 102 to 152 centimeters. In all pedons, soil fragments and isolated peds of relict genetic horizons of pre-mined soils are randomly distributed throughout and are disordered relative to any plane in the profile. Some of the soil fragments have identifiable properties such as clay films, relict concentrations, or soft masses that are characteristic of their previous formation. The organic carbon content decreases irregularly with depth in most pedons because of mixing and because of the presence of flakes and fragments of coal or other carbonaceous material.

The A horizon has hue of 10YR or 2.5Y, value of 4 or 5 and 2 or 3 moist, and chroma of 2 moist, but can range from 1 to 3. It is loam or clay loam. It is neutral or slightly alkaline. A calcareous surface phase is recognized. Some pedons have an A/C horizon.

The 2C/B horizon has hue of 10YR, or 2.5Y, value of 5 to 7 and 4 to 6 moist, and chroma of 2 to 4 moist. It is loam or clay loam, but thin individual layers can include sandy clay loam or silty clay loam. It is slightly alkaline or moderately alkaline. Some horizons have strata, pockets, or soil fragments that do not contain free carbonates. In some pedons, multiple 2C/B horizons can occur.

The 3C horizon has hue of 10YR, 2.5Y, or 5Y, value of 3 to 6 moist, and chroma of 2 to 6 moist. It is loam or clay loam, but thin individual layers can include sandy clay loam, silty clay loam, silty clay, or clay. It is slightly alkaline or moderately alkaline. Some horizons have strata, pockets, or soil fragments that do not contain free carbonates. Some pedons contain one or more dense substratum layers. These layers restrict the movement of roots and water and have high bulk density and low available water capacity. A dense substratum phase is recognized.

COMPETING SERIES: These are the Coleharbor, Boxcut, and Kniferiver series in the same family. These soils are found on similar landscapes. Coleharbor soils have a sandy 3C horizon (spoil material) with 10 to 18 percent clay at depths between 76 to 102 centimeters. Boxcut soils have 3C horizons (spoil material) at depths between 51 to 76 centimeters. Kniferiver soils have 3C horizons (spoil material) at depths between 102 to 152 centimeters and have an SAR greater than 15.

GEOGRAPHIC SETTING: Square Butte soils are on nearly level to strongly sloping summits and back slopes of reconstructed landscapes. Slope gradients commonly range from 0 to 15 percent. The soils formed in materials that were excavated and reclaimed during surface mining operations. Mean annual air temperature ranges from 1 to 7 degrees C, and mean annual precipitation from 30 to 48 centimeters.

GEOGRAPHICALLY ASSOCIATED SOILS: These are the competing Coleharbor, Boxcut, and Kniferiver series and the Bowbells, Max, Niobell, Noonan, Parnell, Tonka, Williams, and Zahl soils on adjacent unmined landscapes. Bowbells soils are pachic. Niobell and Noonan soils have natric horizons. Tonka and Parnell soils are in depressions. They are poorly and very poorly drained, respectively. Williams soils have an argillic horizon.

DRAINAGE AND SATURATED HYDRAULIC CONDUCTIVITY: Well drained. Saturated hydraulic conductivity is moderately.

USE AND VEGETATION: Square Butte soils are used for growing small grains and row crops. Some areas are seeded to grass-legume mixtures for meadow or pasture.

DISTRIBUTION AND EXTENT: Central and western North Dakota. Square Butte soils are of small extent.

MLRA SOIL SURVEY REGIONAL OFFICE (MO) RESPONSIBLE: St. Paul, Minnesota

SERIES ESTABLISHED: McLean County, North Dakota, 2012.

REMARKS: These soils were formerly mapped as mine spoils, surface mines, loamy Orthents, or other miscellaneous land types. They result from mining technology and reclamation procedures adopted around 1975. The topsoil, subsoil, and spoil are removed in separate lifts and stockpiled. After the coal has been mined, the stockpiled materials are replaced. The spoil is laid down first, followed by the subsoil, and finally the topsoil.

Diagnostic horizons and features recognized in this pedon are: There are no diagnostic features recognized. These soils have organic carbon levels and colors that qualify as mollic epipedons, but because of the reclamation process they are no longer considered diagnostic.

ADDITIONAL DATA: Publication 1207. Climatic adjustments on reclaimed cropland yields for final bond release. Dr. Stephan A. Schroeder, 1992.

National Cooperative Soil Survey
U.S.A.

Square Butte Pedon Description

Print Date: Feb. 16, 2023
Description Date: June 2, 2022
Describer: WDB, PFS, LAD, SES
Site ID: S2022ND055002

Soil Survey Area: ND055 -- McLean County, North Dakota 10-BIS -- Bismarck, North Dakota
Pedon ID: S2022ND055002
Quad Name:

Lab Source ID: KSSL

Lab Pedon #: 22N0291

Country:

State: North Dakota

MLRA: 53B – Central Dark Brown Glaciated Plains

Map Unit:

Std Latitude: 47.4570600
Std Longitude: -101.154100

User Transect ID:
Soil Name as Described/Sampled: Square Butte
Classification: Fine-loamy, mixed, superactive, nonacid, frigid Haplic Ustarents
Soil Name as Correlated: Square Butte
Classification: Fine-loamy, spolic, mixed, superactive, nonacid, frigid Anthroportic Ustorthents
Pedon Type: classifies to current taxon name, full description
Pedon Purpose: soil survey inventory
Taxon Kind: series
Associated Soils
Physiographic Division:
Physiographic Province:
Physiographic Section:
Geomorphic Setting: anthroscape on till plain
Upslope Shape: linear
Cross Slope Shape: linear

Particle Size Control Section: 25 to 100 cm.

Description origin: NASIS

Primary Earth Cover: Crop cover
Secondary Earth Cover: Close-grown crop
Vegetation:
Parent Material: till
Bedrock Kind:
Bedrock Depth:
Bedrock Hardness:
Bedrock Fracture Interval:
Surface Fragments:
Description database: KSSL

Diagnostic Features: mollic epipedon 0 to 30 cm.
human-transported material 0 to 188 cm.

Top Depth (cm)	Bottom Depth (cm)	Restriction Kind	Restriction Hardness
110	188	densic material	Strongly coherent

Cont. Site ID: S2022ND055002 **Pedon ID:** S2022ND055002

Slope (%)	Elevation (meters)	Aspect (deg)	MAAT (C)	MSAT (C)	MWAT (C)	MAP (mm)	Frost-Free Days	Drainage Class	Slope Length (meters)	Upslope Length (meters)
4.0								Well drained		

^Ap1--0 to 5 centimeters (0.0 to 2.0 inches); very dark brown (10YR 2/2) loam, dark grayish brown (10YR 4/2), dry; 30 percent sand; 26 percent clay; weak medium platy structure; slightly hard, friable, slightly sticky, moderately plastic; many very fine roots throughout and many fine roots throughout; common fine pores; 4 percent nonflat subangular indurated 5 to 30-millimeter Mixed rock fragments; noneffervescent, by HCl, 1 normal. Lab sample # 22N01263. Pockets of moderate coarse subangular structure.

^Ap2--5 to 10 centimeters (2.0 to 3.9 inches); very dark brown (10YR 2/2) loam, dark grayish brown (10YR 4/2), dry; 30 percent sand; 26 percent clay; weak medium platy structure; slightly hard, friable, slightly sticky, moderately plastic; many very fine roots throughout and many fine roots throughout; common fine pores; 4 percent nonflat subangular indurated 5 to 30-millimeter Mixed rock fragments; noneffervescent, by HCl, 1 normal. Lab sample # 22N01264. Pockets of moderate coarse subangular structure.

^Ap3--10 to 30 centimeters (3.9 to 11.8 inches); very dark brown (10YR 2/2) loam, dark grayish brown (10YR 4/2), dry; 30 percent sand; 26 percent clay; weak medium platy structure; slightly hard, friable, slightly sticky, moderately plastic; many very fine roots throughout and many fine roots throughout; common fine pores; 4 percent nonflat subangular indurated 5 to 30-millimeter Mixed rock fragments; noneffervescent, by HCl, 1 normal. Lab sample # 22N01265. Pockets of moderate coarse subangular structure.

2^C--30 to 110 centimeters (11.8 to 43.3 inches); brown (10YR 4/3) clay loam; 22 percent sand; 34 percent clay; 10 percent coarse prominent (7.5YR 4/6) mottles; structureless massive; hard, firm, moderately sticky, moderately plastic; common very fine pores; 2 percent distinct 7.5YR 3/4), moist, organic stains on surfaces along root channels; 30 percent fine 10YR 7/2) carbonate masses throughout; 7 percent nonflat subrounded indurated 5 to 30-millimeter Mixed rock fragments; strong effervescence, by HCl, 1 normal. Lab sample # 22N01266. 2% pockets of Ap material in fractures and on ped faces.

3^Cd1--110 to 140 centimeters (43.3 to 55.1 inches); dark grayish brown (10YR 4/2) clay; 35 percent sand; 45 percent clay; 10 percent coarse prominent (10YR 4/6) mottles; structureless massive; very hard, very firm, very sticky, very plastic; common very fine pores; 2 percent distinct 7.5YR 3/4), moist, organic stains on surfaces along root channels; 5 percent fine 10YR 7/2) carbonate masses on surfaces along pores; 2 percent nonflat subrounded indurated 2 to 5-millimeter Mixed rock fragments; slight effervescence, by HCl, 1 normal. Lab sample # 22N01267

3^Cd2--140 to 188 centimeters (55.1 to 74.0 inches); 55 percent dark gray (2.5Y 4/1) and 45 percent olive brown (2.5Y 4/3) clay; 25 percent sand; 47 percent clay; 10 percent coarse prominent (7.5YR 4/6) mottles; structureless massive; very hard, very firm, very sticky, very plastic; common very fine pores; 2 percent distinct 7.5YR 3/4), moist, organic stains on surfaces along root channels; 7 percent medium distinct iron-manganese concretions On faces of peds; 5 percent fine 10YR 7/2) carbonate masses on surfaces along pores; 1 percent flat very angular weakly coherent cemented 2 to 15-millimeter Lignite fragments and 10 percent nonflat subrounded indurated 2 to 15-millimeter Mixed rock fragments; violent effervescence, by HCl, 1 normal. Lab sample # 22N01268. From ~ 70 to 85cm the soil was moist. This moist layer was inconsistent.

Pedon ID: S2022ND055002
Sampled Date: 6/2/2022
Series: Square Butte
Classification: Fine-loamy, spolic, mixed, superactive, nonacid, frigid Anthroportic Ustorthent

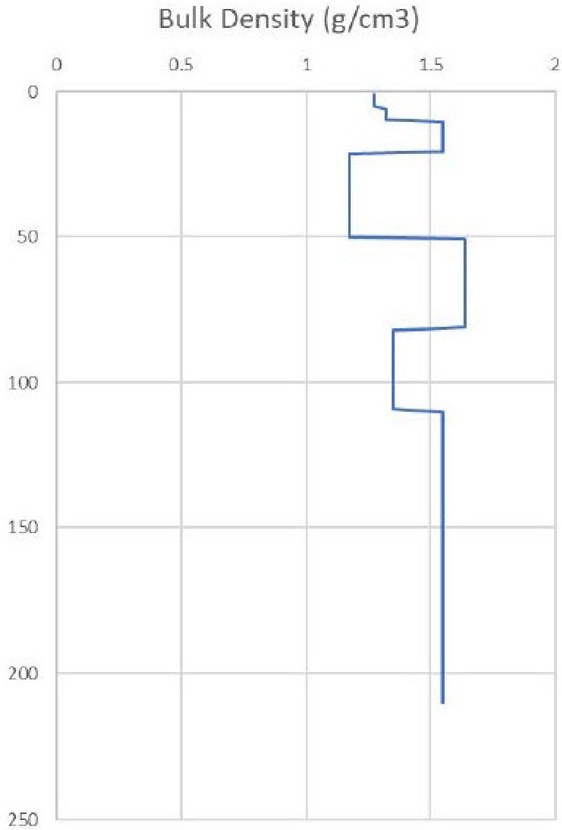
Particle Size Control Section: 25-100
Clay Weighted Average: 30
CEC Activity, CEC7/Clay, Weighted Average: 0.48

Horizon	Depth	Texture	Clay (%)	Silt (%)	Sand (%)	Core Db (g/cm-3)	Est. OC (%)	Fine Silt (%)	Coarse Silt (%)	V. Fine Sand (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	V. Coarse Sand (%)	Coarse Fragments (%)
^Ap1	0-5	cl	29.5	39.6	30.9	0.88	3.4	23.7	15.9	8.3	14.8	4	2.2	1.6	4
^Ap2	5-10	cl	29.6	41.4	29.0	1.09	2.2	24.1	17.3	7.5	11.3	6.2	2.3	1.7	5
^Ap3	10-30	cl	29.3	41.9	28.8	1.33	2.1	24.8	17.1	7.8	11.5	6.2	2.1	1.2	2
2^C	30-110	cl	30.3	29.3	40.4	1.44	0.3	19.8	9.5	8.6	13.4	9.9	5.8	2.7	22
3^Cd1	110-140	cl	27.8	29.0	43.2	1.68	0.7	19.7	9.3	10.3	23.8	7.2	1.2	0.7	4
3^Cd2	140-188	cl	30.3	41.4	28.3	1.69	0.6	24.6	16.8	13.8	9.6	3.1	1.4	0.4	10

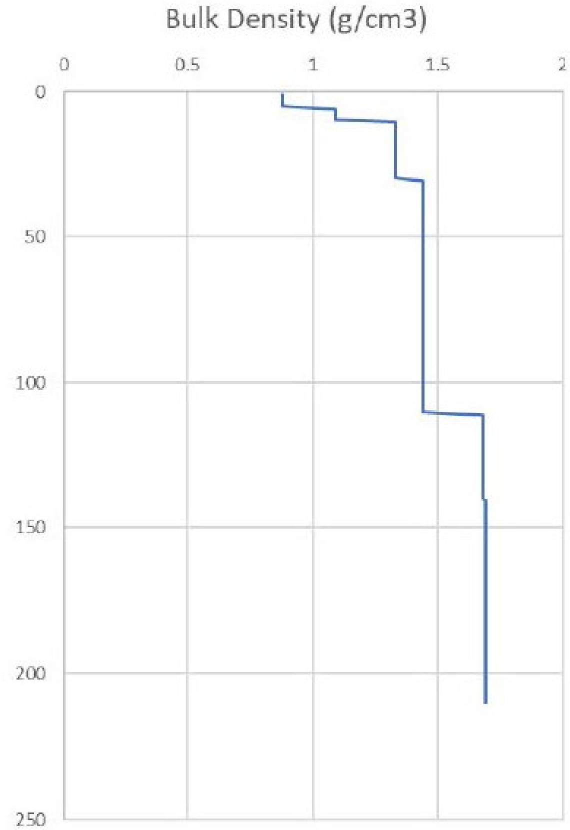
Horizon	Depth	CEC7 (cmo/kg)	CEC7/Clay	Base Saturation (%)	EC (dS/m)	ESP (%)	SAR	Ext. Ca (cmol/kg)	Ext. Mg (cmol/kg)	Ext. Na (cmol/kg)	Ext. Acidity (cmol/kg)	pH Water	CaCO3 (%)
^Ap1	0-5	22.8	0.77	100	1.43	-	tr	32.3	5.9	tr	4.9	7.7	2
^Ap2	5-10	22.8	0.77	100	0.73	tr	tr	40.9	5.3	tr	3.6	7.9	3
^Ap3	10-30	20.8	0.71	100	0.65	tr	tr	43.0	7.0	tr	3.8	8.0	3
2^C	30-110	14.1	0.47	100	0.63	1	tr	45.8	18.5	0.2	-	8.6	20
3^Cd1	110-140	16.4	0.59	100	2.33	1	1	43.1	11.0	0.3	-	8.0	9
3^Cd2	140-188	17.1	0.56	100	3.67	1	1	42.5	12.4	0.4	-	7.8	9

Bulk Density Comparison Between Natural and Reclaimed Soils

William - natural soil



Square Butte - reclaimed soil

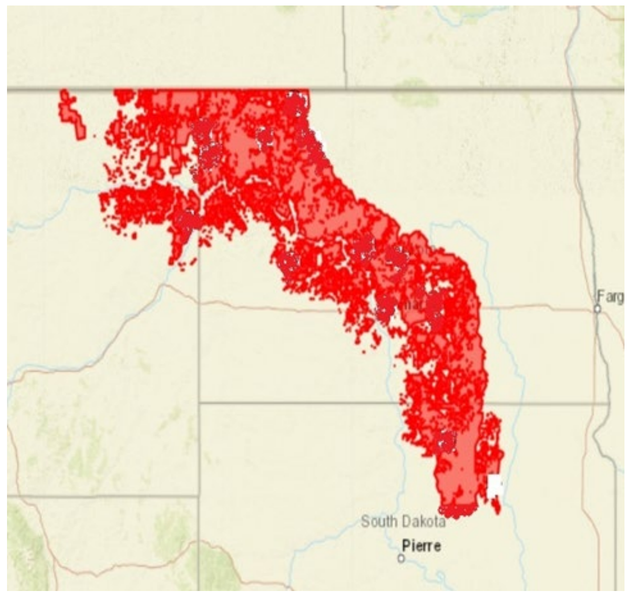


Williams Pedon Information

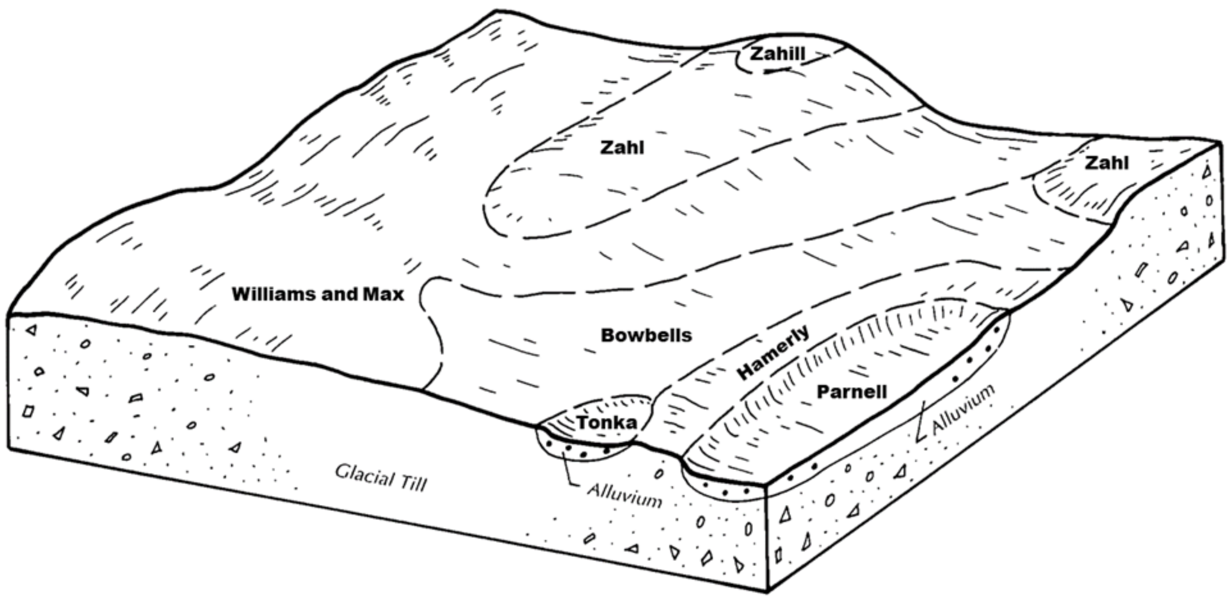
Williams Loam

Williams is the state soil of North Dakota. It is one the most extensive and economically important soils in the state. The native vegetation of the Williams series includes species such as western wheatgrass, blue grama, needle and thread, green needlegrass, and prairie junegrass. These soils have high natural fertility, and their content of organic matter creates highly productive landscapes. Most level to gently rolling areas of Williams soils are used for growing small grain crops such as wheat, barley, oats, flax, and sunflowers, whereas the steeper rolling and hilly areas are used as rangeland.

Profile of a Williams soil (photo courtesy of NRCS).



Extent of the Williams series (photo courtesy of UC Davis).

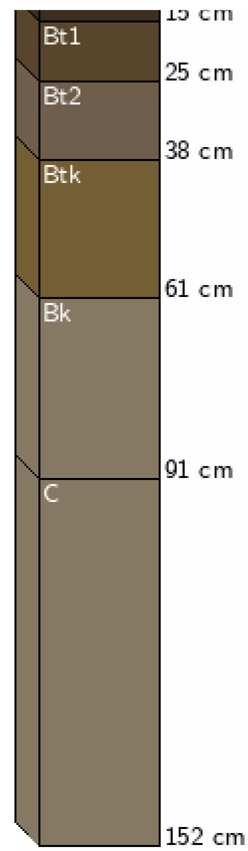

Zahill
Zahl
Zahl
Williams and Max
Bowbells
Hamerly
Parnell
Tonka
Alluvium
Alluvium
Glacial Till

LOCATION WILLIAMS ND+MT SD
Established Series
Rev. CJH
10/98

Scan the QR code for the official series description.

WILLIAMS SERIES

The Williams series consists of very deep, well drained, moderately slow or slowly permeable soils formed in calcareous glacial till. These soils are on glacial till plains and moraines and have slope of 0 to 35 percent. Mean annual air temperature is about 40 degrees F, and mean annual precipitation is about 14 inches.



TAXONOMIC CLASS: Fine-loamy, mixed, superactive, frigid Typic Argiustolls

TYPICAL PEDON: Williams loam - cultivated. (Colors are for dry soil unless otherwise stated)

Ap--0 to 6 inches; dark grayish brown (10YR 4/2) loam, very dark brown (10YR 2/2) moist; weak medium subangular blocky structure; slightly hard, very friable, slightly sticky and slightly plastic; common very fine roots; few pebbles; neutral; abrupt smooth boundary. (4 to 9 inches thick)

Bt1--6 to 10 inches; brown (10YR 4/3) clay loam, dark brown (10YR 3/3) moist; strong medium prismatic structure parting to strong medium angular blocky; hard, firm, sticky and plastic; common very fine roots; many distinct clay films on faces of peds and lining pores; few pebbles; neutral; clear wavy boundary.

Bt2--10 to 15 inches; grayish brown (10YR 5/2) clay loam, dark grayish brown (10YR 4/2) moist; moderate medium prismatic structure parting to strong medium subangular blocky; hard, firm, sticky and plastic; common very fine roots; many distinct clay films on faces of peds and lining pores; slightly alkaline; clear wavy boundary. (Combined Bt horizons 5 to 20 inches thick)

Btk--15 to 24 inches; light olive brown (2.5Y 5/4) clay loam, olive brown (2.5Y 4/4) moist; moderate coarse prismatic structure parting to moderate medium subangular blocky; hard, friable, sticky and plastic; common very fine roots; few faint clay films on faces of peds; few pebbles; common medium irregular masses of carbonates; violent effervescence; slightly alkaline; gradual wavy boundary. (0 to 20 inches thick)

Bk--24 to 36 inches; light brownish gray (2.5Y 6/2) and light gray (2.5Y 7/2) clay loam, grayish brown (2.5Y 5/2) moist; weak medium prismatic structure parting to weak medium subangular blocky; soft, friable, sticky and plastic; few very fine roots; few cobbles; carbonates disseminated throughout and in common masses; violent effervescence; moderately alkaline; gradual wavy boundary. (3 to 30 inches thick)

C--36 to 60 inches; light brownish gray (2.5Y 6/2) clay loam, grayish brown (2.5Y 5/2) moist; few fine prominent yellowish brown (10YR 5/6) redox concentrations and light gray (10YR 7/2) redox depletions; massive; soft, friable, sticky and plastic; few pebbles and cobbles; strong effervescence; moderately alkaline.

TYPE LOCATION: Mountrail County, North Dakota; about 11 miles north and 4 miles west of White Earth; 1,050 feet east and 60 feet south of the northwest corner, sec. 5, T. 158 N., R. 94 W.

RANGE IN CHARACTERISTICS: Depth to carbonates ranges from 10 to 30 inches. The soil typically contains 1 to 10 percent coarse fragments but ranges up to 20 percent. Stony and cobbly phases are recognized.

The A horizon has hue of 10YR, value of 3 to 5 and 2 or 3 moist, and chroma of 2. Some pedons in native grassland have a moist chroma of less than 1.5 in the upper 1 to 3 inches. It is loam, clay loam, sandy loam, fine sandy loam, silty clay loam or silt loam. It is neutral or slightly alkaline.

The Bt horizon has hue of 10YR or 2.5Y, value of 4 to 6 and 2 to 5 moist, and chroma of 2 to 4. It is loam or clay loam and contains 24 to 35 percent clay. It is neutral or slightly alkaline. It has strong or moderate, medium or coarse prismatic structure that parts to strong or moderate, medium or fine angular or subangular blocky.

The Btk horizon, where present, and Bk horizon have hue of 10YR, 2.5Y or 5Y, value of 4 to 8 and 3 to 6 moist, and chroma of 2 to 4. They are loam or clay loam. They are slightly alkaline or moderately alkaline. Carbonates are disseminated and segregated in masses. Some pedons have a BC or BCk horizon.

The C horizon has hue of 10YR, 2.5Y, or 5Y, value of 5 to 8 and 3 to 6 moist, and chroma of 2 to 4. It is loam or clay loam. It is slightly alkaline or moderately alkaline.

COMPETING SERIES: These are the Beartooth, Beeno, Bookcliff, Bullflat, Cortyzack, Dooley, Empedrado, Fairfield, Farnuf, Felor, Greenway, Gurney, Hangdo, Krem, Lefor, Lininger, Livona, Martinsdale, Mauldin, Moen, Reeder, Sponseller, Trag, Ulrant, Vida, Watrous, Wemple and Yegen series. Beartooth soils are above an elevation of 4500 feet. Beeno, Lefor and Reeder soils have a paralithic contact within depths of 20 to 40 inches. Bookcliff soils are calcareous in the upper part of the argillic horizon and have hard sandstone bedrock within depths of 40 to 60 inches. Bullflat soils have a 2C horizon with 15 to 50 percent rock fragments. Cortyzack soils occur at elevations of more than 6800 feet. Dooley and Hangdo soils formed in alluvial or eolian sediments over glacial till and have sandy clay loam Bt horizons. Empedrado soils are dry in the spring and early summer for at least 15 consecutive days. Fairfield soils formed in alluvium and are less than 10 inches deep to the base of the argillic horizons. Farnuf soils formed in alluvium, commonly are more alkaline, and contain stratifications in the C horizon. Felor soils formed in loamy sediments overlying clayey sediments. Greenway soils formed in loamy sediments over firm glacial till and have more clay in the lower part of the solum and substratum. Gurney, Mauldin, Moen and Watrous soils have lithic contact within depths of 20 to 40 inches. Krem soils have a sandy epipedon 20 to 40 inches in thickness over the argillic horizon. Lininger soils are moderately deep over schist. Livona soils formed in eolian sediments over glacial till and have coarse-loamy surface horizons 10 to 20 inches thick. Martinsdale soils formed in alluvium and have 2C and 3C horizons. Sponseller soils have Bt horizons with hues of 7.5YR or redder. Trag soils do not have horizons of carbonate accumulations. Ulrant soils have 20 to 35 percent granite pebbles in the Bt and Bk horizons which formed in alluvium derived from granite or limestone. Vida soils formed in till and are less than 10 inches deep to the base of the argillic horizon. Wemple soils formed in alluvium and are underlain with material high in volcanic ash. Yegen soils formed on uplands and fans and have sandy clay loam Bt horizons.

GEOGRAPHIC SETTING: Williams soils are on level to steep glacial till plains and moraines. Slopes commonly are less than 9 percent but range from 0 to 35 percent. The soils formed in calcareous glacial till of mixed mineralogy. Mean annual air temperature ranges from 34 to 45 degrees F, and mean annual precipitation from 12 to 19 inches.

GEOGRAPHICALLY ASSOCIATED SOILS: These are the Arnegard, Bowbells, Hamerly, Max, Niobell, Noonan, Parnell, Tonka and Zahl soils. Arnegard and Bowbells soils are in nearby, level and nearly level, concave swales. They are pachic. Hamerly soils are in low areas and surround depressions. They have calcic horizons within depths of 16 inches. Max soils are on nearby more convex slopes. They do not have argillic horizons. Niobell and Noonan soils occur on positions similar to Williams soils. They have natric horizons. Parnell and Tonka soils are in nearby depressions. They are poorly and very poorly drained, respectively. Zahl soils are on nearby, steeper, convex slopes. They do not have an argillic horizon.

DRAINAGE AND PERMEABILITY: Well drained. Runoff is negligible to high depending on slope and surface texture. Permeability is moderately slow or slow.

USE AND VEGETATION: Cultivated areas are used for growing small grains, flax, corn, hay or pasture. Native vegetation is western wheatgrass, needle and thread, blue grama, green needlegrass and prairie junegrass.

DISTRIBUTION AND EXTENT: North-central South Dakota, central, and northwestern North Dakota, and northeastern Montana. The soil is extensive.

MLRA SOIL SURVEY REGIONAL OFFICE (MO) RESPONSIBLE: St. Paul, Minnesota

SERIES ESTABLISHED: Williams County, North Dakota, 1906.

REMARKS: Diagnostic horizons and features recognized in this pedon are: mollic epipedon - the zone from the surface of the soil to a depth of 10 inches (Ap and Bt1 horizons); argillic horizon - the zone from 6 to 24 inches (Bt1, Bt2, and Btk horizons).

ADDITIONAL DATA: See data in Soil Survey Investigation Report No. 2.

National Cooperative Soil Survey
U.S.A

Williams Pedon Description

Print Date: Feb. 16, 2023
Description Date: June 2, 2022
Describer: WDB, PFS, LAD, SES
Site ID: S2022ND055001

Soil Survey Area: ND055 -- McLean County, North Dakota
10-BIS -- Bismarck, North Dakota

Pedon ID: S2022ND055001
Quad Name:
Lab Source ID: KSSL

Lab Pedon #: 22N0290
Country:
State: North Dakota
County: McLean
MLRA: 53B – Central Dark Brown Glaciated Plains

Map Unit:

Std Latitude: 47.4595300
Std Longitude: -101.1536000

User Transect ID:
Soil Name as Described/Sampled: Williams
Classification: Fine-loamy, mixed, superactive, frigid Typic Argiustolls
Soil Name as Correlated:
Classification:
Pedon Type: classifies to current taxon name, full description
Pedon Purpose: soil survey inventory
Taxon Kind: series
Associated Soils:
Physiographic Division:
Physiographic Province:
Physiographic Section:
State Physiographic Area:
Local Physiographic Area:
Geomorphic Setting: ground moraine on till plain

Upslope Shape: linear
Cross Slope Shape: linear

Particle Size Control Section: 22 to 72 cm.
Description origin: NASIS
Primary Earth Cover: Crop cover

Secondary Earth Cover: Close-grown crop
Vegetation:
Parent Material: till
Bedrock Kind:
Bedrock Depth:
Bedrock Hardness:
Bedrock Fracture Interval:
Surface Fragments:
Description database: KSSL

Diagnostic Features: mollic epipedon 0 to 22 cm.
argillic horizon 22 to 82 cm.
calcic horizon 51 to 210 cm.
secondary carbonates 51 to 210 cm.

Cont. Site ID: S2022ND055001 **Pedon ID:** S2022ND055001

Slope (%)	Elevation (meters)	Aspect (deg)	MAAT (C)	MSAT (C)	MWAT (C)	MAP (mm)	Frost-Free Days	Drainage Class	Slope Length (meters)	Upslope Length (meters)
4.0								Well drained		

Ap1--0 to 5 centimeters (0.0 to 2.0 inches); very dark gray (10YR 3/1) loam, black (10YR 2/1), moist; 30 percent sand; 25 percent clay; structureless fine cloddy structure; slightly hard, friable, slightly sticky, slightly plastic; common very fine roots; common very fine pores; 1 percent nonflat subrounded indurated 2 to 5-millimeter Mixed rock fragments; noneffervescent, by HCl, 1 normal. Lab sample # 22N01256

Ap2--5 to 10 centimeters (2.0 to 3.9 inches); very dark gray (10YR 3/1) loam, black (10YR 2/1), moist; 30 percent sand; 25 percent clay; structureless fine cloddy structure; slightly hard, friable, slightly sticky, slightly plastic; common very fine roots; common very fine pores; 1 percent nonflat subrounded indurated 2 to 5-millimeter Mixed rock fragments; noneffervescent, by HCl, 1 normal. Lab sample # 22N01257

Ap3--10 to 22 centimeters (3.9 to 8.7 inches); very dark gray (10YR 3/1) loam, black (10YR 2/1), moist; 30 percent sand; 25 percent clay; weak medium subangular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; common very fine roots; common very fine pores; 1 percent nonflat subrounded indurated 2 to 20-millimeter Mixed rock fragments; noneffervescent, by HCl, 1 normal. Lab sample # 22N01258

Bt--22 to 51 centimeters (8.7 to 20.1 inches); clay loam, brown (10YR 4/3), moist; 38 percent sand; 33 percent clay; moderate medium prismatic parts to moderate medium subangular blocky structure; moderately hard, friable, moderately sticky, moderately plastic; common very fine roots; common very fine pores; 25 percent distinct 10YR 3/2), moist, clay films on all faces of peds; 3 percent nonflat subrounded indurated 2 to 10-millimeter Mixed rock fragments; noneffervescent, by HCl, 1 normal. Lab sample # 22N01259

Btk--51 to 82 centimeters (20.1 to 32.3 inches); clay loam, brown (10YR 5/3), moist; 37 percent sand; 34 percent clay; moderate medium prismatic parts to moderate medium subangular blocky structure; moderately hard, friable, moderately sticky, moderately plastic; common very fine roots; common very fine pores; 25 percent faint 10YR 4/2) clay films on bottom faces of peds; 1 percent fine 10YR 7/2) carbonate masses on vertical faces of peds and 1 percent fine 10YR 7/2) carbonate masses around rock fragments; 2 percent nonflat subrounded indurated 2 to 5-millimeter Mixed rock fragments; strong effervescence, by HCl, 1 normal. Lab sample # 22N01260

Bk--82 to 110 centimeters (32.3 to 43.3 inches); clay loam, olive brown (2.5Y 4/3), moist; 39 percent sand; 32 percent clay; 1 percent fine prominent (5YR 4/6) mottles; moderate medium subangular blocky structure; moderately hard, friable, moderately sticky, moderately plastic; common very fine roots; common very fine pores; 1 percent distinct 10YR 2/2), moist, organic stains on all faces of peds; 7 percent medium distinct iron-manganese concretions On faces of peds; 8 percent fine 10YR 7/2) carbonate masses on vertical faces of peds and 1 percent fine 10YR 7/2) carbonate masses around rock fragments; 5 percent nonflat subrounded indurated 2 to 5-millimeter Mixed rock fragments; violent effervescence, by HCl, 1 normal. Lab sample # 22N01261

BCk--110 to 210 centimeters (43.3 to 82.7 inches); clay loam, olive brown (2.5Y 4/3), moist; 36 percent sand; 32 percent clay; 1 percent fine prominent (5YR 4/6) mottles; moderate medium subangular blocky structure; moderately hard, friable, moderately sticky, moderately plastic; 7 percent medium distinct iron- manganese concretions On faces of peds and 7 percent medium distinct iron depletions On faces of peds; 8 percent fine threadlike 10YR 7/2) carbonate masses on bottom of rock fragments and 7 percent fine threadlike carbonate masses on surfaces along pores; 5 percent nonflat subrounded indurated 2 to 20-millimeter Mixed rock fragments; strong effervescence, by HCl, 1 normal. Lab sample # 22N01262

Pedon ID: S2022ND055001
Sampled Date: 6/2/2022
Series: Williams
Classification: Fine-loamy, mixed, superactive, frigid Typic Argiustoll

Particle Size Control Section: 22-72
Clay Weighted Average: 33
CEC Activity, CEC7/Clay, Weighted Average: 0.6

Horizon	Depth	Texture	Clay (%)	Silt (%)	Sand (%)	Core Db (g/cm-3)	Est. OC (%)	Fine Silt (%)	Coarse Silt (%)	V. Fine Sand (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	V. Coarse Sand (%)	Coarse Fragments (%)
Ap1	0-5	l	26.8	35.7	37.5	1.27	3.4	18.5	17.2	9.6	15.1	9	2.7	1.1	4
Ap2	5-10	l	26.7	34.2	39.1	1.32	2.9	17.5	16.7	9.9	15.1	10.2	2.5	1.4	8
Ap3	10-22	cl	27.2	31.1	41.7	1.55	1.7	15.6	15.5	9.2	17	10.7	2.8	2	12
Bt	22-51	cl	29.1	28.1	42.8	1.17	1.2	14.9	13.2	9.7	17.3	10.2	3.9	1.7	7
Btk	51-82	cl	38.3	33.5	28.2	1.64	0.8	23.3	10.2	6.6	11.2	6.6	2.7	1.1	8
Bk	82-110	cl	34.4	32.8	32.8	1.35	0.4	23.8	9	7.6	11.5	7.5	3.4	2.8	18
BCk	110-210	cl	34.7	34.8	30.5	1.55	0.4	24.7	10.1	8.1	11.6	6.4	2.3	2.1	10

Horizon	Depth	CEC7 (cmo/kg)	CEC7/Clay	Base Saturation (%)	EC (dS/m)	ESP (%)	SAR	Ext. Ca (cmol/kg)	Ext. Mg (cmol/kg)	Ext. Na (cmol/kg)	Ext. Acidity (cmol/kg)	pH Water	CaCO3 (%)
Ap1	0-5	23	0.86	100	1.58	-	tr	29.4	5.3	tr	3.8	7.5	1
Ap2	5-10	22.5	0.84	100	0.68	-	tr	33.3	5.2	tr	3.6	7.8	1
Ap3	10-22	21.2	0.78	100	-	tr	-	23.1	5.2	tr	3.8	7.9	1
Bt	22-51	20.5	0.70	100	-	tr	-	22.0	6.1	tr	4.6	7.9	tr
Btk	51-82	17.8	0.46	100	-	tr	-	116.7	12.8	0.1	-	8.4	24
Bk	82-110	17.2	0.50	100	-	1	-	100.2	20.7	0.2	-	8.6	20
BCk	110-210	16.6	0.48	100	0.74	3	2	76.5	25.3	0.7	-	8.7	15

USDA NRCS, MLRA 53B — Loamy Ecological Site Description

Site stage*:* Provisional

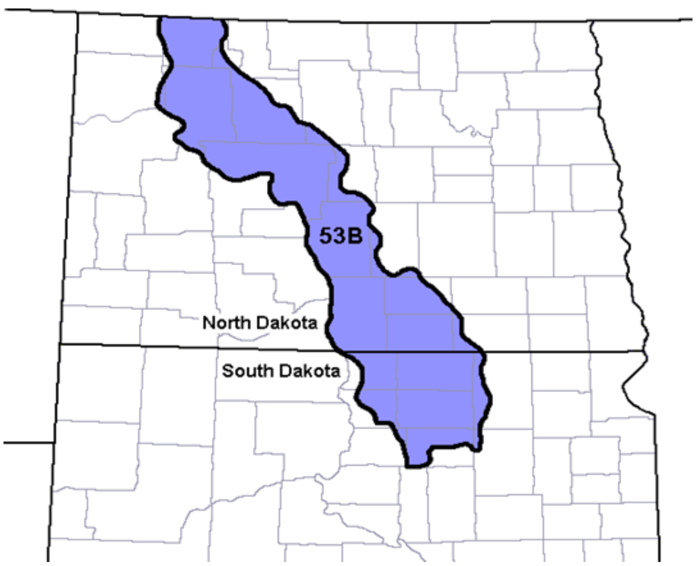
Provisional: An Ecological Site Description (ESD) at the provisional status represents the lowest tier of documentation that is releasable to the public. It contains a grouping of soil units that respond similarly to ecological processes. The ESD contains 1) enough information to distinguish it from similar and associated ecological sites and 2) a draft state and transition model capturing the ecological processes and vegetative states and community phases as they are currently conceptualized. The provisional ESD has undergone both quality control and quality assurance protocols. It is expected that the provisional ESD will continue refinement towards an approved status.

Scan the QR code for the full ecological site description.

Site Name: Loamy

Site Type: Rangeland

Site ID: R053BY011ND



Location of MLRA 53B, Central Dark Brown Glaciated Plains in North Dakota and South Dakota.

Ecological Site Concept

The Loamy ecological site typically is located on uplands – on linear rises and backslopes of till plains, lake plains, and sedimentary plains. Some areas of moraines are covered with silty loess. The site also occurs on flats on outwash plains and on terraces which are no longer impacted by frequent flooding. The soils are moderately deep to very deep. In moderately deep soils, weathered siltstone, mudstone, sandstone, or shale (Cr horizon) occurs at a depth of 20 to 40 inches which affects root growth. On outwash plains, the depth to sand is >20 inches. The thickness of the dark-colored surface soil typically is 7 inches or more; however, it may be as thin as 4 inches in some soils. Surface textures typically are loam or silt loam; but clay loam, silty clay loam, and fine sandy loam also occur. The subsoil is loam, clay loam, silt loam, or silty clay loam (forms a ribbon 1 to 2 inches long). Soil on this site is moderately well drained or well drained. Generally, the depth to effervescence exceeds 12 inches; however, very slight effervescence is allowable where the depth to a layer of accumulated carbonate (strong or violent effervescence) is >20 inches. Soil salinity, typically, is none to very slight in the upper 20 inches, but below that depth may increase to moderate in some soils. On the landscape, this site is below the Thin Loamy, Shallow Loamy, and Shallow Gravel ecological sites and above the Loamy Overflow, Claypan, Wet Meadow, and Shallow Marsh sites. The Clayey and Sandy ecological sites occur on similar landscape positions. The subsoil of the Clayey site forms a ribbon >2 inches long; on the Sandy site, it forms a ribbon <1 inch long. The transition between Loamy and Thin Loamy sites is determined by depth to accumulated carbonates. Soils with strong or violent effervescence within a depth of 8 inches are included in Thin Loamy - even where a thin, non-calcareous subsoil layer occurs above the calcic layer. This soil profile occurs most commonly where there has been cultivation at some time, but it also occurs in some soils in native grass.

Photo courtesy of North Dakota Ducks Unlimited

Physiographic Features

This site typically occurs on level to very steep uplands – till plains, lake plains, outwash plains, and sedimentary plains; some areas of till plains are covered with silty loess. It also occurs on some level to nearly level terraces. Slopes range from 0 to 25 percent. The parent material incudes till, glaciolacustrine deposits, glaciofluvial deposits, weathered residuum (stratified siltstone, mudstone, and sandstone), loess, and alluvium.

Landform: 1) Till plain
2) Lake plain
3) Sedimentary plain
4) Outwash plain
5) Terraces

	Minimum	**Maximum**
Elevation (feet):	1,280	2,560
Slope (percent):	0	25
Water table depth (inches):	42	>80
Flooding		
Frequency:	None	Occasional
Duration:	None	Brief
Ponding		
Frequency:	None	None
Runoff class:	Low	High
Aspect:	No Influence on this site.	

Representative Soil Features

Soils associated with the Loamy ES are in the Mollisol order which are classified further as Typic Argiustolls, Pachic Argiustolls, Typic Haplustolls, Pachic Haplustolls, and Cumulic Haplstolls. These soils were developed under prairie vegetation. They formed in glacial till (some covered with loess), glaciolacustrine sediments, glaciofluvial deposits, alluvium, or in weathered residuum. The soils on this site are very deep to moderately deep. Moderately deep soils typically have siltstone, mudstone, or sandstone starting between a depth of 20 and 40 inches; a few soils have shale at those depths. Also, some soils have sand and gravel below a depth of 20 inches. The soils are well drained or moderately well drained – redoximorphic features, where present, are below a depth of 3.5 feet.

Surface textures most commonly are loam or silt loam; but silty clay loam and clay loam are included. Also, fine sandy loam is allowable where it is <10 inches thick. The surface soil, typically, is 5 to 16 inches thick.

Major soil series correlated to the Loamy site are Amor, Bowdle, Bryant, Falkirk, Farland, Farnuf, Felor, Grassna, Greenway, Linton, Makoti, Mandan, Max, Morton, Omio, Reeder, Roseglen, Sen, Shambo, Stady, Straw (rare to occasionally flooded), Tansem, Temvik, Vida, Williams, and Wilton. Also, Arnegard and Bowbells series with slope >6 percent or not in a run-on landscape position are correlated to the Loamy site. Also, taxadjuncts of the Agar, Akaska, Eakin, and Highmore series (established in mesic temp regime) and of the Eckman, Edgeley, Emrick, and Heimdal series (established in udic moisture regime) are included. In addition, non-calcareous phases of the Boxcut, Coleharbor, Kniferiver, and Square Butte series are included (see Site Development and Testing Plan).

Access Web Soil Survey at https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx for specific local soils information.

Parent Material Kind: glacial till, glaciolacustrine deposits, loess, glaciofluvial deposits, alluvium, residuum
Parent Material Origin: till, lacustrine, outwash, residuum
Surface Texture: (1) loam
(2) silt loam
(3) silty clay loam
(4) clay loam
Surface Texture Modifier: none, stony, very stony
Subsurface texture group: Loamy
Surface fragments <3” (%cover): 0-15
Surface fragments >3” (%cover): 0-10
Subsurface fragments <=3” (% volume): 0-15
Subsurface fragments >3” (%volume): 0-25

	Minimum	Maximum
Drainage class:	Moderately well drained	Well drained
Permeability Class*:	Moderately slow	moderate
Depth to first restrictive layer (inches)	20	>80
Electrical Conductivity (dS/m)*,*:**	0	4
Sodium Absorption Ratio:**	0	5
Soil Reaction (1:1 Water)*:	6.1	8.4
Soil Reaction (0.1M CaCl2):	NA	NA
Available Water Capacity (inches):	5	9
Calcium Carbonate Equivalent (percent):**	0	30

**These attributes represent from 0-20 inches.*
***This attribute represents from 0-40 inches or to the first restrictive layer.*
****Electrical Conductivity (E.C.) values are based on Saturated Paste method; the commonly used 1:1 field method will likely have E.C. values <2.*

Plant Communities

Ecological Dynamics of the Site:

This ecological site description is based on nonequilibrium ecology and resilience theory and utilizes a State-and-Transition Model (STM) diagram to organize and communicate information about ecosystem change as a basis for management. The ecological dynamics characterized by the STM diagram reflect how changes in ecological drivers, feedback mechanisms, and controlling variables can maintain or induce changes in plant community composition (phases and/or states). The application of various management actions, coupled with weather variables, impact the ecological processes which influence the competitive interactions thereby maintaining or altering plant community structure.

Prior to European influence, the historical disturbance regime for MLRA 53B included frequent fires, both anthropogenic and natural in origin. Most fires, however, were anthropogenic fires set by Native Americans. Native Americans set fires in all months except perhaps January. These fires occurred in two peak periods, one from March-May with the peak in April and another from July-November with the peak occurring in October. Most of these fires were scattered and of small extent and duration. The grazing history would have involved grazing and browsing by large herbivores such as American bison, elk, and whitetail deer. Herbivory by small mammals, insects, nematodes, and other invertebrates are also important factors influencing the production and composition of the communities. Grazing and fire interaction, particularly when coupled with drought events, influenced the dynamics discussed and displayed in the following state and transition diagram and descriptions.

Following European influence, this ecological site generally has had a history of grazing by domestic livestock, particularly cattle, which along with other related activities (e.g., fencing, water development, fire suppression) has changed the disturbance regime of the site. Changes will occur in the plant communities due to these and other factors.

Weather fluctuations coupled with managerial factors may lead to changes in the plant communities and may, under adverse impacts, result in a slow decline in vegetative vigor and composition. However, under favorable conditions the botanical composition may resemble that prior to European influence.

Four vegetative states have been identified for the site (Reference, Native/Invaded, Invaded, and Go-Back). Within each state one or more community phases have been identified. These community phases are named based on the more dominant and visually conspicuous species; they have been determined by study of historical documents, relict areas, scientific studies, and ecological aspects of plant species and plant communities. Transitional pathways and thresholds have been determined through similar methods.

State 1: Reference State represents the natural range of variability that dominated the dynamics of this ecological site prior to European influence. Dynamics of the state were largely determined by variations in climate and weather (e.g., drought) as well as that of fire (e.g., timing, frequency) and grazing by native herbivores (e.g., frequency, intensity, selectivity). Due to those variations, the Reference State is thought to have shifted temporally and spatially between two plant community phases.

Currently the primary disturbances are due to the widespread introduction of exotic species, concentrated livestock grazing, lack of fire, and perhaps long-term non-use and no fire. Because of these changes (particularly the widespread occurrence of exotic species), as well as other environmental changes, the Reference State is considered to no longer exist. Thus, the presence of exotic species on the site precludes it from being placed in the Reference State. It must then be placed in one of the other states, most commonly State 2: Native/Invaded State (T1A).

State 2: Native/Invaded State: Colonization of the site by exotic species results in a transition from State 1: Reference State to State 2: Native/Invaded State (T1A). This transition was probably inevitable; it often resulted from colonization by exotic cool-season grasses such as

Kentucky bluegrass, smooth brome, and/or quackgrass which have been particularly and consistently invasive under extended periods of no use and no fire. Other exotics such as Canada thistle and leafy spurge are also known to invade the site.

Three community phases have been identified for this state and are similar to the community phases in the Reference State but have now been invaded by exotic cool-season grasses. These exotic cool-season grasses can be expected to increase. As that increase occurs, plants more desirable to wildlife and livestock may decline. A decline in forb diversity can also be expected. Under non-use or minimal use management, mulch increases and may become a physical barrier to plant growth. It also changes the micro-climate near the soil surface and may alter infiltration, nutrient cycling, and biological activity near the soil surface. As a result, these factors combined with shading cause desirable native plants to have increasing difficulty remaining viable and recruitment declines.

To slow or limit the invasion of these exotic grasses or other exotic plants, it is imperative that managerial options (e.g., prescribed grazing, prescribed burning) be carefully constructed and evaluated with respect to that objective. If management does not include measures to control or reduce these exotic plants, the transition to State 3: Invaded State should be expected (T2A). The threshold to this transition is reached when the exotic cool-season grasses exceed 30% of the plant community and native grasses represent less than 40% of the community.

State 3: Invaded State. The threshold for this state is reached when the exotic cool-season grasses (e.g., Kentucky bluegrass, smooth brome, quackgrass) exceed 30% of the plant community and native grasses represent less than 40% of the community. One community phase has been identified for this state.

The exotic cool-season grasses can be quite invasive and often form monotypic stands. As they increase, both forage quantity and quality of the annual production becomes increasingly restricted to late spring and early summer even though annual production may increase. Forb diversity often declines. Under non-use or minimal use management, mulch can increase and become a physical barrier to plant growth, altering nutrient cycling, infiltration, and soil biological activity. As such, desirable native plants become increasingly displaced.

Once the state is well established, prescribed burning and prescribed grazing techniques have been largely ineffective in suppressing or eliminating the exotic cool-season grasses, even though some short-term reductions may appear successful. However, assuming there is an adequate component of native grasses to respond to treatments, a restoration pathway to State

2: Native/Invaded State may be accomplished with the implementation of long-term prescribed grazing in conjunction with prescribed burning (R3A).

State 4: Go-Back State often results from cropland abandonment and consists of only one community phase. This weedy assemblage may include noxious weeds that need control. Over time, the exotic cool-season grasses Kentucky bluegrass, smooth brome, and/or quackgrass will likely predominate.

Initially, due to extensive bare ground and a preponderance of shallow rooted annual plants the potential for soil erosion is high. Plant species richness may be high, but overall diversity (i.e., equitability) is typically low, with the site dominated by a relatively small assemblage of species. Due to the lack of native perennials and other factors, restoring the site with the associated ecological processes is difficult. However, a successful range planting may result in something approaching State 2: Native/Invaded State (R4A). Following seeding, prescribed grazing, prescribed burning, haying, and the use of herbicides will generally be necessary to achieve the desired result and control weeds, some of which may be noxious weeds. A failed range planting and/or secondary succession will lead to State 4: Invaded State (R4B).

The following state and transition model diagram illustrates the common states, community phases, community pathways, transition and restoration pathways that can occur on the site. These are the most common plant community phases and states based on current knowledge and experience; changes may be made as more data are collected. Pathway narratives describing the site's ecological dynamics reference various management practices (e.g., prescribed grazing, prescribed burning, brush management, herbaceous weed treatment) which, if properly designed and implemented, will positively influence plant community competitive interactions. The design of these management practices will be site specific and should be developed by knowledgeable individuals; based upon management goals and a resource inventory; and supported by an ongoing monitoring protocol.

When the management goal is to maintain an existing plant community phase or restore to another phase within the same state, modification of existing management to ensure native species have the competitive advantage may be required. To restore a previous state, the application of two or more management practices in an ongoing manner will be required. Whether using prescribed grazing, prescribed burning, or a combination of both with or without additional practices (e.g., brush management), the timing and method of application needs to favor the native species over the exotic species. Adjustments to account for variations in annual growing conditions and implementing an ongoing monitoring protocol to track changes and adjust management inputs to ensure desired outcome will be necessary.

The plant community phase composition table(s) has been developed from the best available knowledge including research, historical records, clipping studies, and inventory records. As more data are collected, plant community species composition and production information may be revised.

Plant Communities and Transitional Pathways

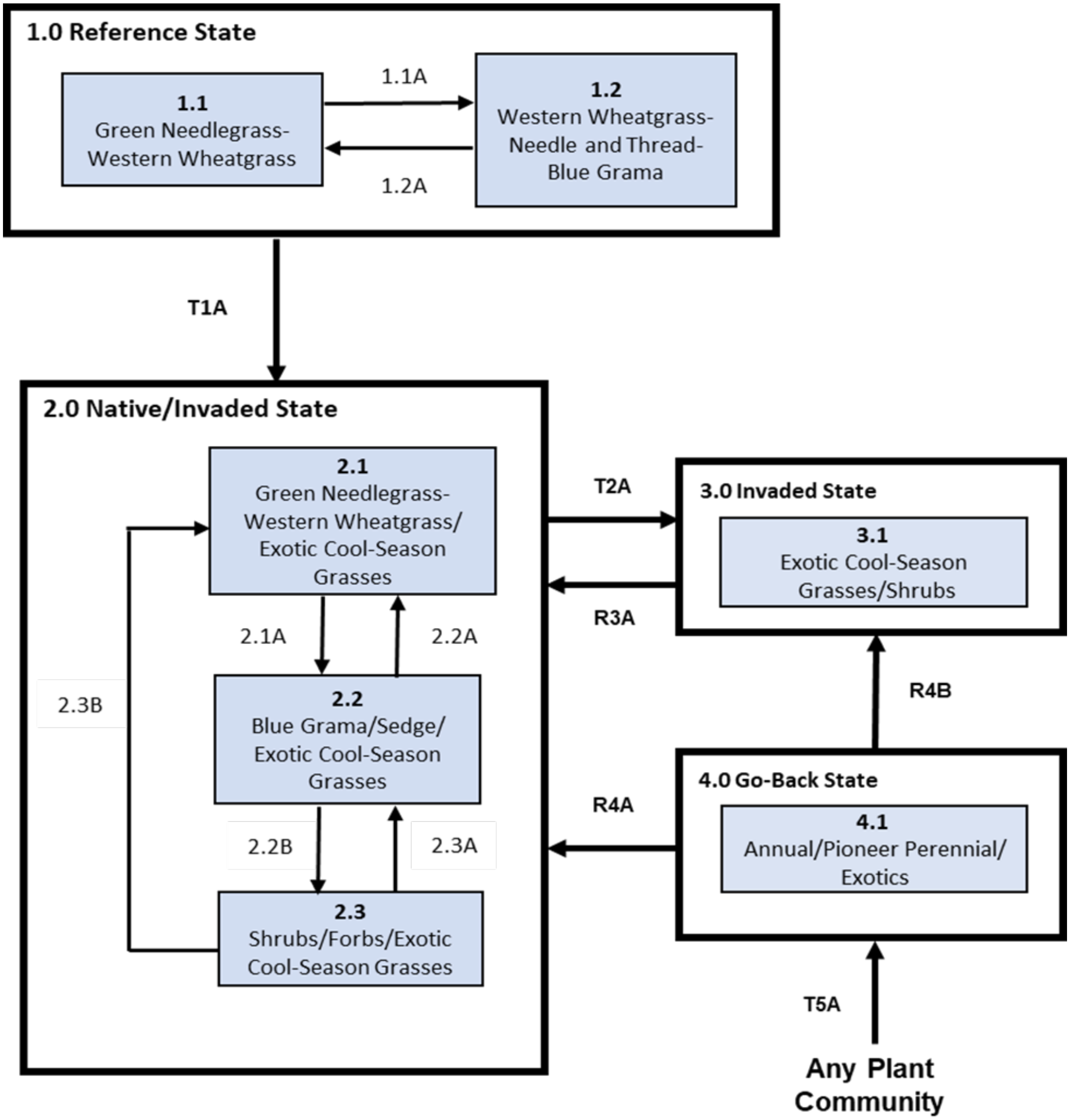


Diagram Legend - MLRA 53B Loamy

T1A	Introduction of exotic cool-season grasses
T2A	Extended periods of non-use or very light grazing, no fire
T5A	Cessation of annual cropping
R3A	Long term prescribed grazing with prescribed burning
R4A	Successful range planting with prescribed grazing and prescribed fire
R4B	Failed range planting
CP 1.1 - 1.2 (1.1A)	Extended drought with/without heavy, long-term grazing
CP 1.2 - 1.1 (1.2A)	Return to average growing conditions and reduced grazing pressure
CP 2.1 - 2.2 (2.1A)	Heavy season-long grazing with or without drought
CP 2.2 - 2.1 (2.2A)	Reduced grazing pressure and return to average precipitation
CP 2.2 - 2.3 (2.2B)	Extended periods of non-use or very light grazing, no fire
CP 2.3 - 2.2 (2.3A)	Heavy season-long grazing with prescribed burning
CP 2.3 - 2.1 (2.3B)	Long term prescribed grazing with prescribed burning

Diagram Legend - MLRA 53B Loamy

T1A	Introduction of exotic cool-season grasses
T2A	Extended periods of non-use or very light grazing, no fire
T5A	Cessation of annual cropping
R3A	Long term prescribed grazing with prescribed burning
R4A	Successful range planting with prescribed grazing and prescribed fire
R4B	Failed range planting
CP 1.1 - 1.2 (1.1A)	Extended drought with/without heavy, long-term grazing
CP 1.2 - 1.1 (1.2A)	Return to average growing conditions and reduced grazing pressure
CP 2.1 - 2.2 (2.1A)	Heavy season-long grazing with or without drought
CP 2.2 - 2.1 (2.2A)	Reduced grazing pressure and return to average precipitation
CP 2.2 - 2.3 (2.2B)	Extended periods of non-use or very light grazing, no fire
CP 2.3 - 2.2 (2.3A)	Prescribed grazing which may include heavy season-long grazing with prescribed burning
CP 2.3 - 2.1 (2.3B)	Long term prescribed grazing with prescribed burning

Plant Community Composition and Group Annual Production

COMMON/GROUP NAME	SYMBOL	Group	Green Needlegrass-Western Wheatgrass lbs./acre	Green Needlegrass-Western Wheatgrass % Comp
GRASSES & GRASS-LIKES			*1800 - 2040*	*75 - 85*
WHEATGRASS		**1**	**240 - 480**	**10 - 20**
western wheatgrass	PASM	1	120 - 480	5 - 20
slender wheatgrass	ELTR7	1	120 - 360	5 - 15
bearded wheatgrass	ELTRS	1	48 - 240	2 - 10
NEEDLEGRASS		**2**	**360 - 720**	**15 - 30**
green needlegrass	NAVI4	2	120 - 480	5 - 20
needle and thread	HECOC8	2	120 - 240	5 - 10
porcupinegrass	HESP11	2	120 - 240	5 - 10
shortbristle needle and thread	HECU9	2	0 - 240	0 - 10
SHORT WARM-SEASON GRASSES		**3**	**120 - 240**	**5 - 10**
blue grama	BOGR2	3	120 - 240	5 - 10
TALL/MID WARM-SEASON GRASSES		**4**	**120 - 360**	**5 - 15**
big bluestem	ANGE	4	48 - 240	2 - 10
sideoats grama	BOCU	4	48 - 240	2 - 10
prairie dropseed	SPHE	4	0 - 120	0 - 5
little bluestem	SCSC	4	0 - 120	0 - 5
OTHER NATIVE PERENNIALS		**5**	**48 - 120**	**2 - 5**
plains reedgrass	CAMO	5	24 - 120	1 - 5
prairie Junegrass	KOMA	5	24 - 72	1 - 3
Fendler threeawn	ARPUL	5	0 - 24	0 - 1
other perennial grasses	2GP	5	0 - 72	0 - 3
GRASS-LIKES		**6**	**24 - 120**	**1 - 5**
needleleaf sedge	CADU6	6	24 - 120	1 - 5
threadleaf sedge	CAFI	6	24 - 120	1 - 5
other grass-likes	2GL	6	24 - 120	1 - 5
FORBS		*7*	*120 - 240*	*5 - 10*
American vetch	VIAM	7	24 - 48	1 - 2
common yarrow	ACMI2	7	24 - 48	1 - 2
white sagebrush	ARLU	7	24 - 48	1 - 2
purple prairie clover	DAPU5	7	24 - 48	1 - 2
hairy false goldenaster	HEVIV	7	24 - 48	1 - 2
gayfeather	LIATR	7	24 - 48	1 - 2
silverleaf Indian breadroot	PEAR6	7	24 - 48	1 - 2
upright prairie coneflower	RACO3	7	24 - 48	1 - 2
white heath aster	SYER	7	24 - 48	1 - 2
goldenrod	SOLID	7	0 - 48	0 - 2
Cuman ragweed	AMPS	7	0 - 24	0 - 1
tarragon	ARDR4	7	0 - 24	0 - 1
sanddune wallflower	ERCAC	7	0 - 24	0 - 1
rush skeletonplant	LYJU	7	0 - 24	0 - 1
scarlet globemallow	SPCO	7	0 - 24	0 - 1
other native forbs	2FORB	7	0 - 120	0 - 5
SHRUBS		*8*	*24 - 120*	*1 - 5*
western snowberry	SYOC	8	24 - 72	1 - 3
prairie sagewort	ARFR4	8	24 - 48	1 - 2
leadplant	AMCA6	8	0 - 48	0 - 2
prairie rose	ROAR3	8	0 - 48	0 - 2
other shrubs	2SHRUB	8	0 - 48	0 - 2

Annual Production lbs./acre	LOW	RV	HIGH
GRASSES & GRASS-LIKES	1265	2148	3025
FORBS	115	180	250
SHRUBS	20	72	125
TOTAL	1400	2400	3400

This list of plants and their relative proportions are based on near normal years. Fluctuations in species composition and relative produ
may change from year to year dependent upon precipitation or other climatic factors. RV = Representative Value.

ARS – Northern Great Plains Research Laboratory

The North Great Plains Research Laboratory (NGPRL) in Mandan, North Dakota, is one of more than 120 Agricultural Research Service (ARS) facilities in the U.S.

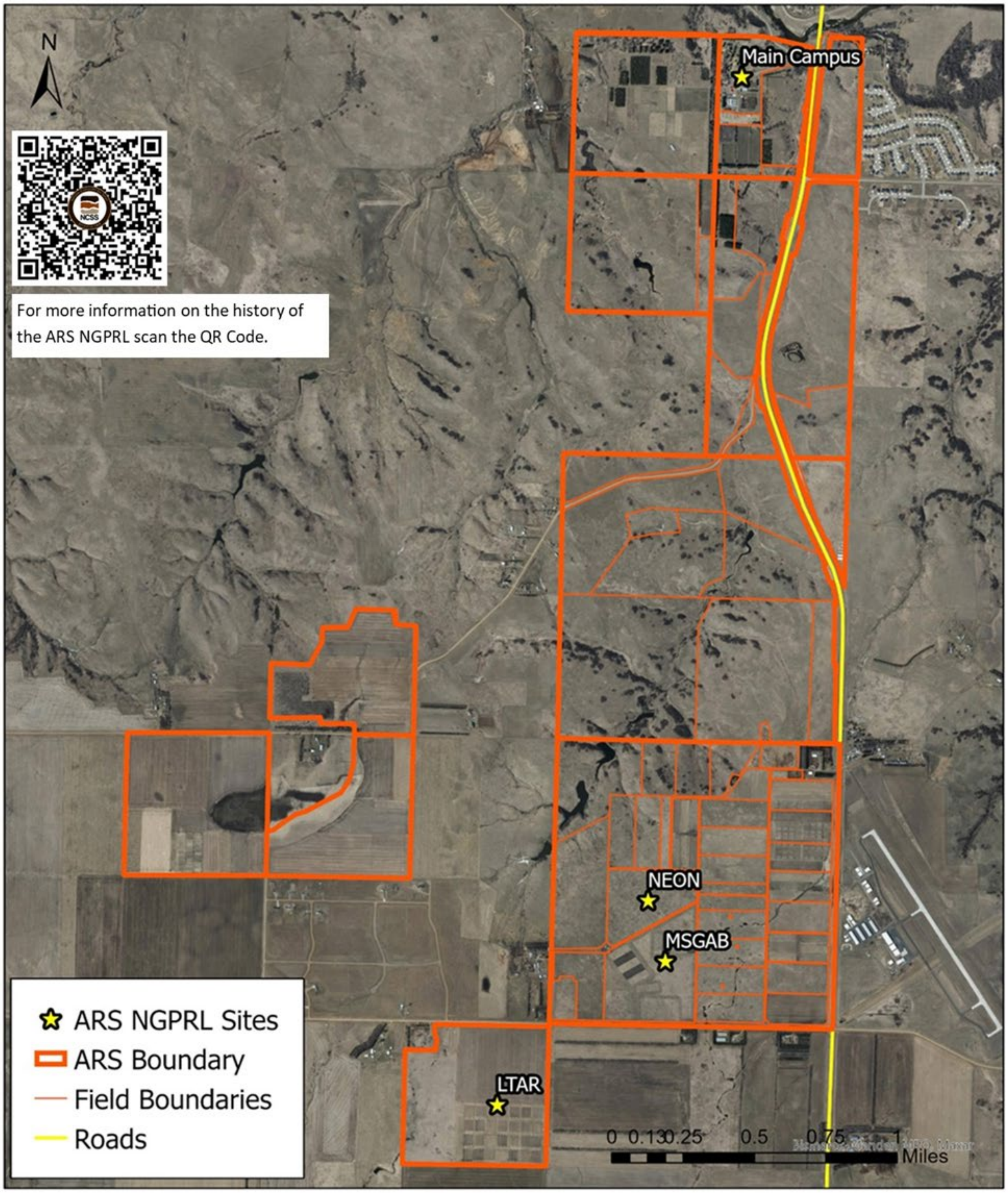
The NGPRL was established by Congress on August 8, 1912, to respond to the needs of farmers and ranchers of the Northern Plains. Research began in 1914 on vegetables, shrubs, ornamentals, berries, fruits, wheat, flax, forages, grazing management, windbreaks, and forestry.

Research programs have changed significantly through the years to address the ever-changing needs of our customers. Programs to evaluate trees and shrubs for windbreaks, to develop methods to reclaim mine-land spoils and to examine the feasibility of dairy production in the Northern Great Plains have been replaced with new long-term research. Modern lines of research include global climate change, biofuel production, dryland cropping, forage production, and rangeland management.

The current vision of the Laboratory is the development of economically and environmentally sustainable integrated crop and livestock management systems to help preserve the family farm.

Mission — To develop environmentally sound practices and add value to agricultural systems in the Great Plains in terms of food, feed, and biomass by conducting team-focused, systems-oriented research and technology transfer.

ARS NGPRL Tour Locations



National Ecological Observatory Network

The National Science Foundation's National Ecological Observatory Network (NEON) is a continental-scale observation facility operated by Battelle and designed to collect long-term open access ecological data. The Observatory's comprehensive design supports greater understanding of ecological change and enables forecasting of future ecological conditions in the United States.

NEON statistically partitioned the continental U.S., Hawaii, and Puerto Rico into 20 ecoclimatic Domains that represent distinct regions of vegetation, landforms, and ecosystem dynamics to capture the full range of U.S. ecological and climatic diversity. In each Domain, NEON collects data on plants, animals, soil, nutrients, freshwater, and the atmosphere using sensor measurements and field observations. Airborne remoted sensing data combined with local, site-level data capture contiguous site-level information and can be combined with existing satellite data to support regional to continental characterization of ecological processes.

81 Field Sites — 47 terrestrial, 34 aquatic **20** Ecoclimate domains **25** States with sites

Consistent, comparable, high-quality data

NEON assures high-quality, comparable data through standardized and quality-controlled data collection and processing methods. The Observatory employs multidisciplinary experts to design and implement infrastructure that provides high-quality data and associated documentation to the community.

Integrated data collection

NEON collects integrated biological, physical, and chemical measurements and samples at all of its field sites using a combination of field-based protocols, as well as in situ and remote sensing methods and technologies, to support the study of complex ecological processes. This coordinated data collection strategy uniquely addresses ecosystem level questions in several key themes, such as biogeochemistry and ecohydrology.


Tick sampling, D19 Healy, Alaska

Open data and samples

All NEON data are free and open data to everyone. Our data products are downloadable in standard formats that are in general use throughout the scientific community. NEON also provides documentation and tutorials to support understanding and interpretation of our data products. The NEON Biorepository is built to house millions of samples collected at our field sites over the course of NEON's lifetime. These samples are available to be loaned to researchers for study, including for destructive purposes.

to learn more and explore the resources, visit **NEONScience.org**

NEON by the Numbers

~600 total staff

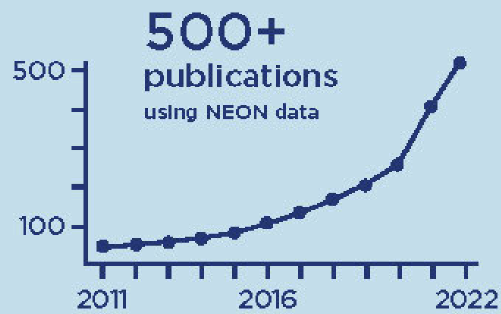
full time staff 320+

250-290 seasonal Domain techs

180+ data products

100,000+ added samples per year

260,000+ samples to date



3 airborne observation platforms
5 mobile deployment platforms
47 flux towers
57 water quality stations

89 meteorological stations
197 groundwater wells
235 soil sensor arrays

A 30+ Year NSF Observatory

As ecosystems in the United States change, NEON plays a fundamental role in our ability to sustainably manage natural resources and support science related to climate resilience. Battelle is proud to manage NEON, one of the most ambitious ecology programs of all time. Since Battelle assumed management for NEON from the National Science Foundation (NSF) in 2016, we:

- Completed the construction of the entire Observatory.
- Transitioned all 81 field sites to successful operation.
- Established NEON as a crucial source of knowledge in our understanding of the dependencies between life and environment.
- Helped the entire program navigate COVID-19 while maintaining all

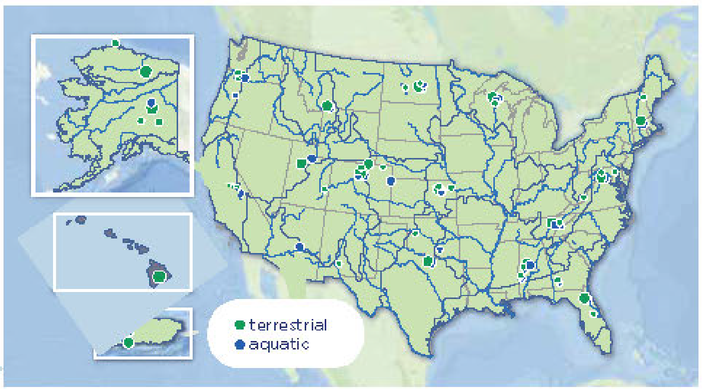
Instrumented buoy system, D05 Crampton Lake, Wisconsin

Battelle's expertise in large research infrastructures has proven to be invaluable to the successful launch and continuation of NEON. Our unique knowledge is critical to ensure the longevity of one of the world's most ambitious ecological data endeavors.

to learn more and explore the resources, visit **NEONScience.org**

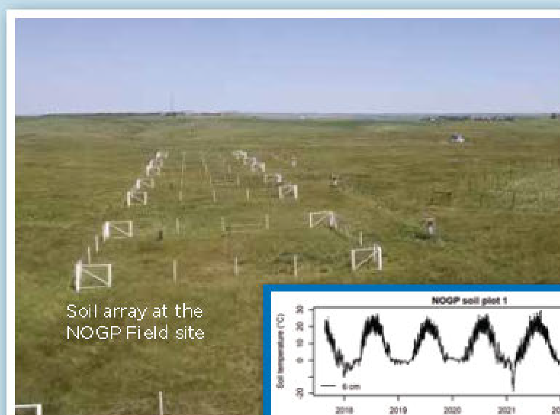
NEON Science at Northern Great Plains Research Laboratory

Funded by the National Science Foundation (NSF) and proudly operated by Battelle, the National Ecological Observatory Network (NEON) program provides open, continental-scale data across the United States to characterize and quantify complex, rapidly changing ecological processes. The Observatory's comprehensive design supports greater understanding of ecological change and enables forecasting of future ecological conditions. NEON collects and processes data from field sites located across the continental U.S., Puerto Rico, and Hawaii over a 30-year timeframe. NEON provides free and open data that characterize plants, animals, soil, nutrients, freshwater, and the atmosphere. These data may be combined with external datasets or data collected by individual researchers to support the study of continental-scale ecological change. NEON's field site at USDA ARS Northern Great Plains Research Laboratory (NOGP) is one of the nodes in this vast, continental-scale network of free and open ecological data.

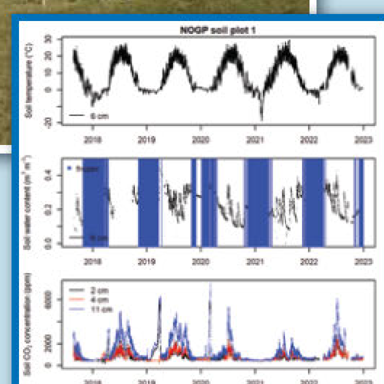


Sensors

NEON collects data about soil using in situ sensors and soil samples collected by technicians at our field sites. The soil sensor assembly includes five soil plots containing a suite of sensors measuring above and below ground variables. The plots are typically arranged along a transect within the locally dominant (~1-km2 scale) soil type and spaced up to 40m apart. Meteorological data includes photosynthetically active radiation, net radiation, infrared temperature, relative humidity, and throughfall precipitation. Belowground, vertical profiles of soil temperature (nine or fewer sensors per plot), moisture (eight or fewer sensors per plot), and CO2 concentration (three sensors per plot) are measured in each plot, with measurement depths based on absolute soil depth, soil horizon thicknesses, and other soil properties. Soil heat flux is measured 5 cm below the soil surface in three of the soil plots. Data are published at 1- and 30-minute averaging intervals. Additional information on soil measurements is available on the Soil Sensors webpage.



Soil array at the NOGP Field site



Time series of soil temperature (top), soil moisture (middle) and soil CO_2 concentrations (bottom) for NOGP soil plot 1

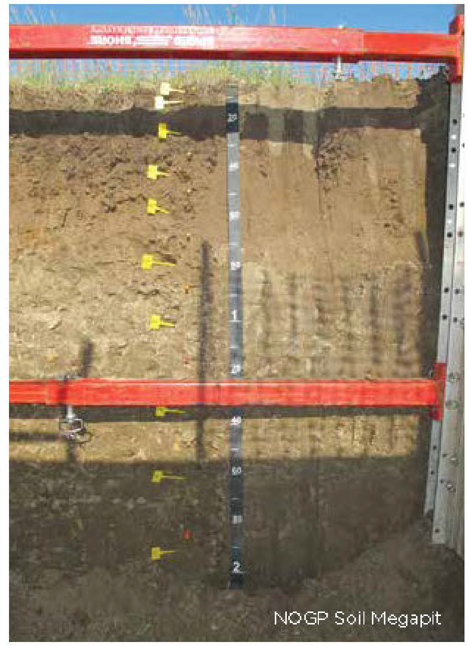
To learn more and explore the resources, visit **NEONScience.org**

Samples

Soil observational sampling at NEON terrestrial field sites occurs in close proximity to organismal sampling and within the airshed of the instrumented towers, with the goal of allowing connectivity between atmospheric, aboveground, and belowground measurements. Biotic and abiotic elements of soil affect the movement and availability of water and elements across ecosystems, determine the availability of nutrients to vegetation and organisms, and play a central role in the global carbon cycle.

Initial Soil Characterization

During site construction of all terrestrial field sites, NEON collected soil from each horizon at a single, temporary soil pit, called the "Megapit." The pit was located in the locally dominant soil type, near the meteorological tower (or flux tower), and was selected to be broadly representative of the soil sensor locations. The Megapit at NOGP was sampled to 2m and included 10 pedogenic horizons. Root biomass was measured along with soil physical and chemical properties. In addition to the Megapits, NEON collected soil pit samples from 18, 1 m deep pits distributed throughout the site for a one-time characterization of site-wide soil properties. For both efforts, NEON worked with the U.S. Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS), and the Kellogg Soil Survey Laboratory to assess soil taxonomy and perform a suite of chemical and physical analyses on each soil sample. Archive material from these collections is available for additional analyses upon request.


NOGP Soil Megapit

Periodic Soil Sampling

Every year, field technicians collect soil cores from plots in the tower airshed as well as plots distributed across the landscape in each terrestrial site. Plots are 40 x 40 m and split into four quadrants: three are randomly selected for sampling during each bout, then one soil sample is collected per quadrant. Cores are sampled up to 30 cm depth or the end of the horizon, and organic and mineral horizons are separated for independent processing if both are present (although for most sampling events, only the top horizon is sampled). Most sites including NOGP have three sampling bouts per year, timed to capture seasonal transitions such as winter to spring or fall to winter transition, as well as peak greenness. Annual measurements include soil moisture, temperature, pH, microbial biomass, and community composition via genomics. All sites send several frozen samples to the NEON Biorepository per bout for storage to support community research.

Every five years, a suite of soil biogeochemical measurements is made during the regular sampling bouts. This includes in situ estimates of net nitrogen transformation rates as well as total organic carbon, nitrogen, and C and N stable isotopes. If both organic and mineral horizons are present, both are sampled during these bouts, to a total depth of 30 cm depth or bedrock. A separate sampling campaign is used to collect soil cores for root biomass estimates in plots located in the tower footprint on the same frequency of every five years.

Publications

A large number of scientists from a variety of disciplines - including biogeochemistry, geophysics, hydrology, and biogeography - have conducted research using NEON data and samples from the North Dakota sites. Many of these studies have used NEON data to investigate questions that contribute to our understanding of climate change. Below are a few examples of soils related publications using North Dakota data:

Hall, Steven J., et al. "Molecular trade-offs in soil organic carbon composition at continental scale." Nature Geoscience 13.10 (2020): 687-692.

Kramer, Marc G., and Oliver A. Chadwick. "Climate-driven thresholds in reactive mineral retention of soil carbon at the global scale." Nature Climate Change 8.12 (2018): 1104-1108.

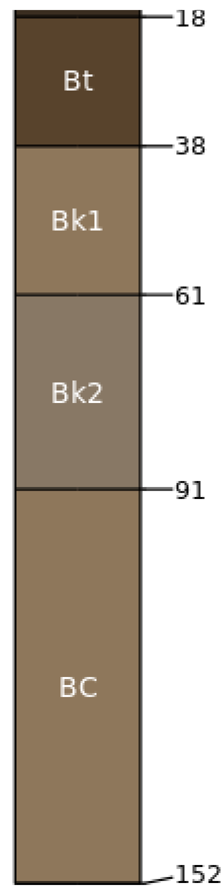
LOCATION FARNUF MT+ND SD WY

Established Series
Rev. GFB-JAL-WDB
02/2009

FARNUF SERIES

Scan the QR code for the official series description.

The Farnuf series consists of very deep, well drained soils that formed in alluvium, glaciolacustrine, or glaciofluvial deposits. These soils are on alluvial fans, stream terraces, hills, sedimentary plains, glacial lake plains, moraines, and outwash plains. Slopes are 0 to 35 percent. Mean annual precipitation is about 406 millimeters (about 16 inches), and mean annual air temperature is about 5.6 degrees C (about 42 degrees F.)



TAXONOMIC CLASS: Fine-loamy, mixed, superactive, frigid Typic Argiustolls

TYPICAL PEDON: Farnuf loam, in grassland. (Colors are for dry soil unless otherwise noted)

A--0 to 18 centimeters (about 0 to 7 inches); dark grayish brown (10YR 4/2) loam, very dark brown (10YR 2/2) moist; moderate very thin platy structure in the upper part and moderate medium prismatic structure in the lower part with plates and prisms that separate to moderate very fine granules; hard, very friable, slightly sticky and slightly plastic; many fine and medium roots; many very fine and fine pores; slightly alkaline (pH 7.4); clear smooth boundary. (10 to 23 centimeters, about 4 to 9 inches, thick)

Bt--18 to 38 centimeters (about 7 to 15 inches); brown (10YR 5/3) clay loam, dark brown (10YR 3/3) moist; strong medium prismatic structure parting to strong fine and medium subangular blocky; very hard, friable, sticky and plastic; many fine and very fine roots; many fine and very fine pores and few medium pores; continuous faint dark grayish brown (10YR 4/2) clay films on faces of peds; slightly alkaline (pH 7.6); clear wavy boundary. (13 to 56 centimeters, about 5 to 22 inches, thick)

Bk1--38 to 61 centimeters (about 15 to 24 inches); pale brown (10YR 6/3) loam, brown (10YR 5/3) moist; moderate medium prismatic structure that separates to weak medium and fine blocky; hard, friable, sticky and plastic; many fine and very fine roots; many fine and very fine pores and few medium pores; few masses of lime; strongly effervescent; moderately alkaline (pH 8.3); diffuse wavy boundary.

Bk2--61 to 91 centimeters (about 24 to 36 inches); light gray (10YR 7/2) loam, grayish brown (10YR 5/2) moist; weak coarse blocky structure; hard, friable, sticky and slightly plastic; common fine and very fine roots; common fine and very fine pores; 5 percent gravel; common masses of lime; continuous faint coatings of lime on gravel; strongly effervescent; moderately alkaline (pH 8.4); diffuse wavy boundary. (Combined Bk horizons 25 to 97 centimeters, about 10 to 38 inches, thick)

BC--91 to 152 centimeters (about 36 to 60 inches); very pale brown (10YR 7/3) loam consisting of layers of stratified sandy clay loam and fine sandy loam, brown (10YR 5/3) moist; massive; hard, very friable, sticky and slightly plastic; few fine and very fine roots; common fine and very fine pores; disseminated lime; strongly effervescent; strongly alkaline (pH 8.5).

TYPE LOCATION: Cascade County, Montana; 1,600 feet west and 1,240 feet south of the northeast corner of sec. 36, T. 18 N., R. 6 E at 1,097 meters (about 3,600 feet) elevation.

RANGE IN CHARACTERISTICS:

Soil temperature: 3.3 to 8.3 degrees C (about 38 to 47 degrees F)
Moisture control section: between 10 and 30 centimeters (about 4 and 12 inches)
Mollic epipedon thickness: 18 to 38 centimeters (about 7 to 15 inches) and includes all or only part of the argillic horizon
Depth to secondary lime horizon: 25 to 64 centimeters (about 10 to 25 inches)

A horizon
Hue: 10YR or 2.5Y
Value: 3, 4, or 5 dry; 2 or 3 moist
Chroma: 2 or 3
Texture (less than 2 mm): loam, clay loam, sandy clay loam, sandy loam, or silt loam
Clay content: 15 to 32 percent
Rock fragments: 0 to 35 percent
0 to 20 percent stones and cobbles
0 to 15 percent gravel
Reaction: pH 6.1 to 7.8

Bt horizon(s)
Hue: 7.5YR, 10YR, or 2.5Y
Value: 3, 4, 5, or 6 dry; 2, 3, or 4 moist
Chroma: 2, 3, or 4

Texture (less than 2 mm): loam, silt loam, clay loam, sandy clay loam or silty clay loam
Clay content: 20 to 35 percent
Sand content: less than 35 percent fine sand and coarser sand
Rock fragments: 0 to 35 percent gravel
Reaction: pH 6.1 to 7.8

Some pedons have a thin Btk horizon.

Bk horizon(s)

Hue: 7.5YR, 10YR, or 2.5Y
Value: 5, 6, or 7 dry; 4, 5, or 6 moist
Chroma: 2, 3, or 4
Texture (less than 2 mm): very fine sandy loam, fine sandy loam, sandy loam, sandy clay loam, loam, silt loam, silty clay loam, or clay loam
Clay content: 15 to 35 percent
Rock fragments: 0 to 35 percent gravel
Calcium carbonate equivalent: 5 to 15 percent
Reaction: pH 7.4 to 8.4

BC, C and BCk horizons, where present

Hue: 7.5YR, 10YR, or 2.5Y
Value: 5, 6, or 7 dry; 4, 5, or 6 moist
Chroma: 2, 3, or 4
Texture (less than 2 mm): loam or clay loam--the strata consist of thin layers of fine sandy loam, sandy clay loam, clay loam, silty clay loam, silty clay, and silt loam
Clay content: 12 to 35 percent
Rock fragments: 0 to 35 percent
0 to 10 percent cobbles
0 to 25 percent gravel
Calcium carbonate equivalent: 3 to 12 percent
EC: 0 to 8 mmhos/cm
Reaction: pH 7.4 to 9.0

COMPETING SERIES:

Absarook (MT) has a lithic contact of sandstone at depths of 50 to 100 centimeters (about 20 to 40 inches).

Archmesa (CO) has a paralithic contact at a depth of 50 to 100 centimeters (about 20 to 40 inches).

Beartooth (MT) has more than 35 percent rock fragments in the Bk horizons.

Beeno (WY) has a paralithic contact at a depth of 50 to 100 centimeters (about 20 to 40 inches).

Bielenberg (MT) are noncalcareous throughout the profile.

Bookcliff (UT) are calcareous at a depth of 4 inches, are not stratified in the C horizon, and have hard sandstone bedrock at a depth of 100 to 150 centimeters (about 40 to 60 inches).

Burtoner (MT) has a paralithic contact at a depth of 50 to 97 centimeters (about 20 to 38 inches).

Clancy (MT) has a lithic contact of granite at depths of 50 to 100 centimeters (about 40 to 60 inches).

Clasoil (MT) does not have a horizon of secondary calcium carbonate accumulation; and is loamy skeletal below the argillic horizon.

Dooley (MT) has till above a depth of 100 centimeters (about 40 inches) that has a bulk density greater than 1.6.

Doughty (MT) has a calcic horizon.

Empedrado (CO) has argillic horizons as deep as 50 to 100 centimeters (about 20 to 40 inches), and the depth to lime is usually deeper than 60 centimeters (about 24 inches).

Fairfield (MT) has calcic horizons.

Farside (MT) does not have a horizon of secondary carbonate accumulation.

Felor (SD) has 2B horizons of silty clay below a depth of 70 centimeters (about 28 inches), and the depth to carbonates is typically deeper than 75 centimeters (about 30 inches).

Greenway (SD) has a high bulk density till substratum that has 35 to 45 percent clay.

Gurney (SD) has a lithic contact at a depth of 50 to 100 centimeters (about 20 to 40 inches).

Hangdo (UT) does not have a Bk horizon or free carbonates above a depth of 100 centimeters (about 40 inches).

High (CO) has a calcic horizon.

Hoppers (MT) has a lithic contact at depths of 50 to 100 centimeters (about 20 to 40 inches).

Hyalite (MT) have a sandy-skeletal discontinuity above a depth of 100 centimeters (about 40 inches).

Jeffcity (MT) has a lithic contact of granite at depths of 50 to 100 centimeters (about 20 to 40 inches).

Kokoruda (MT) do not have a horizon of carbonate accumulation.

Livona (ND) has a discontinuity of till at depths of 25 to 50 centimeters (about 10 to 20 inches).

Martinsdale (MT) has calcic horizons.

Maudlin (CO) has a lithic contact at a depth of 50 to 100 centimeters (about 20 to 40 inches).

Meagher (MT) has a loamy-skeletal discontinuity; and has a calcic horizon.

Moen (CO) has a lithic contact at a depth of 50 to 100 centimeters (about 20 to 40 inches).

Moento (CO) has a lithic contact at a depth of 50 to 100 centimeters (about 20 to 40 inches).

Perrypark (CO) Does not have horizons of secondary carbonate accumulation.

Pianohill (MT) has a lithic contact at a depth of 50 to 100 centimeters (about 20 to 40 inches).

Placerton (MT) has a lithic contact of granite at depths of 100 to 150 centimeters (about 40 to 60 inches).

Reeder (ND) has a paralithic contact at a depth of 50 to 100 centimeters (about 20 to 40 inches).

Reedwest (MT) has a paralithic contact at a depth of 50 to 100 centimeters (about 20 to 40 inches).

Sipple (MT) has a lithologic discontinuity

Snakejohn (UT) has a lithic contact within a depth of 150 centimeters (about 60 inches).

Sponseller (AZ) is noncalcareous throughout the profile.

Trag (CO) does not have a horizon of secondary carbonate accumulation.

Tragmon (CO) does not have horizons of secondary carbonate accumulation.

Trazuni (NM) does not have horizons of secondary carbonate accumulation.

Trujillo (CO) does not have a horizon of secondary carbonate accumulation within 100 centimeters (about 40 inches) of the surface.

Ulrant (WY) has calcic horizons.

Vida (MT) has till above a depth of 100 centimeters (about 40 inches) that has a bulk density greater than 1.6; and is less then 25 centimeters (about 10 inches) deep to carbonates.

Watne (MT) has a calcic horizon.

Watrous (ND) has a lithic contact at a depth of 50 to 100 centimeters (about 20 to 40 inches).

Wemple (MT) has a paralithic contact at a depth of 50 to 100 centimeters (about 20 to 40 inches).

Williams (ND) has till above a depth of 100 centimeters (about 40 inches) that has a bulk density greater than 1.6.

Yegen (MT) has 35 to 50 percent fine sand and coarser sand in the argillic horizon.

GEOGRAPHIC SETTING:

Landform: stream terraces; alluvial fans; hills; sedimentary plains; glacial lake plains; moraines and outwash plains.
Elevation: 579 to 1,890 meters (about 1,900 to 6,200 feet).
Slope: 0 to 35 percent.
Parent material: alluvium derived from mixed rock sources, glaciolacustrine or glaciofluvial deposits.
Climate: long, cold winters; moist springs and warm summers.
Mean annual precipitation: 305 to 610 millimeters (about 12 to 24 inches), with areas receiving less than 356 millimeters (about 14 inches) of precipitation having cooler temperatures and less evaporation. Most of the precipitation falls during spring and early in summer.
Mean annual air temperature: 1.1 to 7.2 degrees C. (about 34 to 45 degrees F).
Frost-free period: 70 to 135 days.

GEOGRAPHICALLY ASSOCIATED SOILS: These are the Arnegard, Reeder and Shambo soils.

Arnegard soils have a mollic epipedon that is 40 to 75 centimeters, about 16 to 30 inches thick, do not have an argillic horizon, and are in swales.

Reeder soils have a paralithic contact at 50 to 100 centimeters, about 20 to 40 inches, and are on shoulders and summits.

Shambo soils do not have an argillic horizon and are on similar landform positions.

DRAINAGE AND PERMEABILITY: Well drained. High saturated hydraulic conductivity.

USE AND VEGETATION: Farnuf soils are used mainly for irrigated and nonirrigated cropland. The potential native vegetation is primarily mid and short grasses such as western wheatgrass, prairie sandreed, green needlegrass, little bluestem, needleandthread, blue grama, shrubs, and forbs.

DISTRIBUTION AND EXTENT: Farnuf soils are widely distributed in the eastern plains of Montana and in western North Dakota. They are extensive.

MLRA SOIL SURVEY REGIONAL OFFICE (MO) RESPONSIBLE: St. Paul, Minnesota

SERIES ESTABLISHED: Cascade County, Montana, 1969.

REMARKS: Soil interpretation records: MT0009, MT0231, MT0241, MT0813, MT0814.

Diagnostic horizons and features recognized in this pedon are: mollic epipedon - the zone from the surface of the soils to a depth of 38 centimeters, about 15 inches (A and Bt horizons); argillic horizon - the zone from 18 to 38 centimeters, about 7 to 15 inches (Bt horizon); horizon of lime accumulation - the zone from 38 to 91 centimeters, about 15 to 36 inches (Bk1 and Bk2 horizons); particle-size control section - the zone from 18 to 38 centimeters, about 7 to 15 inches (Bt horizon).

National Cooperative Soil Survey

U.S.A.

Farnuf Pedon Description

Print Date: Feb. 16, 2023
Description Date: July 30, 2013
Describer: P. Sullivan, W. Bott
Site ID: S2013ND059001

Soil Survey Area: 5-DIC -- Dickinson, North Dakota
Pedon ID: S2013ND059001

Quad Name:
Lab Source ID: SSL
Lab Pedon #: 13N96165

Country:
State: North Dakota
County: Morton

MLRA: 54 -- Rolling Soft Shale Plain
Map Unit: 77 -- Temvik- Wilton silt loams, 0 to 3 percent slopes

Std Latitude: 46.7684600
Std Longitude: -100.9183200

User Transect ID:
Soil Name as Described/Sampled: Farnuf
Classification: Fine-loamy, mixed, superactive, frigid Typic Argiustolls
Soil Name as Correlated: Temvik, taxadjunct
Classification:
Pedon Type:
Pedon Purpose:
Taxon Kind: series
Associated Soils:
Physiographic Division:
Physiographic Province:
Local Physiographic Area:
Geomorphic Setting: on footslope of plains on footslope of alluvial flat
Upslope Shape: linear
Cross Slope Shape: linear

Particle Size Control Section: 31 to 84 cm.
Description origin: Pedon PC 5.1

Primary Earth Cover:
Secondary Earth Cover:
Vegetation:

Parent Material: loess and/or glaciofluvial deposits derived from sandstone and siltstone

Bedrock Kind:
Bedrock Depth:
Bedrock Hardness:
Bedrock Fracture Interval:

Surface Fragments:

Description database: KSSL

Diagnostic Features: mollic epipedon 0 to 31 cm.
argillic horizon 31 to 84 cm.
calcic horizon 84 to 182 cm.

Cont. Site ID: S2013ND059001 **Pedon ID:** S2013ND059001

Slope (%)	Elevation (meters)	Aspect (deg)	MAAT (C)	MSAT (C)	MWAT (C)	MAP (mm)	Frost-Free Days	Drainage Class	Slope Length (meters)	Upslope Length (meters)
2.0			6.0			394	128	Well drained		

A1--0 to 4 centimeters (0.0 to 1.6 inches); very dark grayish brown (10YR 3/2) loam, very dark brown (10YR 2/2), moist; 18 percent clay; moderate fine granular structure; friable, slightly sticky, slightly plastic; many very fine roots throughout and common medium roots throughout and many fine roots throughout; noneffervescent, by HCl, 1 normal; clear wavy boundary. Lab sample # 13N08646

A2--4 to 11 centimeters (1.6 to 4.3 inches); very dark grayish brown (10YR 3/2) loam, very dark brown (10YR 2/2), moist; 18 percent clay; moderate medium subangular blocky structure; friable, slightly sticky, slightly plastic; many very fine roots throughout; noneffervescent, by HCl, 1 normal; clear wavy boundary. Lab sample # 13N08647

A3--11 to 31 centimeters (4.3 to 12.2 inches); very dark grayish brown (10YR 3/2) loam, very dark brown (10YR 2/2), moist; 18 percent clay; weak coarse subangular blocky parts to weak medium subangular blocky structure; friable, slightly sticky, slightly plastic; many very fine roots throughout and many fine roots throughout; noneffervescent, by HCl, 1 normal; clear wavy boundary. Lab sample # 13N08648

Bt1--31 to 46 centimeters (12.2 to 18.1 inches); brown (10YR 4/3) loam, dark grayish brown (10YR 4/2), moist; 25 percent clay; weak coarse prismatic parts to weak medium subangular blocky structure; friable, moderately sticky, slightly plastic; common very fine roots throughout and many fine roots throughout; 25 percent distinct 10YR 2/2) clay films on all faces of peds; noneffervescent, by HCl, 1 normal; gradual wavy boundary. Lab sample # 13N08649. continuous - phpvsfiid 1195252; continuous - phpvsfiid 1195252

Bt2--46 to 64 centimeters (18.1 to 25.2 inches); brown (10YR 4/3) loam, dark grayish brown (10YR 4/2), moist; 26 percent clay; moderate coarse prismatic parts to weak medium subangular blocky structure; friable, moderately sticky, slightly plastic; common very fine roots throughout and many fine roots throughout; 25 percent 10YR 3/3) clay films on all faces of peds; noneffervescent, by HCl, 1 normal; clear wavy boundary. Lab sample # 13N08650. continuous - phpvsfiid 1195253; continuous - phpvsfiid 1195253

Bt3--64 to 84 centimeters (25.2 to 33.1 inches); brown (10YR 4/3) clay loam, brown (10YR 4/3), moist; 29 percent clay; moderate coarse prismatic parts to moderate medium subangular blocky structure; firm, moderately sticky, slightly plastic; common fine roots throughout; 25 percent 10YR 3/3) clay films on all faces of peds; 1 percent 5 to 75-millimeter Mixed rock fragments and 2 percent 2 to 5-millimeter Mixed rock fragments; noneffervescent, by HCl, 1 normal; clear wavy boundary. Lab sample # 13N08651. continuous - phpvsfiid 1195254; continuous - phpvsfiid 1195254

Btk1--84 to 112 centimeters (33.1 to 44.1 inches); clay loam, dark grayish brown (10YR 4/2), moist; 29 percent clay; weak coarse prismatic parts to weak medium subangular blocky structure; friable, moderately sticky, slightly plastic; common very fine roots throughout; carbonate, finely disseminated and 20 percent medium prominent 10YR 8/2) carbonate masses in matrix; 1 percent 5 to 75-millimeter Mixed rock fragments and 2 percent 2 to 5-millimeter Mixed rock fragments; violent effervescence, by HCl, 1 normal; gradual wavy boundary. Lab sample # 13N08652

Btk2--112 to 145 centimeters (44.1 to 57.1 inches); clay loam, brown (10YR 4/3), moist; 28 percent clay; 1 percent fine distinct (7.5YR 4/6) mottles; weak coarse prismatic parts to weak coarse subangular blocky structure; friable, moderately sticky, slightly plastic; common very fine roots throughout; 15 percent distinct 10YR 3/3) clay films on all faces of peds; carbonate, finely disseminated in matrix and 15 percent coarse prominent 10YR 8/2) carbonate masses in matrix; 1 percent 5 to 75-millimeter Mixed rock fragments and 2 percent 2 to 5-millimeter Mixed rock fragments; violent effervescence, by HCl, 1 normal; gradual wavy boundary. Lab sample # 13N08653

Bk--145 to 182 centimeters (57.1 to 71.7 inches); loam, olive brown (2.5Y 4/3), moist; 26 percent clay; 5 percent coarse prominent (7.5YR 4/6) mottles; weak coarse subangular blocky parts to weak medium subangular blocky structure; friable, moderately sticky, slightly plastic; common very fine roots throughout; 10 percent coarse prominent 10YR 8/2) carbonate masses in matrix; 1 percent 5 to 75-millimeter Mixed rock fragments and 2 percent 2 to 5-millimeter Mixed rock fragments; strong effervescence, by HCl, 1 normal; gradual wavy boundary. Lab sample # 13N08654

C--182 to 200 centimeters (71.7 to 78.7 inches); loam, olive brown (2.5Y 4/3), moist; 24 percent clay; 2 percent medium prominent (7.5YR 4/6) mottles; massive; friable, moderately sticky, slightly plastic; common very fine roots throughout; 1 percent 5 to 75-millimeter Mixed rock fragments and 2 percent 2 to 5-millimeter Mixed rock fragments; strong effervescence, by HCl, 1 normal. Lab sample # 13N08655

Pedon ID: S2013ND059001

Sampled Date: 7/28/2013

Correlated as: Temvik, taxadjunct

Correlated Classification: Fine-loamy, mixed, superactive, frigid Typic Haplustolls

Particle Size Control Section: 25 – 100

Clay Weighted Average: 28

CEC Activity, CEC7/Clay, Weighted Average: 0.79

Horizon	Depth	Texture	Clay (%)	Silt (%)	Sand (%)	Core Db (g/cm-3)	Est. OC (%)	Fine Silt (%)	Coarse Silt (%)	V. Fine Sand (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	V. Coarse Sand (%)	Coarse Fragments (%)
A1	0-4	sil	26.0	56.8	17.2	0.40	6.3	29.6	27.2	11.2	5.0	0.4	0.4	0.2	-
A2	4-11	sil	25.4	57.4	17.2	0.74	4.8	29.1	28.3	11.4	4.3	1.1	0.3	0.1	-
A3	11-31	sil	24.4	57.8	17.8	1.08	2.7	27.1	30.7	11.3	5.0	1.3	0.2	-	-
Bt1	31-46	sil	26.7	52.9	20.4	1.36	1.3	23.4	29.5	13.6	5.2	1.2	0.2	0.2	-
Bt2	46-64	sil	26.5	51.2	22.3	1.34	1.0	23.0	28.2	15.3	6.3	0.4	0.2	0.1	1
Bt3	64-84	cl	29.0	41.8	29.2	1.23	0.6	25.0	16.8	15.8	10.0	2.8	0.4	0.2	3
Btk1	84-112	cl	30.0	44.4	25.6	1.33	0.5	28.8	15.6	11.7	11.4	2.2	0.2	0.1	1
Btk2	112-145	cl	28.3	43.0	28.7	1.34	0.4	27.2	15.8	13.2	12.7	2.3	0.4	0.1	1
Bk	145-182	l	24.5	45.0	30.5	1.1	0.3	28.6	16.4	14.0	14.1	1.6	0.6	0.2	1
C	182-200	l	23.9	44.9	31.2	1.35	0.3	29.1	15.8	14.5	13.1	3.3	0.3	tr	2

Horizon	Depth	CEC7 (cmo/kg)	CEC7/Clay	Base Saturation	EC (dS/m)	ESP (%)	SAR	Ext. Ca (cmol/kg)	Ext. Mg (cmol/kg)	Ext. Na (cmol/kg)	Ext. Acidity (cmol/kg)	pH Water	CaCO3 (%)
A1	0-4	29.9	1.15	100	1.24	tr	-	21.1	7.5	-	-	7.2	-
A2	4-11	27.9	1.1	100	-	-	-	19.3	6.5	-	-	6.9	-
A3	11-31	23.5	0.96	100	-	-	-	16.4	6.2	-	-	6.9	-
Bt1	31-46	21.1	0.79	100	-	-	-	14.4	8.0	-	-	7.4	-
Bt2	46-64	20.9	0.79	100	-	-	-	13.6	9.3	-	-	7.7	-
Bt3	64-84	23.4	0.81	100	-	-	-	45.1	13.1	-	-	8.4	3
Btk1	84-112	21.5	0.72	100	0.46	tr	-	55.1	13.5	-	-	8.7	11
Btk2	112-145	21.6	0.76	100	0.45	2	tr	51.8	18.2	0.4	-	8.9	9
Bk	145-182	22.3	0.91	100	0.54	5	2	40.7	19.3	1.2	-	9.0	7
C	182-200	21.4	0.90	100	0.51	8	3	36.5	19.9	1.9	-	9.1	6

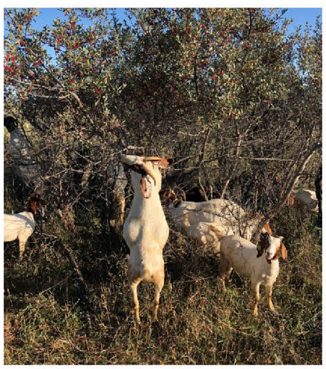
Long-Term Agroecosystem Research
Grazinglands Common Experiment

Long-Term Agroecosystem Research (LTAR) Network:

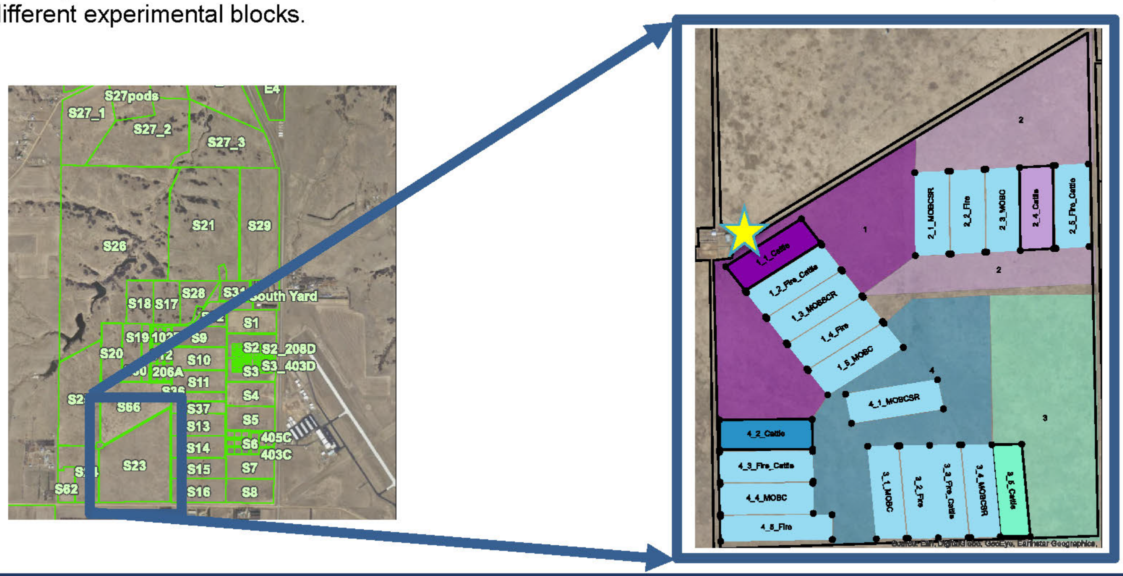
The LTAR network is composed of 18 locations distributed across the contiguous United States working together to address national and local agricultural priorities and advance the sustainable intensification of U.S. agriculture. As part of the LTAR Grazingland Common Experiment, the USDA-ARS Northern Great Plains Research Laboratory (NGPRL) in Mandan, ND initiated a mob grazing, multi-species grazing and burning experiment.

Mob Grazing, Multi-Species Grazing, and Burning:

The objective of this study is to sustainably intensify livestock production on semiarid grazing land by using alternative land management practices including mob grazing with cattle, multi-species grazing with cattle and goats, and prescribed fire.



The experiment is located in field S23 of the NGPRL and consists of 5 different treatments replicated in 4 different experimental blocks.



Long-Term Agroecosystem Research
Grazinglands Common Experiment

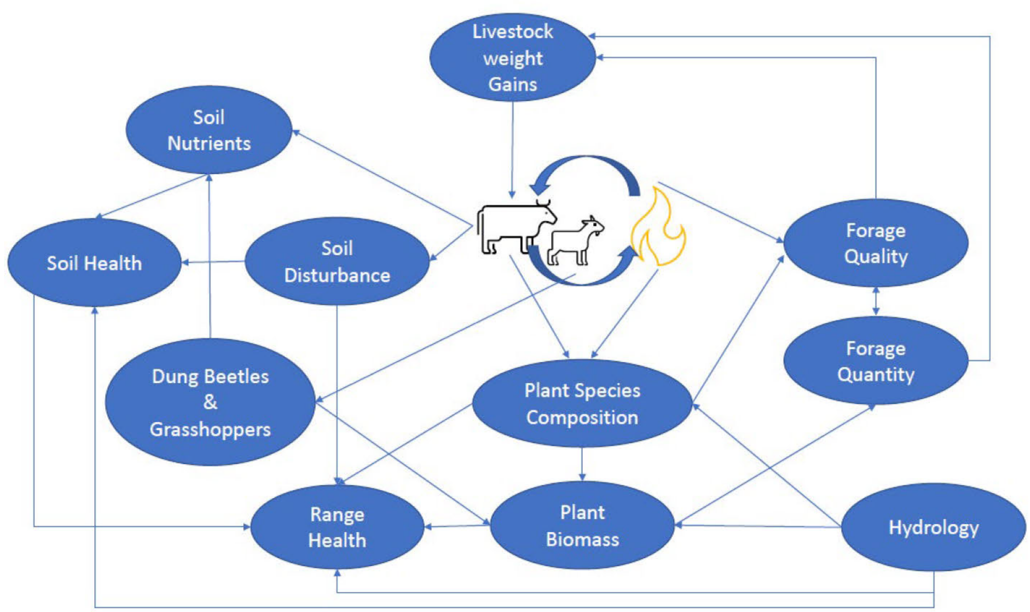
Experiment was initiated in the fall of 2019. Treatments for the grazingland common experiment are being implemented using a staggered start design in which half of the experimental blocks had fire treatments applied in Fall 2019 and the other half began in Fall of 2020. Grazing treatments for half the experiment began in Spring 2020 the other half began in Spring of 2021. Experimental treatments are being guided using input from a collaborative land manager panel and a mail survey.

Our approach is to evaluate selected environmental variables and productivity metrics in a typical season-long livestock grazing system (business as usual) compared to alternative systems (aspirational).

Business as Usual	Aspirational
A predominant management system using management practices typical of the region	A novel system designed to advance sustainable intensification and enhance the ecosystem
Season-long livestock grazing	Mob grazing yearlings Multi-species grazing (cattle & goats) Prescribed burning Prescribed burning and grazing

Assessments of contrasting management practices using common measurements and observations to understand environmental and productivity tradeoffs and synergies

Conceptual model showing the separate and interactive effects of livestock and prescribed fire on grassland ecosystems.



Long-Term Agroecosystem Research Network

Northern Plains Croplands Common Experiment

Contemporary cropland agriculture in the United States is dominated by an emphasis on provisioning services by applying energy-intensive inputs through uniform production systems across variable landscapes. This approach to cropland use is not sustainable and has contributed to negative environmental impacts at multiple spatial scales.

Despite this challenging context, cropland agriculture has the potential to provide many ecosystem services in addition to the provisioning of agricultural products, including pollinator habitat, flood protection, pest/disease suppression, and carbon storage. Understanding how cropland agriculture affects a spectrum of ecosystem services under different forms of management over the long-term is a research area largely unexplored.

Through long-term observational and experimental research, the Long-Term Agroecosystem Research (LTAR) Croplands Common Experiment (CCE) generates critical information to facilitate the adoption of cropland practices that support the delivery of multiple ecosystem services for improved economic, social, and environmental outcomes.

The LTAR CCE at the USDA-ARS Northern Great Plains Research Laboratory develops and evaluates alternative management strategies for cropland agriculture in the northern Great Plains. Specifically, the CCE contrasts common cropping practices in central North Dakota ('Business as Usual') with dynamic/adaptive cropping practices using no-till management, integrated cropping, and cover crops ('Aspirational'). For the initial phase of the experiment (2019-2024), a spring wheat–corn–soybean rotation with and without cover crops is being evaluated at two spatial scales, plot and field. The experiment is conducted southwest of Mandan, ND on the Area 4 SCD Cooperative Research Farm. The experiment resides mostly on Temvik-Wilton silt loam soils.

For more information about the Long-Term Agroecosystem Research Network, please see https://ltar.ars.usda.gov/.

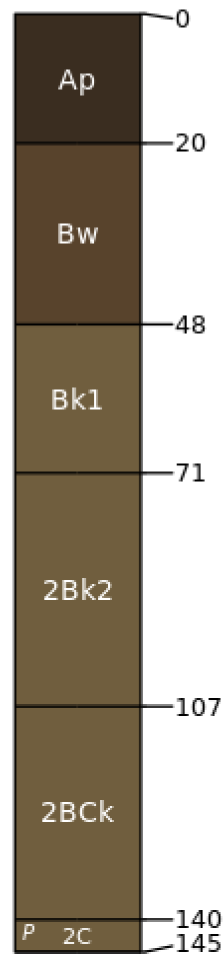
Interseeded cover crops in corn, 26 June 2020. USDA-ARS, Mandan, ND

LOCATION TEMVIK ND+SD

Established Series
Rev. LCB-CJH
10/98

TEMVIK SERIES

Scan the QR code for the official series description.



The Temvik series consists of very deep, well drained soils that formed in a silty loess mantle overlying glacial till. Permeability is moderate in the silty loess mantle and moderately slow in the glacial till. These soils are on upland plains and have slopes of 0 to 15 percent. Mean annual temperature is 42 degrees F, and mean annual precipitation is 16 inches.

TAXONOMIC CLASS: Fine-silty, mixed, superactive, frigid Typic Haplustolls

TYPICAL PEDON: Temvik silt loam - near the crest of a convex north facing 1 percent slope in a cultivated field. (Colors are for dry soil unless otherwise stated. Where described the soil was moist throughout.)

Ap--0 to 7 inches; dark grayish brown (10YR 4/2) silt loam, very dark brown (10YR 2/2) moist; weak medium subangular blocky and weak fine granular structure; slightly hard, very friable, slightly sticky and slightly plastic; many roots; many very fine pores; neutral; abrupt smooth boundary. (Combined A horizons 5 to 13 inches thick)

Bw1--7 to 11 inches; dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; moderate coarse prismatic structure parting to moderate medium prismatic and weak medium subangular blocky; slightly hard, very friable, slightly sticky and slightly plastic; many roots; many pores; faint clay films on vertical faces and common faint clay films on horizontal faces of peds; few thin tongues of Ap extend into this horizon; neutral; gradual wavy boundary.

Bw2--11 to 20 inches; brown (10YR 5/3) silt loam, dark brown (10YR 4/3) moist; moderate coarse and medium prismatic structure parting to moderate coarse and medium subangular blocky; slightly hard, very friable, slightly sticky and slightly plastic; common roots; common fine pores; faint clay films on faces of peds; neutral; clear wavy boundary.

Bw3--20 to 24 inches; pale brown (10YR 6/3) silt loam, brown (10YR 4/3) moist; weak coarse prismatic structure parting to moderate medium subangular blocky; slightly hard, very friable, slightly sticky and slightly plastic; few roots; common fine pores; few pebbles and stones at the base of this horizon; neutral; clear wavy boundary. (Combined Bw horizons 10 to 33 inches thick)

2Bk1--24 to 36 inches; light brownish gray (2.5Y 6/2) clay loam, olive brown (2.5Y 4/4) moist; common fine distinct yellowish brown (10YR 5/4) redox concentrations; weak coarse prismatic structure parting to weak coarse and medium subangular blocky; hard, friable, sticky and plastic; about 3 percent gravel; many medium and few large masses of carbonates; strong effervescence; moderately alkaline; gradual wavy boundary.

2Bk2--36 to 44 inches; light olive gray (5Y 6/2) clay loam, olive brown (2.5Y 4/4) moist; few fine prominent strong brown (7.5YR 5/6) redox concentrations; weak coarse and fine subangular blocky structure; hard, friable, sticky and plastic; about 3 percent gravel; common masses of carbonates; strong effervescence; moderately alkaline; gradual boundary. (Combined Bk horizons 12 to 24 inches thick.)

2C--44 to 60 inches; light olive gray (5Y 6/2) clay loam, olive gray (5Y 5/2) moist; weak subangular blocky structure; hard, firm, sticky and plastic; about 3 percent gravel; few small masses of carbonates; strong effervescence; moderately alkaline.

TYPE LOCATION: Emmons County, North Dakota; about 1/2 mile north of Hazelton; 2,605 feet north and 280 feet east of the southwest corner, sec. 20, T. 135 N., R. 76 W.

RANGE IN CHARACTERISTICS: The silty loess material is 20 to 40 inches thick over the underlying glacial till. The silty loess material contains between 18 and about 28 percent clay. The soil ranges from neutral in the upper horizons to moderately alkaline in the lower horizons. The mollic epipedon ranges from 7 to 16 inches in thickness.

The A horizon has hue of 10YR, value of 4 or 5 and 2 or 3 moist, and chroma of 2 or 3. It typically is silt loam and less commonly silty clay loam, loam or clay loam and contains between 10 and 30 percent very fine sand. It is neutral.

The Bw horizon has hue of 10YR or 2.5Y, value of 4 to 6 and 3 or 4 moist, and chroma of 2 to 4. It typically is silt loam and less commonly silty clay loam, loam or clay loam and contains between 10 and 30 percent very fine sand. It is neutral or slightly alkaline. Some pedons have a 2Bw horizon that formed in the underlying glacial till.

The 2Bk horizon has hue of 2.5Y or 5Y, value of 5 to 7 dry and 4 to 6 moist, and chroma of 2 to 4. It is clay loam or loam. It is slightly alkaline or moderately alkaline. It has few to many masses of carbonates and contains from 4 to 20 percent calcium carbonate equivalent. Some pedons have 2BCk horizons. Some pedons have a Bk horizon that formed in the silty loess material.

The 2C horizon has hue of 2.5Y or 5Y, value of 4 to 7 and 4 to 6 moist, and chroma of 2 to 4. It is loam or clay loam glacial till containing 2 to 8 percent coarse fragments. It is slightly alkaline or moderately alkaline. Soft bedded sandstone, siltstone or shale is below depths of 40 inches in some pedons.

COMPETING SERIES: These are the Amsterdam, Bryant, Golva, Omio, Peritsa and Sen series. Amsterdam soils contain substantial amounts of volcanic glass shards and are in intermountain valleys. Bryant soils formed entirely in glacial drift and contain more sand in the upper part of the solum. Golva soils do not have glacial till 2C horizons. Omio and Sen soils have soft siltstone bedrock within depths of 40 inches. Peritsa soils contain carbonates within depths of 14 inches and have hue of 5YR or redder throughout the soil.

GEOGRAPHIC SETTING: Temvik soils are on level to rolling upland plains. Slopes are dominantly smooth plane or convex. Slope gradients typically are 0 to 5 percent but range to 15 percent. The soil formed in a silty loess mantle overlying loam or clay loam glacial till. Mean annual temperature ranges from 34 to 45 degrees F and mean annual precipitation from 12 to 18 inches.

GEOGRAPHICALLY ASSOCIATED SOILS: These are the Grassna, Linton, Mandan and Williams soils. Grassna soils are in concave swales. They have mollic epipedons commonly 24 inches or more thick. Linton soils occur where the silty loess deposits are more than 40 inches thick. They are coarse-silty. Mandan soils are in swales. They have mollic epipedons more than 16 inches thick and contain less than 18 percent clay throughout the series control section. Williams soils are on adjacent glacial till plains and are typically on higher lying parts of the landscape. They are fine-loamy and have argillic horizons.

DRAINAGE AND PERMEABILITY: Well drained. Surface runoff is medium or rapid. Permeability is moderate in the silty loess mantle and moderately slow in the glacial till.

USE AND VEGETATION: Soils are commonly cropped to flax, small grains and corn. Some areas are used for hay and pasture. Native vegetation is green needlegrass, needleandthread, western wheatgrass, blue grama, upland sedges and forbs.

DISTRIBUTION AND EXTENT: Central North Dakota and north-central South Dakota adjacent to the Missouri River. The series is of large extent.

MLRA SOIL SURVEY REGIONAL OFFICE (MO) RESPONSIBLE: St. Paul, Minnesota

SERIES ESTABLISHED: Burleigh County, North Dakota, 1971.

REMARKS: Revised 8/94.

Diagnostic horizons and features recognized in this pedon are: mollic epipedon - the zone from the surface of the soil to a depth of 11 inches (Ap and Bw1 horizons); cambic horizon - the zone from 11 to 24 inches (Bw2 and Bw3 horizons).

The silty loess mantle is thinner than typical for the range of the series and thus there is more sand in the 10- to 40-inch-control section than normal for the series.

ADDITIONAL DATA: S54NDak-15-1 and S54NDak-15-2 published in Soil Survey Investigations Report No. 2.

National Cooperative Soil Survey

U.S.A.

Temvik Pedon Description

Print Date: Feb. 16, 2023
Description Date: May 14, 2020
Describer: John Kempenich & Jeanne Heilig
Site ID: S2020ND059002

Soil Survey Area: ND059 -- Morton County, North Dakota
5-DIC -- Dickinson, North Dakota
Pedon ID: S2020ND059002

Quad Name:
Lab Source ID: KSSL
Lab Pedon #: 20N0621

Country:
State: North Dakota
County: Morton

MLRA: 54 -- Rolling Soft Shale Plain

Map Unit: 77 -- Temvik- Wilton silt loams, 0 to 3 percent slopes

Std Latitude: 46.7601333
Std Longitude: -100.9262361

User Transect ID:
Soil Name as Described/Sampled:
Classification:
Soil Name as Correlated: Temvik
Classification: Fine-silty, mixed, superactive, frigid Typic Haplustolls Pedon Type: classifies to current taxon name, full description
Pedon Purpose: research site
Taxon Kind: series
Associated Soils: Grassna, Williams, Wilton
Physiographic Division: Interior Plains
Physiographic Province: Great Plains Province
Physiographic Section: Missouri plateau, glaciated

State Physiographic Area:
Local Physiographic Area:
Geomorphic Setting: on base slope of loess bluff on plains
Upslope Shape: linear
Cross Slope Shape: linear

Particle Size Control Section: 25 to 100 cm.
Description origin: NASIS
Primary Earth Cover: Crop cover
Secondary Earth Cover: Close-grown crop

Vegetation:
Parent Material: windblown silty loess over glaciofluvial deposits over residuum weathered from shale and siltstone
Bedrock Kind:
Bedrock Depth:
Bedrock Hardness:
Bedrock Fracture Interval:
Surface Fragments:
Description database: KSSL

Diagnostic Features: mollic epipedon 0 to 32 cm.
cambic horizon 32 to 61 cm.
secondary carbonates 61 to 170 cm.
lithologic discontinuity 61 to 200 cm.
free carbonates 170 to 200 cm.

Cont. Site ID: S2020ND059002 **Pedon ID:** S2020ND059002

Slope (%)	Elevation (meters)	Aspect (deg)	MAAT (C)	MSAT (C)	MWAT (C)	MAP (mm)	Frost-Free Days	Drainage Class	Slope Length (meters)	Upslope Length (meters)
1.0	591.0	135	6.0			406	128	Well drained		

Ap--0 to 15 centimeters (0.0 to 5.9 inches); dark grayish brown (10YR 4/2) silt loam, very dark brown (10YR 2/2), moist; 10 percent sand; 69 percent silt; 21 percent clay; weak medium cloddy parts to weak medium granular structure; soft, very friable, slightly sticky, slightly plastic; common very fine roots throughout; many very fine tubular pores; noneffervescent, by HCl, 1 normal; abrupt smooth boundary. Lab sample # 20N02774, 20N02775, 20N02776

A--15 to 32 centimeters (5.9 to 12.6 inches); grayish brown (10YR 5/2) silt loam, very dark grayish brown (10YR 3/2), moist; 10 percent sand; 70 percent silt; 20 percent clay; weak medium prismatic parts to moderate medium subangular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; common very fine roots throughout; many very fine tubular pores; noneffervescent, by HCl, 1 normal; abrupt smooth boundary. Lab sample # 20N02777

Bw--32 to 61 centimeters (12.6 to 24.0 inches); pale brown (10YR 6/3) silt loam, brown (10YR 4/3), moist; 10 percent sand; 67 percent silt; 23 percent clay; moderate medium prismatic parts to moderate medium subangular blocky structure; slightly hard, friable, slightly sticky, moderately plastic; common very fine roots throughout; common very fine tubular and common fine tubular pores; 25 percent faint 10YR 2/2), moist, clay films on all faces of peds; noneffervescent, by HCl, 1 normal; clear wavy boundary. Lab sample # 20N02778

2Bk1--61 to 115 centimeters (24.0 to 45.3 inches); light brownish gray (2.5Y 6/2) clay loam, dark grayish brown (2.5Y 4/2), moist; 35 percent sand; 36 percent silt; 29 percent clay; moderate medium prismatic parts to moderate medium subangular blocky structure; slightly hard, friable, moderately sticky, moderately plastic; common very fine tubular and common fine tubular pores; 15 percent faint 10YR 2/2), moist, clay films on all faces of peds; carbonate, finely disseminated throughout and 12 percent coarse irregular carbonate masses throughout; 2

percent nonflat rounded indurated 2 to 76-millimeter Mixed rock fragments; strong effervescence, by HCl, 1 normal; gradual wavy boundary. Lab sample # 20N02779

2Bk2--115 to 170 centimeters (45.3 to 66.9 inches); light yellowish brown (2.5Y 6/3) loam, olive brown (2.5Y 4/3), moist; 35 percent sand; 39 percent silt; 26 percent clay; weak medium subangular blocky structure; slightly hard, friable, slightly sticky, moderately plastic; common very fine tubular and common fine tubular pores; carbonate, finely disseminated throughout and 4 percent medium irregular carbonate masses throughout; 2 percent nonflat rounded indurated 2 to 76-millimeter Mixed rock fragments; slight effervescence, by HCl, 1 normal; gradual wavy boundary. Lab sample # 20N02780

2C--170 to 200 centimeters (66.9 to 78.7 inches); light yellowish brown (2.5Y 6/3) loam, olive brown (2.5Y 4/3), moist; 35 percent sand; 39 percent silt; 26 percent clay; structureless massive; moderately hard, firm, slightly sticky, moderately plastic; common very fine tubular pores; 2 percent fine irregular 10YR 4/6), moist, masses of oxidized iron Throughout and 3 percent fine irregular 2.5Y 5/1), moist, iron depletions Throughout; carbonate, finely disseminated throughout; 2 percent nonflat rounded indurated 2 to 76-millimeter Mixed rock fragments; very slight effervescence, by HCl, 1 normal. Lab sample # 20N02781

Pedon ID: S2020ND059002
Sampled Date: 5/14/2020
Series: Temvik
Classification: Fine-silty, mixed, superactive, frigid Typic Haplustoll

Particle Size Control Section: 25-100
Clay Weighted Average: 27
CEC Activity, CEC7/Clay, Weighted Average: 0.74

Horizon	Depth	Texture	Clay (%)	Silt (%)	Sand (%)	Core Db (g/cm-3)	Est. OC (%)	Fine Silt (%)	Coarse Silt (%)	V. Fine Sand (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	V. Coarse Sand (%)	Coarse Fragments (%)
Ap	0-5	sil	22.7	55.8	21.5	0.93	2.1	24.2	31.6	16.1	4.2	0.9	0.2	0.1	tr
Ap	5-10	sil	25.9	55.3	18.8	1.44	1.5	24.2	31.1	13.1	3.7	1.4	0.4	0.2	tr
Ap	10-15	sil	25.9	56.2	17.9	1.42	1.4	23.9	32.3	12.6	3.6	1.0	0.3	0.4	tr
Ap	15-32	cl	27.7	35.4	36.9	1.33	1.4	24.9	10.5	29.6	5.0	1.5	0.5	0.3	tr
Bw	32-61	l	24.6	31.1	44.1	1.25	0.8	24.2	7.1	14.1	17.9	5.9	3.3	2.9	tr
2Bk1	61-115	cl	27.8	35.7	36.5	1.57	0.4	18.0	17.7	14.6	16.3	4.1	1.1	0.4	21
2Bk2	115-170	cl	25.7	33.3	39.2	1.55	0.3	22.8	10.5	16.3	17.3	4.0	1.0	0.6	5
2C	170-200	l	24.3	35.9	39.8	-	0.3	22.7	13.2	16.0	17.5	4.8	0.9	0.6	2

Horizon	Depth	CEC7 (cmo/kg)	CEC7/Clay	Base Saturation (%)	EC (dS/m)	ESP (%)	SAR	Ext. Ca (cmol/kg)	Ext. Mg (cmol/kg)	Ext. Na (cmol/kg)	Ext. Acidity (cmol/kg)	pH Water	CaCO3 (%)
Ap	0-5	18.5	0.81	81	2.31	tr	tr	10.1	3.8	tr	11.3	4.9	-
Ap	5-10	19.0	0.73	74	-	tr	-	9.4	4.1	tr	9.1	5.3	-
Ap	10-15	19.0	0.73	91	-	tr	-	11.9	4.8	tr	7.3	6.0	-
Ap	15-32	19.3	0.70	98	-	tr	-	12.3	6.1	0.1	6.2	6.7	-
Bw	32-61	21.4	0.87	81	-	tr	-	10.5	6.5	0.1	3.7	7.2	-
2Bk1	61-115	18.0	0.65	100	-	1	-	40.2	10.1	0.2	-	8.3	11
2Bk2	115-170	17.4	0.63	100	-	2	-	42.5	13.2	0.4	-	8.5	9
2C	170-200	16.4	0.67	100	-	3	-	28.2	12.0	0.6	-	8.5	6

National Wind Erosion Research Network

The National Wind Erosion Research Network (NWERN) was established in 2014 as a collaborative effort led by the US Department of Agriculture (USDA) Long Term Agroecosystem Research (LTAR) Network and the Bureau of Land Management (BLM) (Webb et al., 2016). The research domain incorporates the diverse soils and vegetation communities in the rangelands and croplands of the western United States. The sites were selected to represent the range of soils and vegetation communities (ecological sites) and land use activities occurring in areas that are susceptible, or may be susceptible in the future, to wind erosion. This includes both croplands and rangelands that are used for food and fiber production, energy development (oil, gas and solar), recreational activities and agricultural research.

Measurements of soil, vegetation, meteorological conditions, and sediment mass flux are made at all Network sites. The measurements provide information on where and when wind erosion and dust emission occur, the amount of sediment transported by wind, and the effects of biophysical controls and land management practices on the processes.

Where possible the Network uses data collection methods that are already nationally adopted and internationally applied. It is intended that this consistency will increase the application of the Network data and models.

Motivation — Field measurements of aeolian (wind) sediment transport rates are needed to quantify wind erosion across the US so that the impacts can be assessed, and best management practices can be identified and tested. However, it is impossible to directly measure all potential combinations of soil, vegetation and climate under which wind erosion could occur.

Predictive models are required that enable assessments of wind erosion and dust emission to be conducted across land use and land cover types and in response to different land management (Edwards et al., 2022). The NWERN will generate data to improve existing models, develop new approaches to representing management impacts, and provide a means for quantifying model performance and uncertainty across application areas.

The NWERN will address one of the primary limitations of existing models: with few exceptions, they have only been tested using small, geographically limited datasets which represent an incomplete set of field conditions. The ability to use multiple datasets for wind erosion model calibration and testing has been limited by a lack of data standardization.

Site Measurements — Each Network site is instrumented with sensors and samplers to measure the controls on sediment transport, and sediment transport rates. The sites occupy a 1 ha area, divided into a virtual 3 x 3 grid that is used to stratify the location of sediment samplers and the soil survey.

A 10 m meteorological tower is located in the center of rangeland sites, or at the downwind edge of cropland sites. The tower provides a platform to measure the wind velocity profile (6 heights), air temperature profile (3 heights), relative humidity, precipitation, and saltation particle counts (Sensit).

The frequency and magnitude of sediment transport are measured using the saltation sensor and 27 rotating MWAC sediment samplers that measure sediment mass flux at four heights to 1 m above the soil surface. Three sampler masts are randomly located within each of the virtual grid cells, enabling the variance in the mass flux to be measured across the 1 ha sites.

Dust deposition traps are used to measure the vertical dust deposition flux and a vertical array of two DustTrak DRX samplers will be used to measure the fine sediment (dust) mass flux (PM10, PM2.5, PM1).

Comprehensive vegetation surveys are conducted four times per year, including the fractional vegetation cover by species, vegetation height, and vegetation canopy gap size distribution. The measurements are made along three intersecting 100 m transects (Fig. 1).

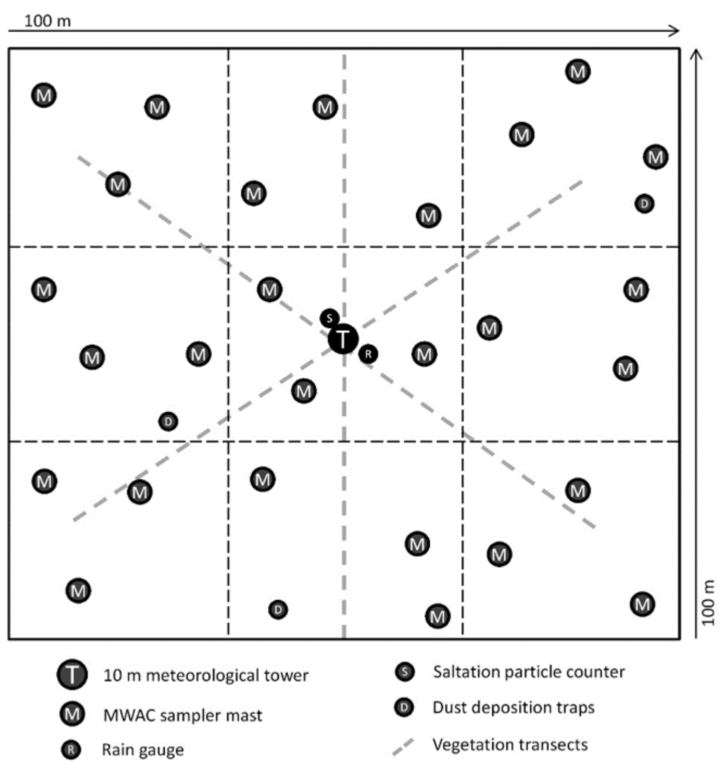


Figure 1.—Depiction of transects and sampling locations for an NWRN site (from Webb et al. (2015)

National Wind Erosion Network at the NGPRL

There are two NWERN sites located at the NGPRL. Sites are designed to measure wind erosion under contrasting cropping systems: prevailing and alternative management. At NGPRL, this contrast includes a spring wheat – corn – soybean rotation with and without cover crops. The experiment is conducted on the Area 4 SCD Cooperative Research Farm on Temvik-Wilton silt loam soils.

References

Edwards et al. 2022. Parameterizing an aeolian erosion model for rangelands. Aeolian Res., 54, 100769. https://doi.org/10.1016/j.aeolia.2021.100769

Webb et al. 2016. The National Wind Erosion Research Network: building a standardized long-term data resource for aeolian research, modeling and land management. Aeolian Res., 22, 23-36. https://doi.org/10.1016/j.aeolia.2016.05.005

Webb et al. 2015. Standard Methods for Wind Erosion Research and Model Development: Protocol for the National Wind Erosion Research Network. USDA-ARS Jornada Experimental Range, Las Cruces, USA. https://winderosionnetwork.org/documents

Points of Interest

A. Double Ditch Indian Village State Historic Site

Left image: Detail of Double Ditch Village illustration from the cyclorama at the North Dakota Heritage Center and State Museum (photo courtesy of NDSCSM); Right image: 1988 aerial photo of Double Ditch State Historic Site (photo courtesy of the University of North Dakota).

Double Ditch Indian Village was a major city and trading center from the late 1400s to the late 1700s. Thousands of people lived and were buried at this site for more than 300 years—spanning 10 generations of Mandan Indians. The Mandan, who live today throughout much of North Dakota and the northern Great Plains, were North Dakota's first agriculturalists, cultivating hundreds of acres of gardens near the 24-acre village.

Scan the QR code for more information.

B. Wilton Wind Farm

Wilton Windfarm operated by NextEra energy. Completed phase 1 on 2006 with 33 turbines and 49.5 megawatts. Completed Phase 2 in 2009 with 33 turbines and 49.5 megawatts. Baldwin Wind Energy Center completed in 2010 with 64 turbines and 102.4 megawatts. Wilton Wind 4 is proposed with a capacity of 112 megawatts. The state has substantial and nearly continuous wind energy resources. In 2021, wind was the second-largest electricity generating source in North Dakota and provided about one-third of the state's net generation.

C. Painted Woods Creek

Painted woods creek may seem to get its name from the bright leaves with fall colors. However, the history of the Painted Woods is older and less obvious. It is a story of love, loss, and warfare.

Scan the QR code for more information.

D. Lewis and Clark Interpretive Center and Fort Mandan

Photo courtesy of North Dakota Parks and Recreation

The North Dakota Lewis and Clark Interpretive Center, operated by the North Dakota Parks and Recreation Department, interprets the history of the Lewis and Clark Expedition. It focuses on the winter of 1804–1805, which they spent at Fort Mandan, a post they built near a Mandan village. The center was opened in 1997 and overlooks the Missouri River on the outskirts of Washburn, North Dakota. The center also interprets other aspects of North Dakota history, including the farming-based cultures of the Mandan and Hidatsa Native American nations. In the early 1970s, a local historical group constructed a replica of the original fort Mandan on the shores of the Missouri River two miles west of Washburn, North Dakota.

Scan the QR code for more information.

E. Rainbow Energy Coal Creek Station

Photo courtesy of the Rainbow Energy Center

Scan the QR code for more information.

Coal Creek Station is the largest and most efficient power plant in North Dakota. Located near the Missouri River between Underwood, North Dakota and Washburn, North Dakota, it burns lignite. Its two generators are each rated at 605 megawatts (Unit 1 went in service in 1979, Unit 2 came online in 1980), with a peak total production of nearly 1.2 gigawatts. Rainbow Energy Center plans to focus on baseload energy from Coal Creek Station with carbon capture and incremental generation from renewables to fully utilize the capacity of the HVDC transmission system. In addition to the electrical energy generation, Coal Creek Station is home to Blue Flint Ethanol. This plant uses process and waste steam from Coal Creek Station in the production of ethanol, corn oil and distillers' grains. Blue Flint Ethanol produces 60 million gallons of ethanol per year.

F. McClusky Canal

The McClusky Canal is part of the Garrison Diversion with construction beginning in 1970. The 73.6-mile-long canal carries water from Lake Audubon to Lonetree Wildlife Management Area. The canal was designed to carry 1,950 cfs of water for irrigation of 250,000 acres, as well as to provide water for municipal and rural water systems.

Scan the QR code for more information.

G. Elevated Ice-walled Lake Plains

Elevated stable ice-walled lake plains and less stable collapsed ice-walled lake sediments are scattered throughout the Missouri Coteau. They range from flat to undulating and are usually perched above the surrounding dead-ice moraine. The topography was inverted on numerous occasions as buried ice blocks melted out. What were once lakes are now high places. The lacustrine soils formed on these landforms are of statewide importance to North and South Dakota, both agriculturally and economically, because they are nearly level, stone free, and very fertile.

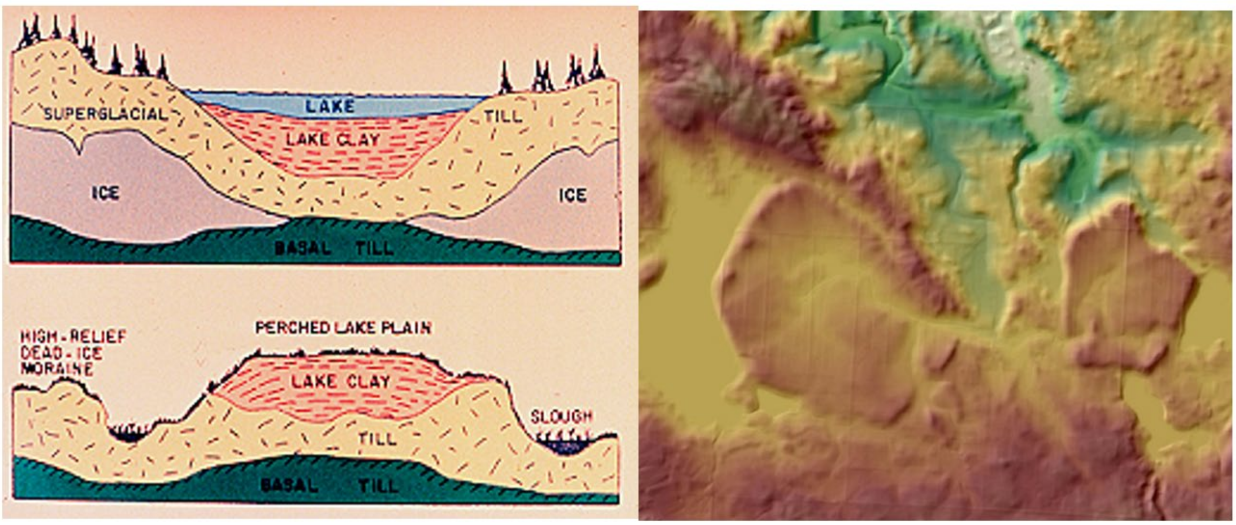


Photo courtesy of North Dakota Geologic Survey

H. Garrison Dam and Lake Sakakawea

Aerial view of Garrison Dam, impounding Lake Sakakawea on the Missouri River (photo courtesy of USACE).

1Scan the QR code for more information.

The reservoir was created by construction of Garrison Dam as part of a flood control and hydroelectric power generation project. The dam was completed in 1956. It is the second (and largest) of six main-stem dams on the Missouri River built and managed by the U.S. Army Corps of Engineers. Lake Sakakawea, named for the Shoshone-Hidatsa woman Sakakawea (who accompanied the Lewis and Clark Expedition), is known for its premier fishing. The lake is home to walleye, northern pike, and chinook salmon.

I. Knife River Indian Village

Left image: Reconstructed Hidatsa Indian Earth lodge; Right image: Interior of the Earth Lodge (photo courtesy of the National Park Service).

At the Knife River Indian Villages National Historical Site, there are the visible remains of earth-lodge dwellings, cache pits, and Travois trails. The remains of the earth-lodge dwellings can be seen as large circular depressions in the ground. These dwellings were as large as 40 feet (12 m) in diameter. Many were once large enough to house up to 20 families, a few horses, and dogs. The dwellings were constructed at ground level. As the dwellings were abandoned, the walls and roof collapsed and created the visible outer circular rim.

Scan the QR code for more information.

J. Scientific Center of North America

The U.S. Geologic Survey determined the center of North America to be near Rugby, North Dakota in 1928. To do this a cardboard cutout of the continent with a pin stuck through it was balanced on a finger. Peter Rogerson, geography professor at the University of Buffalo, created a geographic algorithm for determining geographic centers. When he applied his method to North America, he found the geographic center to be near Center, North Dakota.

Scan the QR code for more information.

K. Nelson Lake

Nelson Lake was formed in 1968 with the damming of Square Butte Creek to provide a cooling water reservoir for the Milton R. Young Station coal power plant. Water is taken in near the dam on the southeastern end of the reservoir by the facility and utilized for cooling, boiler makeup and other station uses in the power production process. After the water is used, treated, and tested to follow state and federal standards, it is discharged along a cooling canal that runs along the south shore of the lake. Typically, the water stays around 60 degrees but fluctuates throughout the year and does not freeze over in the winter. The warm water provides a long growing season for the largemouth bass, white crappie, and bluegill that inhabit the lake.

L. Glacial Deposits

In Oliver County till from two separate glacial advances can be identified on the ground surface. The Morton Drift is referred to as the oldest advance. It is early Wisconsinian, and its outer limit is southwest of the Square Butte Creek. The Napoleon Drift is also early Wisconsinian and its outer limit is the north boundary of the Square Butter Creek drainage area. Pre-Wisconsinian till can be identified in scattered locations in Oliver County. The till mantle in this area is relatively thin over the bedrock and follows the pre-existing bedrock slope. Generally, soils developed from glacial till are the best for agriculture in this area. The image above shows a contact between the darker iron stained till and the lighter colored bedrock.

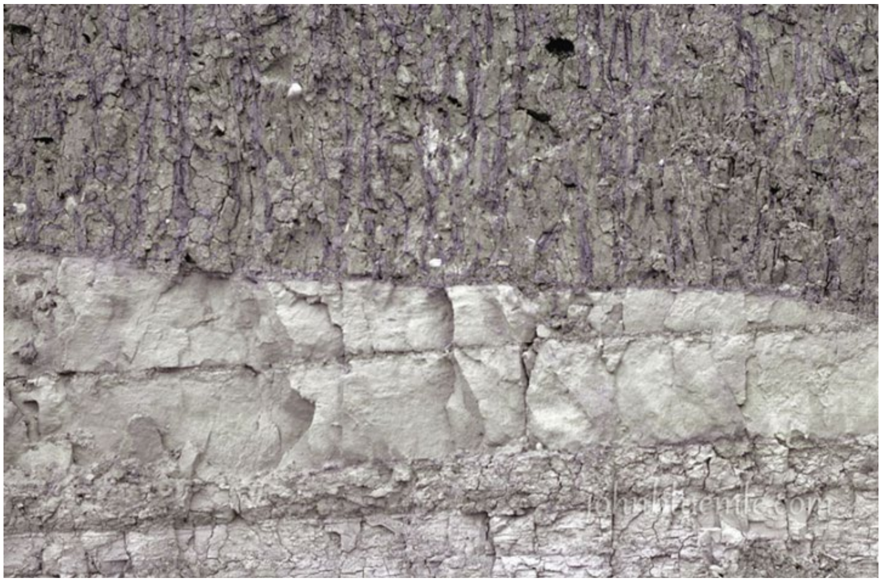


Photo by JohnBluemle.com

M. Landslides

Photo courtesy of Burleigh County Sheriff's Department.

There have been seventeen landslides identified in the Bismarck-Mandan area. Most of these predate European settlement of the area and are likely hundreds if not thousands of years old. Recent landslides in the areas likely exist on older and larger landslide complexes. Most landslides occur during the spring and early summer when snow melt and rainfall increase available moisture.

N. Fort Abraham Lincoln

Left image: Fort Abraham Lincoln Cavalry Post Blockhouse; Right image: Custer House, Fort Lincoln State Park Mandan, North Dakota (photo courtesy of North Dakota Parks and Recreation).

Fort Abraham Lincoln State Park, established in 1907, is the oldest state park in North Dakota. The park is home to the replica Mandan On-A-Slant Indian Village and reconstructed military buildings including the Custer House. Lieutenant Colonel George Armstrong Custer, commander of the 7th Cavalry, was stationed at Fort Abraham Lincoln in North Dakota from 1873 to 1876. Lieutenant Colonel Custer and his wife, Libbie, lived on Fort Abraham Lincoln from 1873 until Custer died at the Battle of the Little Big Horn in the summer of 1876. With a total complement of about 650 men, the fort was among the largest and most important forts on the Northern Plains. Its primary purpose was to protect the survey crew and railroad workers when the Northern Pacific Railroad began advancing westward.

Scan the QR code for more information.

O. Glacial Lake McKenzie

Map by johnblumle.com

In Bismarck, the Missouri River Valley is about two miles wide at the I94 crossing, but on the south side of Bismarck the valley broadens to six miles wide. The valley widens due to historic river channels. Prior to glaciation, the Heart and Little Heart Rivers merged east of where Bismarck is now. As the combined river flowed farther east, it joined with the Cannonball River.This combined river system still exists as a broad lowland south and southeast of Bismarck. The Heart/Little Heart River system was dammed multiple times by glaciers advancing westward. Each time a glacier advanced, a lake formed ahead of the river valley. These proglacial lakes are referred to as glacial Lake McKenzie. At least once, and possibly several times, glacial Lake McKenzie overflowed, carving what is now the Missouri River valley south of the Bismarck-Mandan area.

Carbon and Water Use Efficiencies Under Rainfed Cropping Practices in a Semiarid Region

Nicanor Z. Saliendra, Mark A. Liebig & David W. Archer, USDA ARS Northern Great Plains Research Laboratory, Mandan, ND

BACKGROUND

Increased adoption of warm season crops in the northern Great Plains is changing traditional cropping practices. Greater inclusions of corn (*Zea maize* L.) and soybean (*Glycine max* L.) in crop rotations have the potential to alter carbon and water balances on agricultural lands. Thus, we evaluated carbon and water fluxes under business-as-usual (BAU) management for a no-till, rainfed spring wheat (*Triticum aestivum* L.) – corn – soybean rotation using eddy covariance.

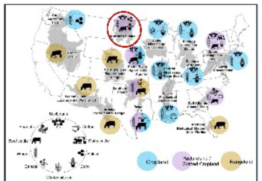


Fig. 1 The LTAR network's Common Experiment is being conducted in croplands, rangelands, pasturelands, and grazed croplands across the United States (adapted from Spiegal et al, 2018).

Study sites near Mandan, ND, USA were a part of the Long-Term Agroecosystem Research (LTAR) Network – Croplands Common Experiment (Fig. 1).

OBJECTIVES

- Quantify net ecosystem exchange (NEE) for carbon dioxide (CO_2) and evapotranspiration (ET) for BAU cropping practices in central North Dakota
- Partition NEE into ecosystem respiration (ER) and gross ecosystem production (GEP)
- Compare carbon use efficiency (CUE) and water use efficiency (WUE ≈ GEP/ET) between fields across years or crops

SITE DESCRIPTION

- A pair of fields (>20 ha each) in a 3-year rotation of spring wheat (SW) – corn (C) – soybean (SB)
- No-till, rainfed, standard fertilizer and pest protection practices for each crop
- Field management was aligned with practices by local farmers

Fig. 2 Study sites near the USDA ARS NGPRL, Mandan, ND (Lat/Lon, 46.8/-100.9). Eddy covariance towers were positioned near the center of fields h5 and i2 (Saliendra et al, 2018).

Poster presentation at the 1st Virtual (105th Annual) Meeting of the Ecological Society of America (ESA) August 3-6, 2020.
https://eco.confex.com/eco/2020/meetingapp.cgi/Paper/87733
E-mail: Nicanor.Saliendra@usda.gov

METHODS

- We used EddyPro to process raw data (10 Hz) from eddy covariance to compute half-hourly fluxes of carbon (NEE, NEP [net ecosystem production] ≈ −NEE) and water (ET).
- REddyProc was used to gap-fill half-hourly eddy fluxes & partition NEE into ER and GEP.

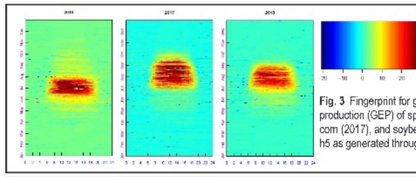


Fig. 3 Fingerprint for gross ecosystem production (GEP) of spring wheat (2016), corn (2017), and soybean (2018) at field h5 as generated through REddyProc.

RESULTS

Annual means of daily carbon and water fluxes indicated corn had higher carbon uptake (i.e., higher NEP or more negative NEE), ER, and GEP than wheat and soybean. Annual means of carbon fluxes (NEE, ER, GEP) were similar between fields, although h5 has slightly lower ET than i2 (1.15 ± 0.04 mm d^{-1} vs. 1.23 ± 0.04 mm d^{-1}). Annual sums of NEP (g C m^{-2} yr^{-1}) suggested corn was a net sink for CO_2 (121 ± 32), whereas soybean and spring wheat were near neutral (7 ± 7 and −32 ± 0, respectively) (Table 2). Overall mean NEP across the SW–C–SB rotation implied CO_2 fluxes were near equilibrium with the atmosphere (32 ± 30 g C m^{-2} yr^{-1}). During the growing season, CUE (unitless) was in the order of wheat (0.42 ± 0.02) > soybean (0.40 ± 0.02) > corn (0.33 ± 0.01) (Table 1), whereas annual WUE (g C m^{-2} mm^{-1}) was in the order of corn (1.93 ± 0.10) > wheat (1.47 ± 0.04) > soybean (1.44 ± 0.08) (Table 2).

Table 1 Carbon use efficiency (CUE) and average weather in a 3-year rotation of spring wheat (2016)–corn (2017)–soybean (2018) in two replicates (fields H5 and I2); slope of the linear regression (*b*) provide an estimate of CUE

Period	Crop	Days	Replicate (Field)	NEE = *a* + *b**GEP: *a*	*b*	Average Weather[1]: Days	$PCPN_{avg}$	SWC	RH	T_{air}
2016 6/3 – 7/29	Spring Wheat	57	1 (h5)	−96	0.40	97	2.32 abc	25 e	67 bc	19 ab
			2 (i2)	−107	0.44		2.82 a	34 a	67 bc	19 ab
			Mean	***−102***	***0.42***					
			Std. Error	***6***	***0.02***					
2017 6/28 – 10/5	Corn	100	1 (h5)	−93	0.33	150	1.69 bc	25 e	64 cd	17 b
			2 (i2)	−92	0.32		1.65 c	28 c	62 d	17 b
			Mean	***−93***	***0.33***					
			Std. Error	***1***	***0.01***					
2018 6/20 – 9/1	Soybean	74	1 (h5)	−129	0.38	103	2.74 ab	28 cd	69 ab	20 a
			2 (i2)	−125	0.42		2.71 abc	31 b	66 bc	20 a
			Mean	***−127***	***0.40***					
			Std. Error	***2***	***0.02***					

[1]Days = length of growing season, $PCPN_{avg}$ = average precipitation (mm d^{-1}), SWC = soil water content (%, v/v) at 5 cm depth, RH=relative humidity (%), T_{air} = air temperature (°C). Means followed by the same letter within a column are not significantly different at P = 0.05.

RESULTS

Table 2 Annual fluxes of carbon (NEP, ER, GEP) and water (ET), and WUE in a 3-year rotation of spring wheat (2016) – corn (2017) – soybean (2018) in two replicates (fields h5 and i2)

Year	Crop	Replicate (Field)	NEP (g C m^{-2} yr^{-1})	ER (g C m^{-2} yr^{-1})	GEP (g C m^{-2} yr^{-1})	ET (mm yr^{-1})	WUE (g C m^{-2} mm^{-1})
		Between Years (Crops)					
2016	**Spring Wheat**		−32	648	616	421	1.46
2017	**Corn**		121	778	900	465	1.93
2018	**Soybean**		7	595	601	418	1.44
		Mean	***32***	***674***	***706***	***435***	***1.61***
		Std. Error	***46***	***54***	***97***	***15***	***0.16***
		Between Replicates (Fields)					
		1 (h5)	19	662	681	420	1.62
		2 (i2)	45	685	730	449	1.63
		Mean	***32***	***674***	***706***	***435***	***1.62***
		Std. Error	***13***	***12***	***25***	***15***	***0.00***
		Between Crops x Fields					
2016	Spring Wheat	1 (h5)	−33	649	616	409	1.51
		2 (i2)	−32	648	616	433	1.42
		Mean	***−32***	***648***	***616***	***421***	***1.47***
		Std. Error	***0***	***0***	***0***	***12***	***0.04***
2017	Corn	1 (h5)	89	711	800	438	1.83
		2 (i2)	153	845	999	492	2.03
		Mean	***121***	***778***	***900***	***465***	***1.93***
		Std. Error	***32***	***67***	***99***	***27***	***0.10***
2018	Soybean	1 (h5)	−1	627	626	413	1.52
		2 (i2)	14	563	576	424	1.36
		Mean	***7***	***595***	***601***	***418***	***1.44***
		Std. Error	***7***	***32***	***25***	***5***	***0.08***
Overall		Mean	32	674	706	435	1.61
		Std. Error	30	39	67	12	0.11

CONCLUSIONS

- Inclusion of corn in the crop rotation has increased the CO_2 sink capacity and water use efficiency in no-till, rainfed agroecosystems
- Field-scale study did not allow all phases (crops) to be observed within each year, implying weather conditions may influence crop outcomes
- Results indicate the importance of long-term monitoring to assess the impacts of cropping systems on CUE and WUE in a semiarid environment

REFERENCES

Saliendra NZ, Liebig MA, Kronberg SL (2018) Carbon use efficiency of hayed alfalfa and grass pastures in a semiarid environment. Ecosphere 9(3):e02147. 10.1002/ecs2.2147
Spiegal S, Bestelmeyer BT, Archer DW, et al (2018) Evaluating strategies for sustainable intensification of US agriculture through the Long-Term Agroecosystem Research network. Environ. Res. Lett. 13, 034031. https://doi.org/10.1088/1748-9326/aaa779

Land Use Influence on Soil Water Dynamics in a Semi-Arid North Dakota Soil

Luciano, R.[1], S.E. Samson-Liebig[1], W.D. Bott[1], and M.A. Liebig[2]*
[1]USDA-NRCS Bismarck, ND, [2]USDA-ARS, NGPRL, Mandan, ND

CONTEXT

Soil water movement and agricultural land use are inextricably linked. While soil-plant root contact points are important for enhanced water and nutrient uptake, excessive compaction can reduce rates of water and air fluxes, restrict root growth, and impede nutrient and water uptake, thereby reducing crop yields and increasing negative environmental impacts. Soil water movement is an important process in soil because it controls the amount of water available to plants, how much water can be stored in the soil, and whether the root zone has excess water.

OBJECTIVE

This project sought to quantify soil-water and structural properties for three contrasting land uses in southcentral North Dakota. Since the field sites are on long-term established fields, North Dakota USDA-NRCS will be able to re-sample the sites every 5 years.

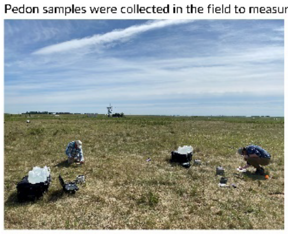
SITE INFORMATION and METHODS

The sampling sites are located at the USDA-ARS Northern Great Plains Research Laboratory (NGPRL) near Mandan, North Dakota, USA.

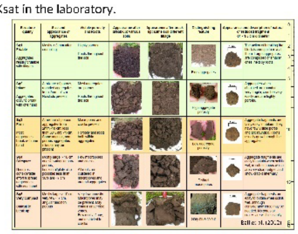
The sites are on gently rolling uplands in a Temvik-Wilton silt loams, 0 to 3 percent slopes soil map unit. Climate is characterized as semi-arid to sub-humid continental, with cold and dry winters, warm to hot summers, and erratic precipitation.

Five sampling points were selected within each of three management systems using digital soil mapping techniques to ensure similarity in soil type and landscape position across study sites. The cropland managements include No-till small grain-fallow (est. 1984), No-till continuous cropping (est. 1984), and Moderately grazed pasture (est. 1916).

Saturated hydraulic conductivity (Ksat) using SATURO[a,b] instruments, bulk density, Visual Evaluation of Soil Structure (VESS) score, and stability class score data were collected in-situ at each sampling point. Pedon samples were collected in the field to measure Ksat in the laboratory.



USDA staff conducting sorptivity tests and collecting Ksat data with SATURO[a,b] units at the moderately grazed pasture.



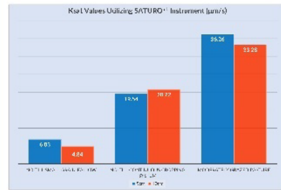
Visual Evaluation of Soil Structure. The scale of the test ranges from Sq1, good structure, to Sq5, poor structure.

Staff collecting soil samples for Dynamic Soil Properties (DSP) project in 2020.

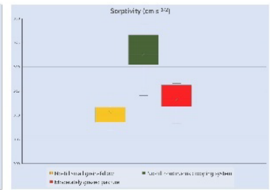
Ksat data collection with SATURO[a,b] units at the No-till small grain-fallow field.

a: METER Group inc. Pullman, WA, USA.
b: Mention of commercial products and organization in this manuscript is solely to provide specific information. It does not constitute endorsement by USDA over other products and organizations not mentioned.

RESULTS

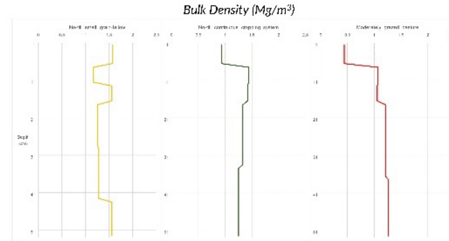


Soil Ksat was affected by a compaction layer and very firm aggregates on the small grain-fallow field. Ksat values were higher with better soil structure and increased macroporosity on the continuous cropping system and the moderately grazed pasture, respectively.



Continuous cropping promoted development of pore space with root channels which increases soil stability. In contrast, on the small grain-fallow field, bulk density was higher and water infiltration was reduced. Kentucky Bluegrass (Poa pratensis L.) and Smooth brome grass (Bromus inermis L.) pasture cover promoted development of a thatch layer which slowed the initial water infiltration.

Bulk Density (Mg/m³)



Managements:	VESS Score* (1-5)	Stability Class** (1-6)
No-till small grain-fallow	2.8	1.5
No-till continuous cropping system	1.6	5
Moderately grazed pasture	1.3	6

**Visual Evaluation of Soil Structure based on Ball et al. (2017).*
***Stability Class scored utilizing standard characterization of slake test.*

DISCUSSION

Limited biomass inputs over a long period caused by a no-till small grain-fallow system increased bulk density, reduced macro-porosity, and reduced infiltration and Ksat. When a no-till continuous cropping system replaced a no-till small grain-fallow system, the associated increase in biomass facilitated soil reconsolidation. Over time, on this transitional no-till system, connective pores were re-established, soil structure was strengthened or re-established, and infiltration increased. The data collected in a DSP sampling is used to predict long-term dynamics of soil water with land use. Practices that improve ecosystem services are critical for the management of soil water in semi-arid areas.

ACKNOWLEDGEMENTS

We gratefully acknowledge Andrew Carrison, Marvin Hatzenbuhler, and Robert Kolberg for establishment and maintenance of field plots, and Michael DeGreef, Justin Feld, Ruth Anderson, Stanley Boltz, Jessica Enger, Jeanne Heilig, John Kempenich, Perry Sullivan, Kyle Thompson, Hal Weiser, and Brianna Wegner for sample collection, processing, and analyses.

An Evaluation of Select Dynamic Soil Properties in a Semi-arid Region in North Dakota

Samson-Liebig, S.E.[1], W. Bott[1], R. Luciano[1], and M.A Liebig[2]*
[1]USDA-NRCS, Bismarck, ND; [2]USDA-ARS, NGPRL, Mandan, ND

BACKGROUND

Assessing dynamic soil properties (DSP) across various land uses on a single soil type provides valuable insights into soil change through the quantification of select soil physical, chemical, and biological properties. This study was initiated in 2020 and serves as a baseline for future monitoring and assessments to understand the impact of land management on dynamic soil properties and soil health in a semi-arid region of North Dakota.

STUDY SITE and LAND USE

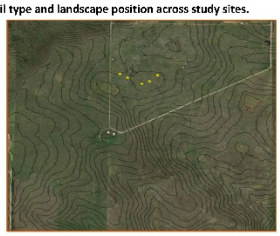
USDA-ARS Northern Great Plains Research Laboratory (NGPRL) near Mandan, North Dakota. Soils studied are on gently rolling uplands in a Temvik-Wilton silt loams, 0 to 2 percent slopes soil map unit in MLRA 54. Temvik are Fine-silty, mixed, superactive, frigid Typic Haplustolls and Wilton are Fine-silty, mixed, superactive, frigid Pachic Haplustolls.

Three contrasting land uses:

- No-till small grain-fallow (est. 1984)
- No-till continuous cropping (est. 1984)
- Moderately grazed pasture (est. 1916)

SAMPLING and ANALYSES

Each field has five sampling points which were determined using digital soil mapping techniques to ensure similarity in soil type and landscape position across study sites.



Example contour map containing sampling points.

Sampling points included a central pedon that was sampled to approximately 200cm and four satellite pedons sampled to approximately 50cm each. Detailed soil pedon descriptions were completed at each sampling point.

A suite of in-field and laboratory measurements were used to evaluate land use effects on select soil chemical, physical, and biological properties. Properties measured included bulk density, water infiltration and saturated hydraulic conductivity, aggregate stability, soil structure using Visual Evaluation of Soil Structure (VESS), Haney Nutrient Test for select chemical analyses, total elemental analyses by pXRF, and Phospholipid Fatty Acid (PLFA) for general biological assessment. Soil samples were sent to the Kellogg Soil Survey Laboratory in Lincoln, NE for complete soil characterization analyses. Select data are presented in this presentation.

No-till small grain - fallow

No-till continuous cropping

Moderately grazed pasture

RESULTS and DISCUSSION

Variable (0-10cm)	No-till Small Grain – Fallow	No-till Continuous Cropping	Moderately Grazed Pasture
Soil bulk density (Mg/m^3)	1.39	1.30	0.89
Soil organic matter (%)	3.4	4.3	9.3
Soluble Organic C (ppm)	158	186	295
Soluble Organic N (ppm)	20	27	23
Soil Respiration – CO_2-C (ppm C)	61	91	395
Soil pH (-log[H^+])	5.4	5.4	6.4

Data indicates implementing a no-till continuous cropping system improves select soil chemical, biological, and physical properties related to soil health such as increased soil organic matter, higher biological activity, and lower soil bulk density. Despite long-term no-till management, inclusion of fallow resulted in lower soil C and N and greater bulk density. Soil acidification was evident in both cropping practices compared to grazed pasture.

Variable (0-10cm)	No-till Small Grain – Fallow	No-till Continuous Cropping	Moderately Grazed Pasture
Total Biomass (ng/g)	1472	3158	2127
Diversity Index	1.40	1.40	1.45
Fungi:Bacteria	0.34	0.42	0.39
Arbuscular Mycorrhizal (%)	2.40	3.13	4.19
Gram(+):Gram(-)	1.38	1.08	1.16

Soil microbial biomass was more than two-fold greater under continuous cropping compared to small grain-fallow. Arbuscular mycorrhizal fungi increased across land uses in the order of small grain – fallow < continuous cropping < grazed pasture.

Future project plans include resampling the field sites every five years to assess changes in soil properties across management and time. This data will be used to document and predict the effects of land use and management on these soils and associated ecosystem functions.

ACKNOWLEDGEMENTS

The authors gratefully appreciate those that helped with project design, field sampling, and assessments. Perry Sullivan, Kyle Thompson, Jessica Enger, Jeanne Heilig, John Kempenich, Ruth Anderson, Brianna Wegner, Hal Weiser, Stanley Boltz, Justin Feld, and Michael DeGreef.

Greenhouse Gas Flux from Prairie Dog Mounds

Justin Feld, Mike DeGreef, Scott Kronberg, and Mark Liebig
USDA-ARS Northern Great Plains Research Laboratory, Mandan, North Dakota

USDA United States Department of Agriculture
Agricultural Research Service

Background

Prairie dogs (*Cynomys* spp.) can induce considerable soil heterogeneity in grazing lands, with mound areas frequently acting as nutrient 'hot spots' compared to non-mound areas. Little is known about greenhouse gas fluxes from prairie dog mounds. This study sought to quantify soil-atmosphere dynamics of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) fluxes on grassland with and without prairie dogs.


Black-tailed Prairie Dog (Cynomys ludovicianus). Photo by David Toledo

Methods

The study was conducted near Mandan, ND USA on a crested wheatgrass [*Agropyron desertorum* (Fisch. ex. Link) Schult.] pasture affected by prairie dog activity since 2012. Evaluated treatments included two biomes (prairie dog mounds and undisturbed grassland) with and without incorporated wood shavings (hypothesized to immobilize available N). Treatments were replicated four times. Gas fluxes were measured *in-situ* 31 times over a 12-month period using a portable gas analyzer.

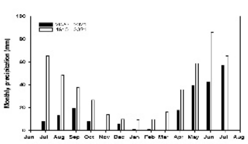

Implementing chip treatment on mounds


On mound gas sampling set up. July 27, 2020

Results

	CO_2 flux	CH_4 flux	N_2O flux
Effect	(mg CO_2-C m^{-2} h^{-1})	(μg CH_4-C m^{-2} h^{-1})	(μg N_2O-N m^{-2} h^{-1})
Biome			
Grassland	55.9 (3.2)[1]	-32.4 (1.5)	-0.3 (0.3)
Mound	37.5 (2.0)	-11.9 (1.0)	6.0 (0.7)
P value	0.0283	0.0010	0.0158
Chip treatment			
Chip	47.5 (2.8)	-23.0 (1.1)	2.8 (0.5)
No chip	46.7 (2.7)	-22.0 (1.3)	3.1 (0.6)
P value	0.8792	0.6683	0.5200

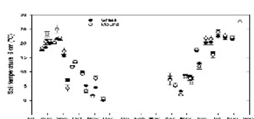
- Biome strongly affected soil-atmosphere gas fluxes, while wood shavings did not.

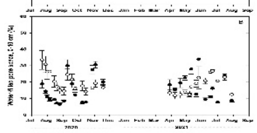


- 2020-2021 witnessed historic drought levels, similar to 1988 and 1936.
- Cumulative precipitation over the course of the study was approximately half of the long-term mean (211 vs. 417 mm).

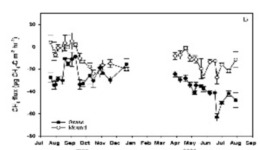
Soil property (units)	Mound	Grass	P-value
Nitrate N (mg NO_3-N kg^{-1})	70.0 (17.9)	3.1 (1.1)	0.0387
Ammonium N (mg NH_4-N kg^{-1})	18.9 (3.8)	5.8 (0.6)	0.0409

- Soil properties were measured at 0-10 cm prior to gas flux assessments, July 2020.
- Prairie dog mounds had higher soil nitrate and ammonium compared to grassland.

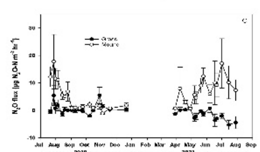




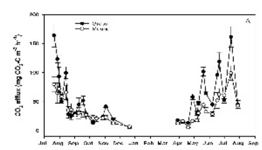
- Soil temperature was often similar between mounds and grassland.
- Water-filled pore space tended to be lower in mounds during summer and early fall.



- Methane uptake was greater on grassland than mounds during most sampling events.
- Mounds were rarely a CH_4 source.



- N_2O flux from mounds was positive.
- For grassland, N_2O flux was negative or not different from zero.



- CO_2 efflux was frequently greater from mounds compared to grassland. Root respiration was lacking on the mounds.
- CO_2 efflux was associated with soil temperature.
- Though infrequent, precipitation pluses caused strong CO_2 fluxes.


'Enhanced' on mound collar set up

Key Takeaways & Further Questions

- Compared to undisturbed grassland, prairie dog mounds were greater CO_2 and N_2O sources, but smaller CH_4 sinks.
- Wood shavings did not affect soil-atmosphere gas fluxes.
- This study was conducted during a historic drought. How might the treatments respond under more typical precipitation levels?
- Are there other soil amendments that could immobilize nutrients on prairie dog mounds? How might they affect soil-atmosphere gas fluxes?

Contact: justin.feld@usda.gov

Western North Dakota Wildlife

White-tailed deer are the most common big game animals found in North Dakota (photo courtesy of NRCS).

The coyote is native to the Northern Great Plains and is found throughout North Dakota (photo by Peter Eades, USFWS via North Dakota Tourism).

Bison with calves in Theodore Roosevelt National Park (photo courtesy of Theodore Roosevelt National Park via North Dakota Tourism).

Moose are the largest members of the deer family, and their numbers are gradually increasing in western North Dakota (photo by Terry Reimink via Adobe Stock Photos).

Pronghorn Antelope can sprint at 60 to 70 miles per hour. A fawn just a few hours old can keep up with its mother running 45 miles per hour (photo courtesy of NRCS).

Bighorn sheep were absent from North Dakota for about 50 years until reintroduction by the ND Game and Fish Dept in 1956. They are the rarest big game species in North Dakota (photo courtesy of NRCS).

Short-horned lizards found in and around the badlands of western North Dakota are often referred to as “horned toads,” but they are reptiles, not amphibians (photo by Jeff Printz, NRCS).

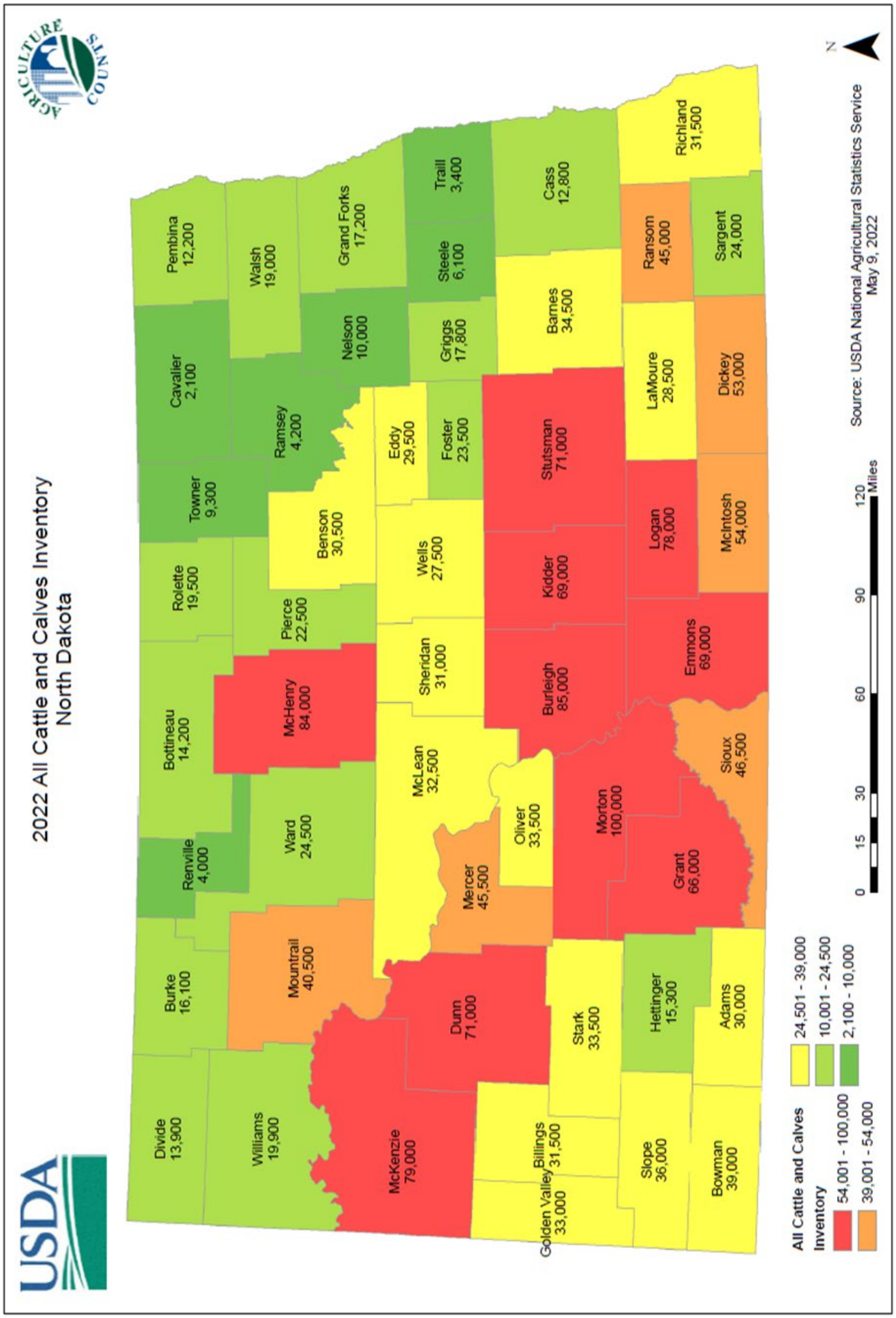
Native bumblebee on bee balm (wild bergamot). Although they don’t produce honey, native bees are essential pollinators for flowers, fruit trees, and vegetable crops (photo by Jeff Printz, NRCS).

Pair of Canada geese with goslings. Canada geese are common migratory birds in North Dakota but will winter in ND along the larger rivers as long as open water is available (photo courtesy of North Dakota Game & Fish).

Bullsnakes are large (4-6 feet long) nonvenomous constrictors that will coil like a rattlesnake and hiss when threatened. They are often seen in areas with high rodent populations, so they are common in places like prairie dog towns (photo by Jeff Printz, NRCS).

A first-rate digger, the badger is a fur-bearing carnivore that lives in dens that they dig under the North Dakota prairie. Their preferred diet is small rodents and they have been known to hunt cooperatively with coyotes in prairie dog towns (photo by Jen via Adobe Stock Photos).

Black-tailed Prairie Dogs live in large colonies known as “towns.” Their preferred colony site is a prairie landscape with short vegetation, medium-textured soils, and relatively flat topography. Many carnivorous grassland species depend on prairie dogs as a source of food (photo courtesy of the National Park Service via North Dakota Tourism).


2022 All Cattle and Calves Inventory
North Dakota
Divide 13,900
Burke 16,100
Renville 4,000
Bottineau 14,200
Rolette 19,500
Towner 9,300
Cavalier 2,100
Pembina 12,200
Williams 19,900
Mountrail 40,500
Ward 24,500
McHenry 84,000
Pierce 22,500
Benson 30,500
Ramsey 4,200
Walsh 19,000
Nelson 10,000
Grand Forks 17,200
McKenzie 79,000
Dunn 71,000
Mercer 45,500
McLean 32,500
Oliver 33,500
Sheridan 31,000
Wells 27,500
Eddy 29,500
Foster 23,500
Griggs 17,800
Steele 6,100
Traill 3,400
Golden Valley 33,000
Billings 31,500
Stark 33,500
Morton 100,000
Burleigh 85,000
Kidder 69,000
Stutsman 71,000
Barnes 34,500
Cass 12,800
Slope 36,000
Hettinger 15,300
Grant 66,000
Sioux 46,500
Emmons 69,000
Logan 78,000
LaMoure 28,500
Ransom 45,000
Richland 31,500
Bowman 39,000
Adams 30,000
McIntosh 54,000
Dickey 53,000
Sargent 24,000
All Cattle and Calves Inventory
54,001 - 100,000
39,001 - 54,000
24,501 - 39,000
10,001 - 24,500
2,100 - 10,000
0 15 30 60 90 120 Miles
N
Source: USDA National Agricultural Statistics Service
May 9, 2022

Rank

Ten Leading States and North Dakota's Rank

Item	1	2	3	4	5	6	7	8	9	10	North Dakota's rank	Percent of nation [1]
						Crop production – 2021						
Wheat, all	KS	**ND**	OK	MT	WA	ID	TX	CO	MN	IL	2	11.9
Spring	**ND**	MN	MT	ID	SD	WA					1	52.7
Durum	**ND**	MT	AZ	CA	ID						1	52.8
Winter	KS	OK	TX	WA	CO	MT	IL	ID	MI	OH	34	0.2
Barley	ID	MT	**ND**	WY	CO	WA	PA	MN	AZ	MD	3	18.6
Oats	MN	IA	**ND**	WI	SD	PA	NY	TX	ME	NE	3	10.0
Rye	OK	**ND**	WI	PA	MN						2	11.7
Sunflower, all	SD	**ND**	MN	KS	CA	CO	TX	NE			2	40.0
Oil	SD	**ND**	MN	CA	KS	CO	TX	NE			2	41.2
Non-oil	SD	**ND**	KS	CO	TX	NE	MN	CA			2	27.8
Canola	**ND**	MT	WA	MN	OK	KS					1	84.7
Soybeans	IL	IA	MN	NE	IN	MO	OH	SD	KS	**ND**	10	4.1
Flaxseed	**ND**	MT									1	82.1
Corn, grain	IA	IL	NE	MN	IN	KS	SD	OH	MO	WI	11	2.5
Silage	WI	CA	MN	NY	ID	IA	MI	PA	SD	TX	20	1.4
Dry edible beans, all	**ND**	MI	MN	NE	ID	WA	CO	WY	CA		1	28.2
Pinto	**ND**	NE	ID	CO	WA	WY	MN	MI			1	56.6
Navy	MI	MN	**ND**	ID							3	23.0
Black	MI	MN	**ND**	WA	ID						3	17.0
Chickpeas	MT	WA	ID	**ND**	CA						4	7.1
Dry edible peas	**ND**	MT	WA	NE	ID	SD					1	41.9
Lentils	MT	**ND**	WA	ID							2	28.4
Potatoes, All	ID	WA	WI	OR	**ND**	CO	MI	ME	MN	CA	5	5.3
Sugarbeets	MN	ID	**ND**	MI	NE	MT	CA	WY	CO	OR	3	17.6
Hay, all	TX	MO	NE	KS	KY	CA	OK	ID	CO	IA	26	1.7
Alfalfa	ID	NE	CA	IA	CO	WI	MT	KS	AZ	SD	22	1.7
Other	TX	MO	KY	OK	TN	KS	AR	NE	PA	AL	19	1.8
Total acreage:												
Principal crops planted	KS	IA	**ND**	IL	TX	NE	MN	SD	MO	IN	3	7.6
Principal crops harvested	IA	KS	**ND**	IL	NE	MN	TX	SD	MO	IN	3	7.6
Grain storage, December 1:												
On-farm capacity	IA	MN	IL	NE	**ND**	IN	SD	OH	MO	KS/WI	5	6.9
Off-farm capacity	IL	IA	KS	NE	MN	TX	IN	OH	**ND**	SD	9	3.9
						Livestock on hand – January 1, 2022						
All cattle and calves	TX	NE	KS	CA/OK		MO	IA	SD	WI	CO	15	2.0
Cattle and calves on feed	TX	NE	KS	IA	CO	CA	SD	MN	ID	OK	23	0.3
Cows that have calved	TX	CA	OK	MO	NE	SD	KS	WI	MT	ID/IA	14	2.4
Milk	CA	WI	ID	TX	NY	PA	MN	MI	NM	WA	35	0.2
Beef	TX	OK	MO	NE	SD	KS	MT	KY	**ND**	IA	9	3.1
All sheep and lambs	TX	CA	CO	WY	UT	SD	ID	MT	IA	OR	23	1.2
						Livestock on hand – December 1, 2021						
All hogs and pigs	IA	MN	NC	IL	IN	NE	MO	OH	OK	SD	24	0.2
						Livestock production – 2021						
Calf crop	TX	CA	OK	MO	NE	SD	KS/WI		MT	IA	13	2.6
Lamb crop	TX	CA/WY		UT	SD	CO	MT	ID	IA	OR	19	1.6
Pig crop [2]	IA	NC	MN	IL	MO	NE	OK	SD	IN	OH	23	0.6
Wool production	CA	CO	WY	UT	SD	MT	ID	TX	OR	NM	17	1.8
Honey production	**ND**	SD	CA	FL	TX	MN	MT	MI	GA	WA	1	22.4

[1] North Dakota's percent of Nation's total. [2] December 2020 - November 2021.

NORTH Dakota | Commerce
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VALUE-ADDED AGRICULTURE

INDUSTRY FACTS

$4.3 BILLION
AGRICULTURE EXPORTS ABROAD

26,000
FARMS AND RANCHES ACROSS 39.3 MILLION ACRES

40
FARMERS MARKETS

GROWING VALUE IN NORTH DAKOTA AGRICULTURE

Agriculture is a leading industry in North Dakota, consistently ranking high in crop and livestock production. North Dakota offers tremendous opportunity in value-added agriculture, such as food processing and manufacturing, as only a small percentage of production is processed in-state.

A STATE POISED FOR ECONOMIC GROWTH

North Dakota has all the key elements for successful food processors with the potential for future growth. North Dakota is focused on developing and expanding markets for crops, livestock and bio-fuels. The state offers an array of incentives to encourage continued growth in the industry. Enhanced with attractive business incentives, North Dakota is drawing some of the world's most successful companies to the state. Cavendish Farms, Roman Meal, JR Simplot, Pro Gold and Minot Milling are just a few of the businesses taking advantage of North Dakota's legendary business climate and workforce. North Dakota leads the nation in the production of 8 crops and, with the application of industry leading technology and cutting edge farming practices, our production increases year over year, creating ongoing value-added opportunities.

NORTH DAKOTA LEADS THE NATION

North Dakota leads the nation in the production of the following commodities:

- dry beans, all
- pinto beans
- canola
- flaxseed
- honey
- peas, dry edible
- wheat, durum
- wheat, spring

1

(USDA 2022 report on 2021 production)

UPDATED 08/15/2022

DID YOU KNOW?

Wheat is produced in all 53 counties in North Dakota. Around 19,200 farms grow wheat — 74% spring, 25% durum and 1% winter wheat.

Beef cattle are raised in every North Dakota county with about 945K beef cattle and calves across the state. That's more than **1.2 cattle for every person** in North Dakota.

The state has 55 dairy farms that produce nearly **40 million gallons of milk** each year.

There are approximately **12,127 head of bison** in North Dakota. They are raised for meat and hides.

North Dakota has **Seven renewable fuel facilities.**

TOP 10 EXPORT COUNTRIES FROM NORTH DAKOTA

1. Canada
2. Mexico
3. Dominican Republic
4. Japan
5. Peru
6. Colombia
7. Panama
8. Spain
9. Chile
10. Jamaica

Source: U.S. Department of Commerce, International Trade Administration

PROCESSING AND PRODUCTION INCENTIVES

- North Dakota offers a range of agricultural processing and production incentives along with ease of access to local financing institutions – including the only state-owned bank in the nation
- Sales tax exemptions on construction materials
- Property tax exemption of up to five years for new or expanding businesses and up to 10 years for ag processors
- In lieu of property tax exemption, in full or part, a company may negotiate a fixed or graduated property tax rate for up to 20 years
- Corporate income tax exemption of up to five years for new or expanding manufacturers
- Wage and salary corporate income tax credit for new businesses
- Income tax credit for research expenditures
- Sales and use tax exemption for manufacturing equipment
- No personal property tax, including equipment, inventory, materials in process and accounts receivable
- Numerous grants and low-interest loans
- Assistance for job training and workforce development
- Lowest workers compensation premium rates in the United States

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For more information, contact Kevin Sonsalla at ksonsalla@nd.gov

Energy Industry in North Dakota

Lignite Coal — Now

2023 — One of the draglines at the Coteau Freedom Mine near Beulah, ND. The bucket capacity is 124 cubic yards, which is enough space to park 3 Chevy Suburbans (photo courtesy of Basin Electric Power Cooperative).

Lignite Coal — Then

1942—Strip mining lignite coal at the Binek Coal Mine near Dickinson, North Dakota (photo by Osborn's Studio courtesy of Dickinson Museum Center).

Oil Drilling Rig — Most of North Dakota's current oil production is in the western and north-central parts of the state in shale beds of Paleozoic age. Current oil production in North Dakota is more than 1,000,000 barrels per day (photo by Goce Risteski).

Eco-pad with 6 pumping units in Dunn County, North Dakota. Horizontal drilling in different directions has made it possible to have multiple pumping units spaced close together on a single large well pad (photo courtesy of NRCS).

Hydroelectric power generation at Garrison Dam

Garrison Dam is an earth-fill embankment dam on the Missouri River in central North Dakota and is the fifth-largest earthen dam in the world. Garrison Dam was constructed in the late 1940s and early 1950s. The reservoir impounded by the dam is Lake Sakakawea. The power plant at the dam utilizes 5 turbines rated at a total capacity of 583 megawatts and generates between 1.8 and 2.6 billion kilowatt-hours of electricity each year (photo by Joel Galloway courtesy of USGS).

Wind Turbines

North Dakota is one of the leading U.S. states for wind power generation. Wind conditions in the state are very favorable for electricity generation from wind year-round but are especially good during the spring and the fall (photo by Rawpixel.com via Adobe Stock Photos).

Scan the QR code to visit the North Dakota Spotlight on Energy.

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ENERGY AND NATURAL RESOURCES

INDUSTRY FACTS

ND RANKS 3RD IN NATIONAL OIL PRODUCTION

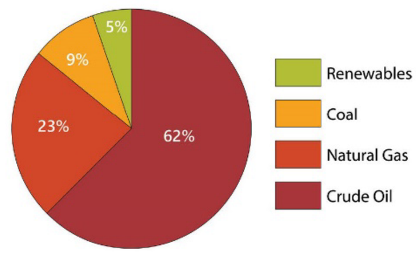
42.2 MILLION MEGAWATT HOURS OF ELECTRICITY GENERATED

5th IN SHARE OF WIND GENERATED ELECTRICITY

2nd LARGEST KNOWN LIGNITE DEPOSIT IN THE WORLD

North Dakota is the second-largest energy-producing state in the nation offering opportunities in oil and gas, coal and alternative energy production. North Dakota is a proactive producer and serves as a model in fostering innovative, long-term strategies to meet our nation's growing energy demand. The state strives with an "all of the above" approach in the development of its wide-ranging energy sector while meeting the need for energy security in an environmentally responsible manner. North Dakota offers a comprehensive package of incentives to stimulate growth in all energy sectors and creates a broad-based energy strategy that maximizes the state's resources.

NORTH DAKOTA TOTAL ENERGY PRODUCTION



ENERGY DEVELOPMENT INCENTIVES

Financial Incentives

- North Dakota Development Fund – Gap financing loan and equity program.
- Bank of North Dakota PACE Program – Interest buy down program.
- Bank of North Dakota Match Program – Loans at U.S. Treasury yield rate +0.25% to businesses other than retail that create new wealth, provide jobs and demonstrate considerable financial strength.
- Clean and Sustainable Energy program – Grant and funding options for research, development and commercialization of large scale innovative energy projects administered through the ND Industrial Commission.
- Renewable Energy Program – Grant and funding options to foster the development of renewable energy and related industrial technologies within a broad range of commercial applications. Overseen by the ND Industrial Commission.

Property Tax Exemptions

- Up to five-year property tax exemption. Additional five years available for agricultural processors or projects located on property leased from a governmental entity.
- Payment in lieu of a property tax exemption, in full or part. A company may negotiate a fixed or graduated rate for a period not to exceed 20 years. A privilege tax may be applied to coal conversion facilities.
- Exemptions on all personal property from property taxation except that of certain oil and gas refineries and utilities.

Corporate Tax Exemptions

- Five-year corporate income tax exemption for new or expanding primary sector business.

UPDATED 05/13/2022

ENERGY HIGHLIGHTS

Williston Basin crude oil export capacity included nearly 1.5 million barrels transported by pipeline per day and 800K barrels by rail per day, totaling **nearly 2.3 million barrels per day.**

32 North Dakota facilities process natural gas and have a capacity of over four billion cubic feet per day.

Electric vehicle charging stations have doubled across North Dakota with plans for more.

In 2021, North Dakota had over **4,000 MW of installed wind capacity**, with interest in an additional 6,200 MW. Ranked **7th in the nation** for installed capacity share with 31% of total electric generation coming from wind.

Sales Tax Exemptions

- Sales and use tax exemptions on manufacturing and processing equipment.
- Sales and use tax exemptions may be granted for purchasing tangible personal property used to construct or expand electrical generating facilities, gas or liquefied natural gas processing facilities or oil refineries.
- Sales and use tax exemptions may be granted for purchasing tangible personal property used for carbon-dioxide enhanced oil or gas recovery, to extract or process by-products from coal gasification and to produce coal from a new mine.

Job Training Programs

- One-stop job training assistance – Both state and federal programs available for businesses.
- New Jobs Training Program – Grant program utilizing employee withholding tax.

SUPPORTING INFRASTRUCTURE

29,655 Miles of Pipeline

- 17 major crude oil pipelines, including Enbridge, Keystone, Marathon Petroleum and Dakota Access.
- Nine natural gas pipelines, including Alliance, Northern Border and WBI Energy.
- Four product pipelines, including Cenex, Kinder Morgan Cochin, Magellan, and NuStar Energy.

Rail Services

- Class 1 Carriers – BNSF and Canadian Pacific.
- Four regional lines.
- 38 container service/transloading facilities.
- 42 loop/ladder tracks.

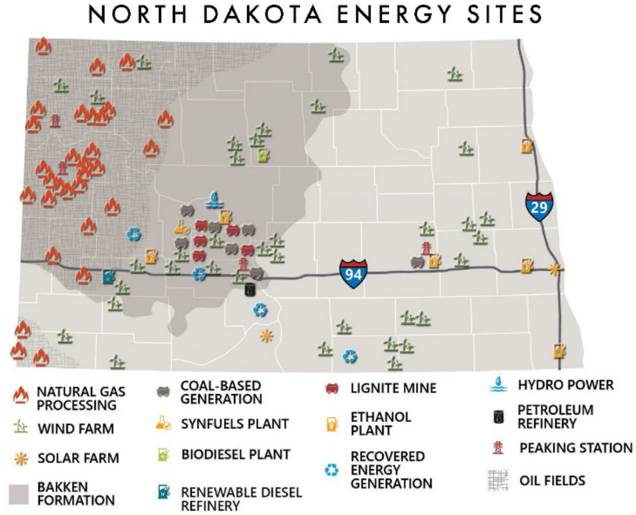
North Dakota Port Services Inc. Serviced by BNSF

- Adjacent to mainline switch yard.
- Daily service and highway access.
- Fully operational intermodal facility with LNG capacity.

Electrical Capacity

- More than 42 million megawatt hours of electricity generated annually.
- More than half of state's generated electricity is exported.

NORTH DAKOTA ENERGY SITES



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For more information, contact Rich Garman at rgarman@nd.gov or Tom Oakland at thomas.oakland@nd.gov

Bibliography

Biek, R. F. and Murphy, E. C. 1997. Dickinson Geology: A Guide to the Geology, Mineral Resources, and Geologic Hazards of the Dickinson Area. North Dakota Geological Survey. Geologic Investigation No. 1.

Bluemle, John. *Buried Glaciers and Dead-Ice Moraine*. North Dakota Geologic Survey. Retrieved January 25, 2023 from https://www.dmr.nd.gov/ndgs/ndnotes/ndn14.asp.

Bluemle, John. (May 23, 2015). *9-How The Missouri River Formed*. North Dakota Geology. http://johnbluemle.com/9-the-missouri-river/

Bluemle, John. (May 26, 2015). *12-Dead-Ice Moraine*. North Dakota Geology. http://johnbluemle.com/12-buried-glaciers-and-dead-ice-moraine/

Bluemle, J. P. 2000. *The Face of North Dakota, Third Edition.* North Dakota Geological Survey. Educational Series 26.

Bluemle, J. P. 2016. *North Dakota's Geological Legacy: Our Land and How It Formed.* North Dakota State University Press.

Bluemle, J. P. *North Dakota's Badlands*. North Dakota Geological Survey. Retrieved February 3, 2023, from https://www.dmr.nd.gov/ndgs/ndnotes/ndn12.htm

State Historical Society of North Dakota. *Chateau de Mores - History*. SHSND - Chateau de Mores History. (n.d.). Retrieved February 3, 2023, from https://www.history.nd.gov/historicsites/chateau/chateauhistory2.html

Cihacek, L., Augustin, A., Buetow, R., Landblom, d., Alghamdi, R., Şentürklü, S. *What is Soil Acidity?* 2021. North Dakota State University Extension. SF2012 https://www.ag.ndsu.edu/publications/crops/what-is-soil-acidity

Connel, L., Wilbur, R., Poresnsky, L., Scasta, J. D. 2019. *Prairie Dog Ecology and Management in Wyoming.* B-1346. University of Wyoming.

Daley, Jason. (January 30, 2017). *New Calculations Reposition the Geographical Center of North America.* Smithsonian Magazine. https://www.smithsonianmag.com/smart-news/new-calculations-reposition-geographical-center-north-america-1-180961932/

Dickinson Museum Center. *Fieldwork*. Retrieved February 3, 2023, from https://dickinsonmuseumcenter.com/badlands_fieldwork/

Helm, M. (2022, May 1). *Fort Sauerkraut*. Prairie Public Broadcasting. Retrieved February 3, 2023, from https://news.prairiepublic.org/show/dakota-datebook-archive/2022-05-01/fort-sauerkraut

Mandan Historical Society. *Northern Great Plains Experiment Station - South Hwy 6*. Retrieved October 23, 2022 from http://www.mandanhistory.org/arealandmarks/greatplainsexpermtstn.html.

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