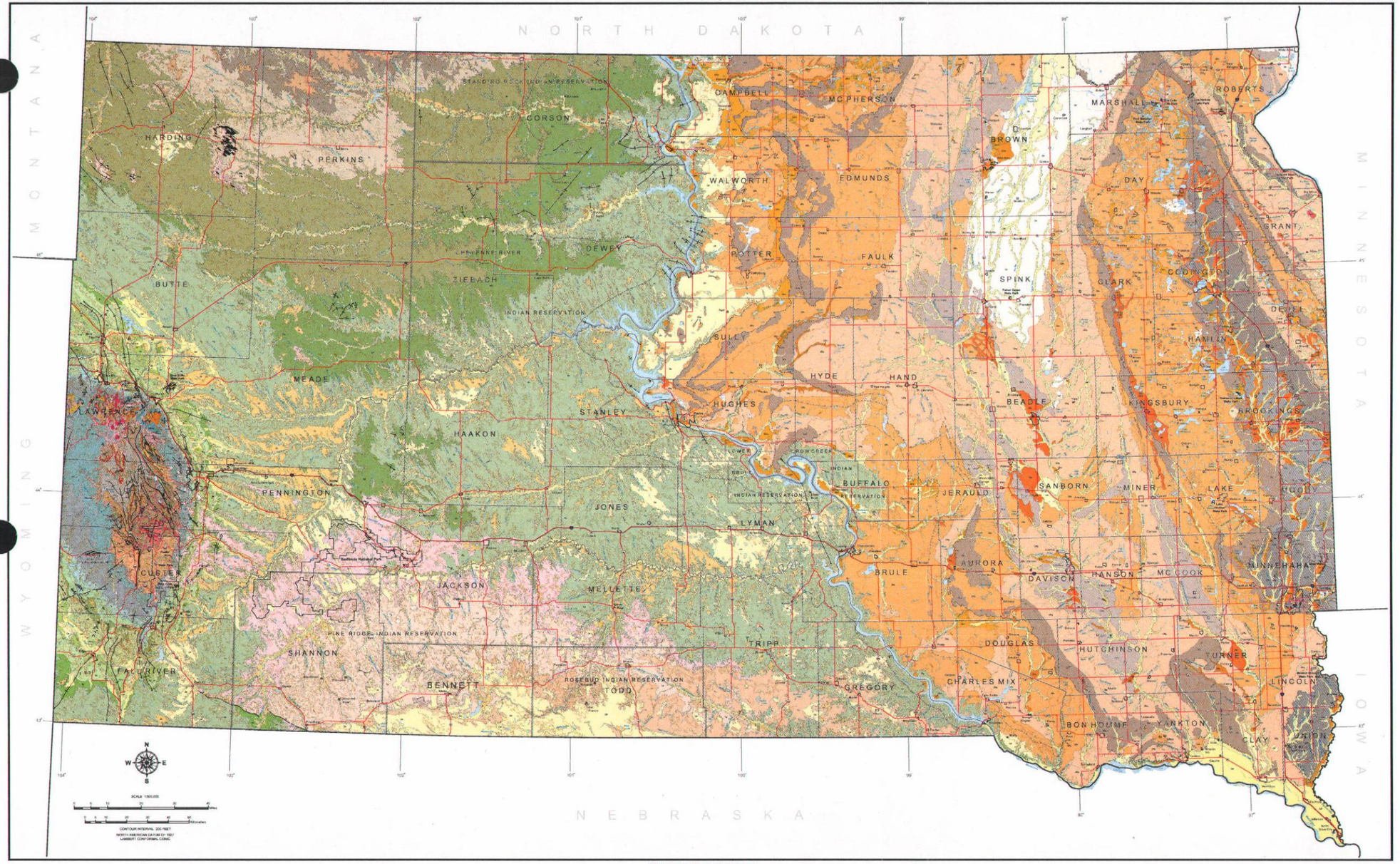


DESCRIPTION OF MAP UNITS

(Order of rock description: areal distribution, stratigraphic position, name of formation)

Qal **Alluvium** (Quaternary) – Clay- to boulder-sized clasts with locally abundant organic materials. Thickness up to 70 ft (21 m).

Qc **Colluvium** (Quaternary) – Clay- to boulder-sized clasts forming rubble mantle on hillslopes. Thickness up to 30 ft (9 m).

Ql **Landslide deposits** (Quaternary) – Landslide, slump, and collapsed material composed of chaotically mixed boulders and finer grained rock debris. Thickness up to 100 ft (30 m).

Qe **Eolian deposits** (Quaternary) – Silt to medium-grained sand. Deposited as sand sheets, barchan, linear, and dome dunes. Also includes loess and alluvial deposits. Includes the Sand Hills Formation. Thickness up to 200 ft (61 m).

Qt **Terrace deposits** (Quaternary) – Clay- to boulder-sized clasts deposited as paleosols, paleosols, and fluvial terraces. Thickness up to 70 ft (23 m).

Qbdt **Outwash, terrace** (Upper Wisconsin) – Heterogeneous clay to gravel of glaciofluvial origin. Thickness up to 40 ft (16 m).

Qbvt **Outwash, valley train** (Upper Wisconsin) – Heterogeneous silt to gravel. Confined to valleys of glaciofluvial origin. Thickness up to 60 ft (18 m).

Qbog **Outwash, collapsed** (Wisconsin) – Heterogeneous sand and gravel of glaciofluvial origin. Deposited as outwash sediments that collapsed due to melting of buried ice. Thickness up to 80 ft (27 m).

Qbod **Outwash, ice-walled** (Upper Wisconsin) – Heterogeneous sand and gravel of glaciofluvial origin. Typically forms sinuous ridges with hummocky terrain locally at former ice sheet margins. Composite thickness of all Upper Wisconsin till may be up to 300 ft (91 m).

Qbd **Outwash, delta** (Upper Wisconsin) – Heterogeneous sand and gravel of glaciofluvial origin. Typically forms near-horizontal terraces at elevations of the Lake Dakota and Glacial Lake Dakota. Thickness up to 30 ft (9 m).

Qbdu **Outwash, undifferentiated** (Upper Wisconsin) – Heterogeneous sand and gravel with minor clay and silt of glaciofluvial origin, including outwash plains, kames, kame terraces, and other undifferentiated deposits. Thickness up to 70 ft (21 m).

Qbl **Lacustrine sediments** (Upper Wisconsin) – Glaciolacustrine clay and silt with minor sand and gravel. Forms low-lying terrain. Includes deposits from Glacial Lake Dakota and Glacial Lake Agassiz. Thickness up to 80 ft (24 m).

Qbls **Lacustrine sediments, ice-rafted** (Upper Wisconsin) – Glaciolacustrine clay and silt with minor sand and gravel. Forms elevated, level terrain. Thickness up to 80 ft (18 m).

Qbg **Till, ground moraine** (Upper Wisconsin) – Compact, silty, clay-rich matrix with sand- to boulder-sized clasts of glacial origin. A geomorphic feature characterized by smooth, rolling terrain. Composite thickness of all Upper Wisconsin till may be up to 300 ft (91 m).

Qbm **Till, stagnation moraine** (Upper Wisconsin) – Compact, silty, clay-rich matrix with sand- to boulder-sized clasts of glacial origin. A geomorphic feature characterized by hummocky terrain with abundant irregular depressions. Includes the Coleharbor Formation. Composite thickness of all Upper Wisconsin till may be up to 300 ft (91 m).

Qbmt **Till, minor moraine** (Upper Wisconsin) – Compact, silty clay-rich matrix with sand- to boulder-sized clasts of glacial origin. A geomorphic feature characterized by hummocky terrain with abundant irregular depressions of recessional moraines. Composite thickness of all Upper Wisconsin till may be up to 100 ft (30 m).

Qbmg **Till, end moraine, ice-walled** (Upper Wisconsin) – Compact, silty clay-rich matrix with sand- to boulder-sized clasts of glacial origin. A geomorphic feature characterized by hummocky terrain with numerous kettle lakes. Includes the Altamont moraine. Composite thickness of all Upper Wisconsin till may be up to 300 ft (91 m).

Qbv **Valentine Formation** (Miocene) – Gray, unconsolidated, fine- to coarse-grained, fluvial siltstone, channel sandstone, and gravel derived from western sources. Thickness 170–220 ft (53–67 m).

Qbf **Fort Randall Formation** (Miocene) – Pink and gray diatomite with interbedded sandstone. Also includes green to gray unfossiliferous, nonmarine clay and conglomerate. Thickness up to 130 ft (40 m).

Qbs **Batesland Formation** (Miocene) – Tan to green, calcareous siltstone, fine- to coarse-grained sandstone, conglomerate, and silcrete. Thickness up to 80 ft (15 m).

Qbou **Outwash, undifferentiated** (Broadwell and pre-Illinoian) – Heterogeneous sand and gravel with minor clay and silt of glaciofluvial origin. Thickness up to 80 ft (27 m).

Qbu **Till, mantle (pre-Illinoian)** – Compact, silty, clay-rich matrix with sand- to boulder-sized clasts of glacial origin. Includes the Wolsey Till Member. A dissected surface. Contains prominent weathered zone at the top. Contains clasts of pebble gossanite. Typically overlies up to 40 ft (14 m) of loess. Composite thickness of all pre-Illinoian till may be up to 100 ft (30 m).

Tcg **Cave Hills Formation** (Lower Paleocene) – Tan to green, calcareous siltstone, fine- to coarse-grained sandstone, and clay. Contains abundant fossil wood. Thickness 0–300 ft (0–91 m).

Tg **Grand Deposits** (Tertiary) – Clay- to boulder-sized clasts primarily from igneous and metamorphic rocks of the central Black Hills. Also includes Pleistocene Mini clasts and rare carnelonia fossils. Thickness up to 60 ft (18 m).

Tgb **Ogallala Group** (Pliocene and Miocene) – Includes the Brule, Chadron, Valentine, and Fort Randall Formations. Also includes the Arikaree Gp. Bon Homme, Hemlock, Medicine Root, and "western Banded" gravels.

Tab **Ash Hollow Formation** (Miocene) – White, tan, and gray, well-sorted, calcareous sandstone and silty limestone. Also referred to as "marine beds." Thickness 80–200 ft (27–76 m).

Tv **Valentine Formation** (Miocene) – Gray, unconsolidated, fine- to coarse-grained, fluvial siltstone, channel sandstone, and gravel derived from western sources. Thickness 170–220 ft (53–67 m).

Tf **Fort Randall Formation** (Miocene) – Pink and gray diatomite with interbedded sandstone. Also includes green to gray unfossiliferous, nonmarine clay and conglomerate. Thickness up to 130 ft (40 m).

Tbs **Batesland Formation** (Miocene) – Tan to green, calcareous siltstone, fine- to coarse-grained sandstone, conglomerate, and silcrete. Thickness up to 80 ft (15 m).

Tu **Arikaree Group** (Miocene and Oligocene) – Includes the Rosebud, Harrison, Turtle Butte, Monroe Creek, and Sharps Formations.

Tro **Rosebud Formation** (Miocene and Oligocene) – Pink siltstone with channel sandstone and concretions, may be in part equivalent to the Sharps Formation. Thickness up to 200 ft (70 m).

Th **Harrison Formation** (Miocene) – Gray, silty sandstone and reworked bentonite with calcareous siltstone and marl. Thickness approximately 600 ft (200 m).

Tt **Turtle Butte Formation** (Miocene) – Light green to gray siltstone with sandstone channels containing claystone pebbles. Thickness approximately 65 ft (20 m).

Tsh **Sharps Formation** (Oligocene) – Pink siltstone and claystone with concretionary layers, petrocalcareous, and beds of reworked volcanic ash. Thickness approximately 300 ft (100 m).

Tw **White River Group** (Oligocene and Eocene) – Includes the Brule, Chadron, Interbedded Flats, and Sam Ruffus Formations.

Tbr **Brule Formation** (Oligocene) – White, pink, light-green, and light-brown massive to thin-bedded, bentonitic claystone, tuffaceous siltstone, and fine-grained, calcareous, tuffaceous quartz sandstone. Thickness up to 1500 ft (460 m).

Tch **Chadron Formation** (Eocene) – Upper facies are gray to light-brown to maroon bentonitic claystone, siltstone, and tuffaceous fine-grained sandstone with local silicified carbonate lenses. Basal portion consists of poorly cemented, white, coarse-grained arkose and conglomerate. Thickness up to 160 ft (49 m).

Tcr **Chamberlain Pass Formation** (Eocene) – Pale olive to pale red, mottled mudstone containing white, cross-bedded channel sandstone with basal conglomerate. Thickness up to 22 ft (10 m).

Tbo **Bon Homme Formation** (Eocene) – White, gray, and light-brown, massive and poorly bedded, clayey siltstone, bentonitic claystone, medium to fine-grained sandstone, and conglomerate. Thickness up to 40 ft (10 m).

Tfh **Fox Hills Sandstone** (Upper Cretaceous) – Bluish-green to green, white to tan, calcareous, sandstone, and siltstone. Interbedded with bioturbated, very fine- to coarse-grained, glauconitic sandstone and siltstone. Interbedded with gray and green to brown shale and silty shale. Thickness 20–400 ft (6–122 m).

Tpi **Pierre Shale** (Upper Cretaceous) – Blue-gray to dark-gray, fissile to blocky shale with persistent beds of bentonite. Black organic shale, and light-brown, blocky shale. Contains minor sandstone, conglomerate, and abundant bentonite and ferruginous concretions. Thickness up to 2 500 ft (760 m).

Tnb **Niobrara Formation** (Upper Cretaceous) – White to dark-gray chalk, chalky shale, and calcareous shale. Contains fish scales. Contains thin, laterally continuous bentonite beds, shaly carbonaceous shale, minor sand, and small concretions. Thickness 180–220 ft (46–60 m).

Tcu **Carlile Shale** (Upper Cretaceous) – Dark-gray to black, silty to sandy shale with localized zones of septarian, fossiliferous, carbonate concretions. Contains up to three sandstone units near the middle of the formation and sandy calcareous marl at the base. Thickness 340–620 ft (105–189 m).

Tgr **Greenhorn Formation, Belle Fourche Shale, Mowry Shale, Newcastle Sandstone, Skull Creek Shale, Ingen Kara Group, Fall River Formation, Lakota Formation, Morrison Formation, Sundance Formation, Spearfish Formation, Minnekahta Limestone, Opeche Shale, Minnelusa Formation, and Paleozoic Limestone** (Upper Cretaceous to Lower Mississippian)

Tgr **Greenhorn Formation** (Upper Cretaceous) – Gray shale, mudstone marl, calcareous, and shaly limestone grading upward into light-gray to tan, alternating marl and thin-bedded, fossiliferous limestone. Thickness 225–315 ft (69–96 m).

Tbe **Belle Fourche Shale, Mowry Shale, Newcastle Sandstone, and Skull Creek Shale** (Upper and Lower Cretaceous)

Tbf **Belle Fourche Shale** (Upper Cretaceous) – Dark-gray to black bentonitic shale containing minor ferruginous concretions. Thickness 180–280 ft (55–85 m).

Kmw **Mowry Shale, Newcastle Sandstone, and Skull Creek Shale** (Lower Cretaceous)

Mowry Shale (Lower Cretaceous) – Black to gray, siliceous, fissile shale and siltstone containing bentonite layers and sparse sandstone lenses. Thickness 120–250 ft (36–76 m).

Newcastle Sandstone (Lower Cretaceous) – Gray and light-brown to yellow, fine- to medium-grained, well-sorted, massive sandstone and fine-grained siltstone. Thickness up to 200 ft (61 m).

Skull Creek Shale (Lower Cretaceous) – Dark-gray to black shale with beds containing ferruginous and carbonate concretions. Thickness 150–270 ft (46–84 m).

Ikh **Ingen Kara Group** (Lower Cretaceous) – Includes the Fall River and Lakota Formations.

Kfr **Fall River Formation** (Lower Cretaceous) – Variegated brown, red, and gray to purple, calcareous, well-sorted, fine-grained sandstone and shale containing iron. Thickness 100–250 ft (30–61 m).

Kl **Lakota Formation** (Lower Cretaceous) – Yellow, brown, red-brown, and gray to black siltstone, silty pebble conglomerate, and massive to thin-bedded, cross-bedded sandstone. Locally interbedded with fresh-water limestone and bituminous coal beds. Thickness 35–600 ft (11–182 m).

Jmo **Morrison Formation, Unkpapa Sandstone, Sundance Formation, and Gypsum Spring Formation** (Upper and Middle Jurassic)

Morrison Formation (Upper Jurassic) – Light-gray to green and red-brown, bentonitic claystone and siltstone. Contains lenticular, fine-grained, calcareous sandstone and limestone. Thickness up to 150 ft (46 m).

Unkpapa Sandstone (Upper Jurassic) – White, massive to thin-bedded, fine-grained, argillaceous sandstone. May be variegated or banded red, yellow, brown, and lavender. Thickness up to 297 ft (91 m).

Sundance Formation (Upper and Middle Jurassic) – Greenish-gray, yellow, tan, red to orange, and white, variegated, interbedded fine- to coarse-grained sandstone, siltstone, clay, and limestone. Thickness 260–550 ft (79–168 m).

Gypsum Spring Formation (Middle Jurassic) – Massive white gypsum and minor maroon siltstone and shale. Thickness up to 40 ft (12 m).

Kspf **Spearfish Formation** (Lower Cretaceous) – Red and reddish to tan, siliceous, fine- to coarse-grained, iron-stained orthoquartzite with calcite- and gypsum-filled fractures. Thickness 0–400 ft (0–122 m).

Pmw **Minnekahta Limestone and Opeche Shale (Permian)**

Minnekahta Limestone (Upper and Lower Permian) – Purple to gray fine-grained thin- to medium-bedded limestone with varying amounts of red shale. Thickness 30–80 ft (9–27 m).

Opeche Shale (Lower Permian) – Red siltstone, argillaceous sandstone, and shale with intermittent calcite lenses. Thickness 85–130 ft (26–40 m).

PPm **Minnelusa Formation** (Lower Permian and Upper Pennsylvanian) – Variegated, yellow to red, gray to brown, pink to purple, and black, fine- to medium-grained sandstone, shale, limestone, dolomite, chert, and brecciated beds. Thickness 394–1 378 ft (120–398 m).

Mp **Pahasapa Limestone, Englewood Limestone, Whitewood Limestone, Winnipeg Formation, and Deadwood Formation** (Lower Mississippian to Cambrian)

Mw **Madison Group** (Lower Mississippian and Upper Devonian)

Pahasapa Limestone (Lower Mississippian) – White, light-gray to tan, fine- to medium-grained limestone and dolomite containing brown to gray chert. Solution features include collapse breccia, sinkholes, and caves. Thickness 300–630 ft (91–192 m).

Englewood Limestone (Lower Mississippian and Upper Devonian) – Pink to lavender to light-gray, thin- to medium-bedded, fine-to-medium grained, argillaceous, dolomitic limestone. Thickness 30–50 ft (9–15 m).

Whitewood Limestone, Winnipeg Formation, and Deadwood Formation (Upper Ordovician to Middle Cambrian)

Whitewood Limestone (Upper Ordovician) – Mottled tan and gray to lavender, fine- to medium-grained, sparsely fossiliferous limestone and dolomite. Thickness up to 70 ft (21 m).

Winnipeg Formation (Upper Ordovician) – Tan calcareous siltstone and shale with interbedded, thin, platy, light-gray and light-green shale. Thickness up to 110 ft (34 m).

Deadwood Formation (Upper Ordovician and Middle Cambrian) – Variegated, yellow to red, brown, gray, and green glauconitic, fine- to coarse-grained sandstone, dolomitic limestone, and dolomite. Thickness 400 ft (120 m).

Mmc **Mesa Quartzite** (Lower Proterozoic) – Pink and reddish to tan, siliceous, fine- to coarse-grained, iron-stained orthoquartzite with cross-bedded, well-sorted sandstone. Thickness greater than 1 000 ft (305 m).

Hpc **Harney Peak Granite** (Lower Proterozoic) – Pink to tan, fine-grained to pegmatitic, porphyritic to muscovite granite and pegmatite, containing accessory biotite, garnet, apatite, and tourmaline. Main body is a composite dome-shaped mass consisting of hundreds of separate intrusions, more than 30 000 dikes and dikes occur adjacent to batholith.

Mp **Metamorphosed pelite** (Lower Proterozoic) – Gray to dark-gray phyllite, slate, and mica schist. Estimated thickness at least 3 000 ft (1,524 m).

Mb **Metabasalt** (Lower Proterozoic) – Metamorphosed basalt, greenstone, amphibolite schist. Includes metabasalt conglomerate and iron-rich schist.

Mq **Metagraywacke** (Lower Proterozoic) – Light- to dark-gray, siliceous mica schist and impure quartzite. Differentiated where possible into three primary lithologic units. Thickness greater than 1 000 ft (305 m).

Mgs **Metagraywacke unit 3** (Lower Proterozoic) – Upper Kyle

Mgm **Metagraywacke unit 2** (Lower Proterozoic) – Middle Kyle

Mgi **Metagraywacke unit 1** (Lower Proterozoic) – Lower Kyle

Mgu **Upper metagraywacke** (Lower Proterozoic) – Light- to dark-gray quartz-mica-feldspar schist, quartz-mica schist, staurolite- and garnet-rich schist, metaconglomerate, rare silicate gneiss, and cummingtonite quartz schist. Thickness up to 10 000 ft (3,048 m).

Mgl **Lower metagraywacke** (Lower Proterozoic) – Light- to dark-gray, medium- to thick-bedded, quartz-mica schist containing rare silicate lenses and ellipsoidal masses. Thickness up to 7 000 ft (2,134 m).

Mgt **Metagraywacke tuffaceous schist** (Lower Proterozoic) – Light-gray to light-tan, muscovite schist and muscovite phyllite. Laterally equivalent to Mgl. Thickness exceeds 6 000 ft (1,829 m).

Mcg **Metaconglomerate and metaquartzite** (Lower Proterozoic) – Light-gray to gray, conglomeratic and feldspathic schist, quartz schist, gneiss, and phyllite; individual conglomerate and feldspathic-quartzite ledges from 100–1 800 ft (30–457 m) thick. Total thickness more than 10 000 ft (3 048 m).

Xp **Pegmatite** (Lower Proterozoic or Upper Archean?) – Light-tan to pale pegmatite.

Mbs **Metabasalt** (Lower Proterozoic or Upper Archean?) – Dark-green amphibolite and amphibolitic schist. Thickness of individual flows 50–200 ft (15-61 m).

Mgr **Metagreywacke** (Lower Proterozoic or Upper Archean?) – Gray, siliceous mica schist and impure quartzite.

Xg **Granite** (Upper Archean) – Pink and gray, strongly foliated, medium- to coarse-grained, locally pegmatitic, biotite-muscovite granite and gneissic granite.

Xbg **Millbank Granite** (Upper Archean) – Pink to dark-red, coarse-grained granite composed of microcline, quartz, and biotite.

Mm **Older metasedimentary rocks** (Upper Archean) – Gray phyllite, mica schist, and biotite-plagioclase schist. Approximately 600 ft (183 m) exposed.

SYMBOLS

CONTACT

FAULT – Location of fault; dashed where approximate; dotted where inferred. Bar and ball shown on downthrown side where space allows.

WESTERN EXTENT OF GLACIATION – Approximate location of the western extent of Pleistocene glaciation in South Dakota. Hachures on side of line from which ice advanced.

GLACIAL ADVANCES – Location of major glacial advances in South Dakota. Includes Big Stone/Grantham, Gary/Dickinson, and Big Stone/Cassa. Dashed where approximate. Hachures on side of line from which ice advanced.

IRON FORMATION

FOLD LINES – Location of fold; dashed where approximate; dotted where inferred. Arrow on fold axis indicates direction of plunge.

ANTICLINE

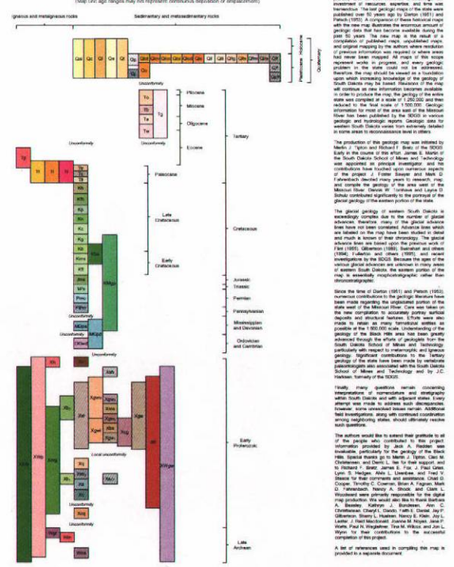
SYNCLINE

MONOCLINE

DOME

CORRELATION OF MAP UNITS

(Map Unit age ranges may not represent continuous deposition or emplacement)



DISCUSSION

The Geological Map of South Dakota has been a continuing project of the Survey since its inception. Many of the South Dakota Geological Survey (SDGS) Publications have included geologic maps of the state at various scales. The last geologic maps of the state were published over 50 years ago by Darton (1951) and Petsch (1955). A comparison of these historical maps with the new map illustrates the enormous amount of geologic data that has been collected in the state in the past 50 years. The new map is the result of a compilation of published maps, unpublished maps, and geologic mapping by the authors. Many generations of geologists have worked in the regions in which some had never been mapped. All maps of this scope represent works in progress, and geologic problem in the state could not be addressed, understood, or solved without the geologic framework upon which increasing knowledge of the geology of South Dakota may be based. Revisions of the map will continue as new information becomes available. In order to produce the map, the geology of the entire state was compiled at a scale of 1:250,000 and then reduced to the final scale of 1:500,000. Geologic information for most of the area east of the Missouri River was compiled by Martin J. Tipton, consulting geologist and hydrologist, Geologic data for western South Dakota varies from extremely detailed in some areas to reconnaissance level in others.

The production of this geologic map was initiated by Martin J. Tipton and Richard F. Bretz of the SDGS. Early in the course of the effort, James E. Martin of the University of South Dakota (USD) joined the project as principal investigator and his contributions have touched upon numerous aspects of the project. J. Foster Sawyer and Mark D. Fahrenbach directed many years to research, map compilation, and publication. Dennis W. Tomhave of the Missouri River Geologic Mapping Project and Layne D. Schulz contributed significantly to the portrayal of the glacial geology of the eastern portion of the state.

The glacial geology of western South Dakota is exceedingly complex due to the number of glacial advances; therefore, many of the glacial advance boundaries are approximate. Some glacial units are tabulated on the map have been studied in detail and much is known of their chronology. The glacial advance lines are based upon the previous work of Flint (1955), Gilbertson (1988), Boellstorf and others (1978), and Clayton and others (1980). Recent investigations by the SDGS. Because the ages of the various glacial advances are unknown in many areas of western South Dakota, the Pleistocene portion of the map is essentially morphostratigraphic rather than chronostratigraphic.

Since the time of Darton (1951) and Petsch (1955), considerable knowledge of the geology of the state has been made regarding the unglaciated portion of the state west of the Missouri River. Care was taken in the compilation of this map to show all geologic units as tabulated on the map have been studied in detail and much is known of their chronology. The glacial advance lines are based upon the previous work of Flint (1955), Gilbertson (1988), Boellstorf and others (1978), and Clayton and others (1980). Recent investigations by the SDGS. Because the ages of the various glacial advances are unknown in many areas of western South Dakota, the Pleistocene portion of the map is essentially morphostratigraphic rather than chronostratigraphic.

Initially, many geologic problems remain concerning interpretations of nomenclature and stratigraphy within South Dakota's eastern borders. Every effort was made to address such discrepancies and inconsistencies in the compilation of this map; however, vast investigations still need to be continued to address many neighboring states, should ultimately resolve such questions.

The authors would like to extend their gratitude to all of the geologists who contributed to this project, particularly those mentioned by Josh A. Rahlfen, see Publication 2004-01 for a complete list. Special thanks to Mike Sulentic and Dr. Ken Gabert for their support, and to Martin J. Tipton, Dr. Terry C. Paul, Dr. Robert Lisle, Dr. Terry C. Hedges, Alvis L. Lisenbee, and Fred Y. Steece for their reviews of the manuscript. Thanks to Duane Thorsby, C. Goerman, Brian A. Fagnan, Mark D. Fahrenbach, Nancy A. Brook, and Clark L. Pettyjohn for their assistance in the field. Thanks to Mark Wolfe, Paul A. Wiggins, Trent K. Wilcox and Jon L. Wynn for their contributions to the successful completion of this project.

A list of references used in compiling this map is provided in a separate document.

Publication Date: June 30, 2004

STATE OF SOUTH DAKOTA
M. Michael Rounds, Governor

DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES
Steven M. Pirner, Secretary

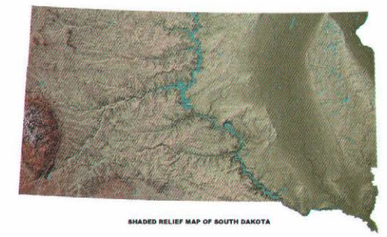
DIVISION OF FINANCIAL AND TECHNICAL ASSISTANCE
David Templeton, Director

GEOLOGICAL SURVEY
Derric L. Iles, State Geologist

GEOLOGIC MAP OF SOUTH DAKOTA

James E. Martin, J. Foster Sawyer, Mark D. Fahrenbach,
Dennis W. Tomhave, Layne D. Schulz

2004



SHADED RELIEF MAP OF SOUTH DAKOTA

MAP AREA

This map was prepared in cooperation with the U.S. Geological Survey

STATE OF SOUTH DAKOTA
Walter D. Miller, Governor

DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES
Robert E. Roberts, Secretary

DIVISION OF GEOLOGICAL SURVEY
C.M. Christensen, State Geologist

OPEN-FILE REPORT 69-UR

INVESTIGATION OF GROUND-WATER RESOURCES FOR THE TRIPP COUNTY WATER USER DISTRICT

by

LAYNE D. SCHULZ

Science Center
University of South Dakota
Vermillion, South Dakota

1994

CONTENTS

FIGURES

TABLES

APPENDICES

INTRODUCTION

The Tripp County Water User District has four production wells located approximately 9 miles south of the city of Winner, South Dakota. Due to increased demand for water, the Division of Geological Survey, Department of Environment and Natural Resources, was contacted in November 1991 to investigate an area located in the SE¼ sec. 12, T. 97 N., R. 77 W. to determine the ground-water quality and quantity. Field work started in July of 1992 and the results of the investigation are presented in this report. This investigation was financed by the Division of Geological Survey and the Tripp County Water User District.

Previous Investigations

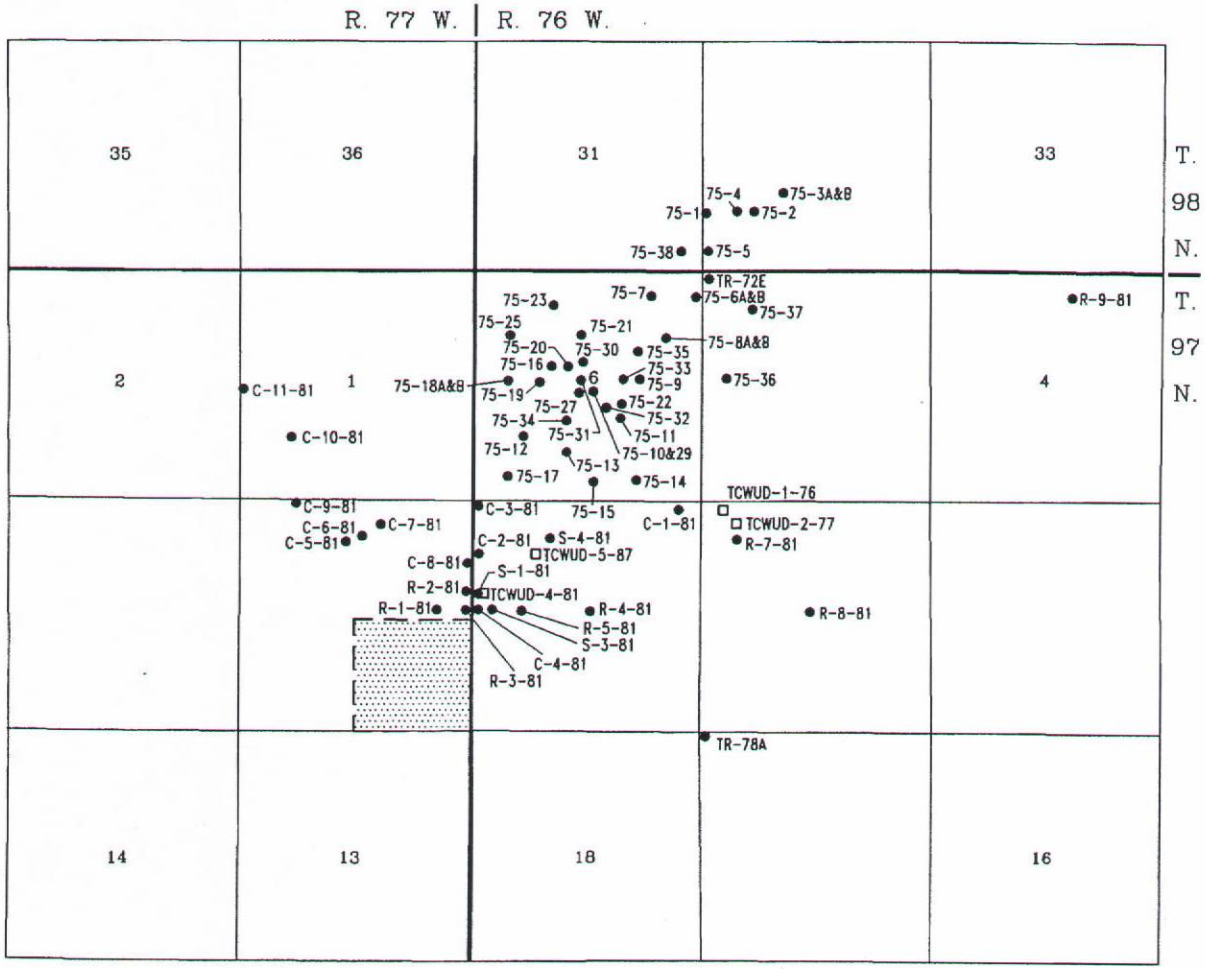
The first hydrogeologic investigation conducted by the Division of Geological Survey near the present Tripp County Water User District well field was done in June and July of 1965 for the city of Winner, South Dakota. The results of that study are presented in Barari (1966). During exploration for the city of Winner, it was found that the Valentine Formation south of Winner had sufficient saturated thickness and water quality for the construction of a municipal well field. In 1975, the newly formed Tripp County Water User District requested an investigation to further delineate the area that was previously investigated for the city of Winner. The results of that investigation are presented in Barari (1976). In that report, the Division of Geological Survey recommended the construction of a test well in section 6, T. 97 N., R. 76 W. The Tripp County Water User District could not reach an agreement with the landowners for that section and the District made the decision to locate a production well at the NW¼ sec. 8, T. 97 N., R. 76 W., where an easement agreement was reached. However, this area did not produce an adequate quantity of water for this District. In June of 1981, the Tripp County Water User District again contacted the Division of Geological Survey to find an area that could produce a higher yield of water to a production well. Results of that investigation prompted the construction of two additional production wells in NW¼ sec. 7, T. 97 N., R. 76 W. The basic data produced by that investigation are on file at the Division of Geological Survey. Figure 1 shows the location of test holes and wells drilled for previous investigations and also shows the study area for the current project.

METHODS

Drilling

In 1992, 12 test holes were drilled for this investigation. Four of those test holes were completed as observation wells (fig. 2, app. A). Drilling was accomplished by using a forward rotary drill rig with a bit diameter of 5 inches. Samples were collected at 10-foot intervals and a lithologic log was written. A geophysical log of the test holes was then made to further evaluate at what depth aquifer material might be present. The lithologic and geophysical logs were then used jointly to determine where observation wells should be placed.

Figure 1. Study area for this project and locations of test holes and wells drilled for previous investigations.



75-4 — Test hole or well drilled in 1975 by the Division of Geological Survey. The numbers identify the year drilled and hole number. Where the letters A&B follow the last digit, more than one test hole was drilled at that location.

C-11-81 or R-6-81 — Test hole or well drilled in 1981 by the Division of Geological Survey. The letter and numbers identify the rig name, the hole number, and the year drilled.

S-4-81 — Test hole or well drilled in 1981 by Sargent Irrigation. The letter and numbers identify the company's first letter, the hole number, and the year drilled.

TCWUD-4-81 — Tripp County Water User District production well. The letters and numbers identify the initials of the water district, well number, and year drilled.

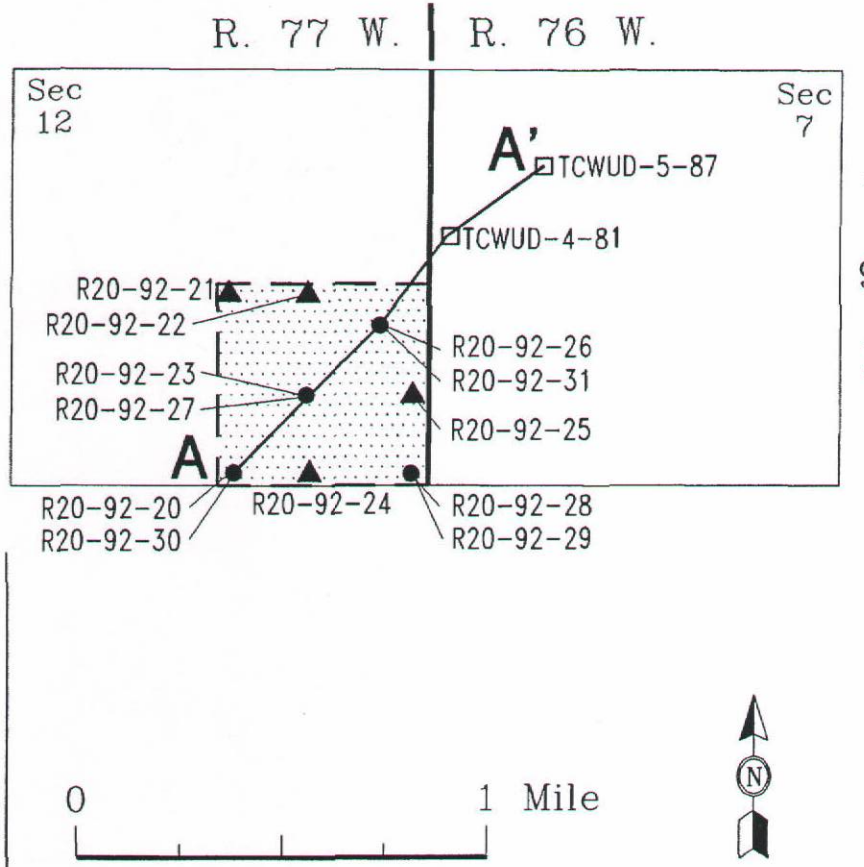
TR-78A — Division of Water Rights observation well. The letters and number identify the well name.

All logs are on file at the Division of Geological Survey.

Study area for this project.

0 1 Mile

Figure 2. Locations of test holes and observation wells drilled for this project, current production wells, and geologic cross section.



▲ R20-92-24 — Test hole drilled by the Division of Geological Survey for this study. Number is the test-hole/well identifier.

● R20-92-20 R20-92-30 — Location where a test hole and an observation well were drilled only a few feet apart by the Division of Geological Survey for this project. The upper letter and numbers are the test-hole identifier and the lower letter and numbers are the well identifier.

□ TCWUD-4-81 — Tripp County Water User District production well. The letters and numbers identify the initials of the water district, well number, and year drilled.

A A' — Location of geologic cross section A-A'. See figure 3 for cross section.

Study area for this project.

Well Construction

Observation wells were constructed using 2-inch diameter, schedule 80, flush-threaded, polyvinyl chloride (PVC) casing and screen. Screen length, well depth, and other well-construction information are given in appendix A. Filter pack was placed through a tremie line to a depth that covered the entire screen and provided for settlement around the screen. Bentonite grout was then placed in the remaining annular space from the top of the filter pack to a depth no less than 20 feet below ground surface. At a later date, neat cement grout was placed directly on top of the bentonite grout to land surface and a locking steel well protector was installed.

Well Development and Sampling

All wells for this study were developed using compressed air. Wells were pumped until the water temperature and conductivity had stabilized and the well water was clear. Sampling occurred immediately after each well was developed.

Sampling procedures were consistent with the *South Dakota Geological Survey Water Sampling Manual* (Coker and others, 1988). Samples were collected using a laboratory-cleaned bailer.

RESULTS OF INVESTIGATION

Geology

The geology of the study area consists of Tertiary-age sediments of the Ogallala Group overlying the older, Cretaceous-age, Pierre Shale. Table 1 provides the geologic age, formation names, and a brief description of each unit encountered during the investigation. Figure 3 shows the relative positions of the different units encountered while drilling. No attempt was made to correlate individual silt, sand, and clay layers within the Valentine Formation.

Pierre Shale

The Pierre Shale is a very fine textured, medium-gray to dark-gray clay that weathers to a yellow-brown to buff-orange in color and is marine in origin (Collins, 1958). The shale underlies the entire study area and its surface is undulatory due to post-Cretaceous erosion. A narrow channel which has been eroded into the Pierre Shale surface has been identified by test drilling. This channel crosses the study area from the northeast toward the southwest and has an approximate maximum relief of 100 feet (fig. 4). This small channel has subsequently been filled with sediments of the Valentine Formation deposited during the Tertiary period.

Ogallala Group

The Ogallala Group consists of continental deposits of fluvial and lacustrine origin. These sediments were derived from the erosion of mountains to the west (Collins, 1958). Two formations were

TABLE 1. Description of geologic units.

Geologic Age	Group Name	Formation Name	Description[1]
Tertiary	Ogallala Group	Ash Hollow Fm.	Light-gray to olive-gray fine sandstone and siltstone, mostly moderately cemented by calcite and silica to a plaster-like "mortar bed"; weathers to a light-gray.
		Valentine Fm.	Gray to olive-green fine sand and silt, slightly calcareous in part, poorly consolidated; weathers to light-tan unconsolidated silt and sand; local lenses of olive or greenish silty clay.
Cretaceous		Pierre Shale	Medium to dark-gray marine clay; mostly noncalcareous; weathers to a yellowish-brown.

[1] Modified from Collins (1958)

recognized in or near the study area: the Ash Hollow Formation and the Valentine Formation. The Valentine Formation is the lower formation of the Ogallala Group in south-central South Dakota and consists primarily of fine, poorly consolidated, gray to light-olive-green sands and silts but may contain layers of olive-drab to greenish-gray, silty clay (Agnew, 1957; Collins, 1958). The Valentine Formation is found in all test holes and wells drilled across the study area (figs. 2 and 3). The Ash Hollow Formation is the upper formation of the Ogallala Group and consists of fine olive-gray to light-gray sandstones and silts cemented to a plaster-like appearance which has earned the cemented zones the name "mortar beds" (Collins, 1958). The Ash Hollow Formation is present near the study area capping the hills to the east, west, and south but was not encountered in any test holes drilled for this investigation.

Figure 3. Geologic cross section A - A'.

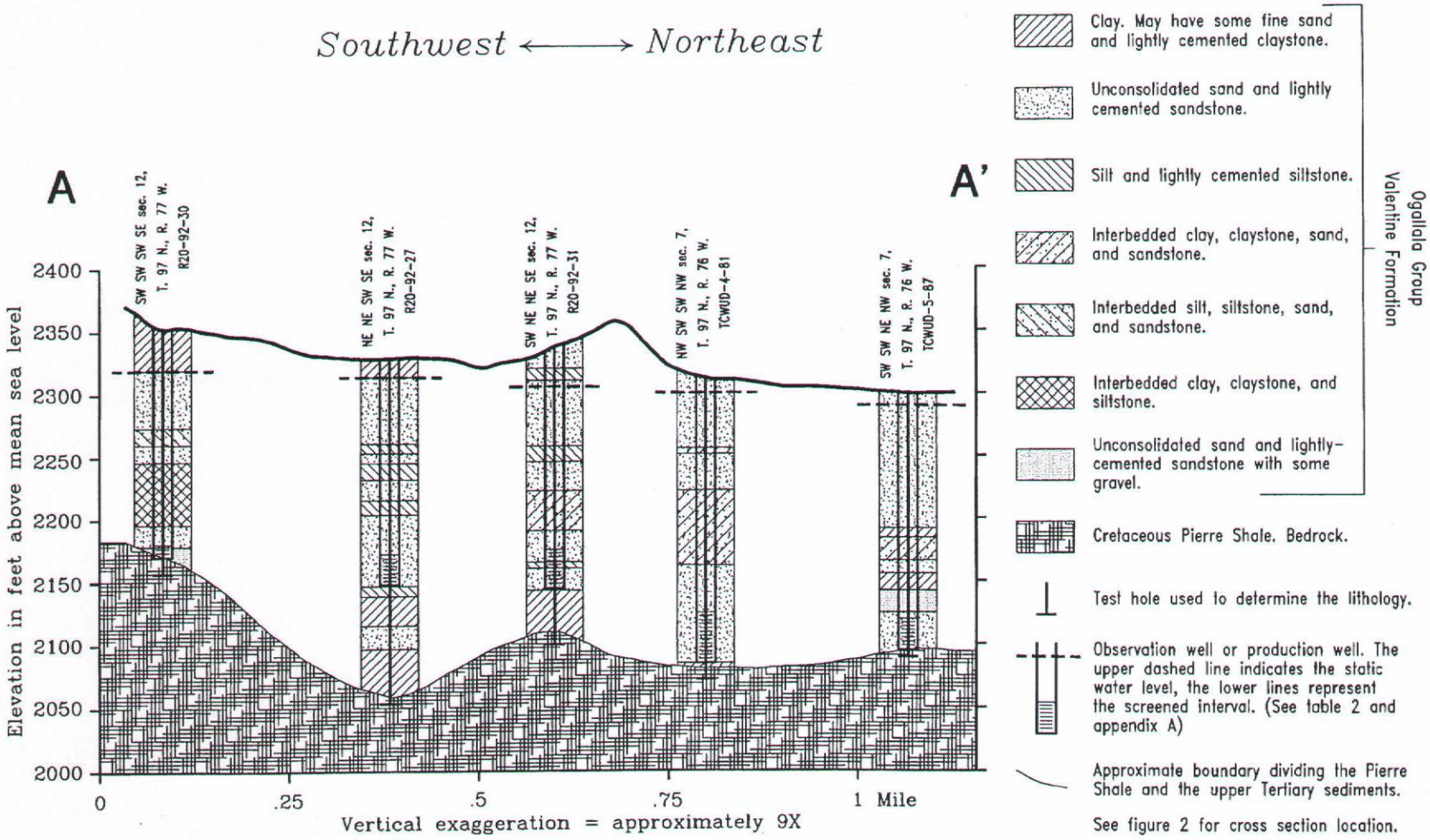
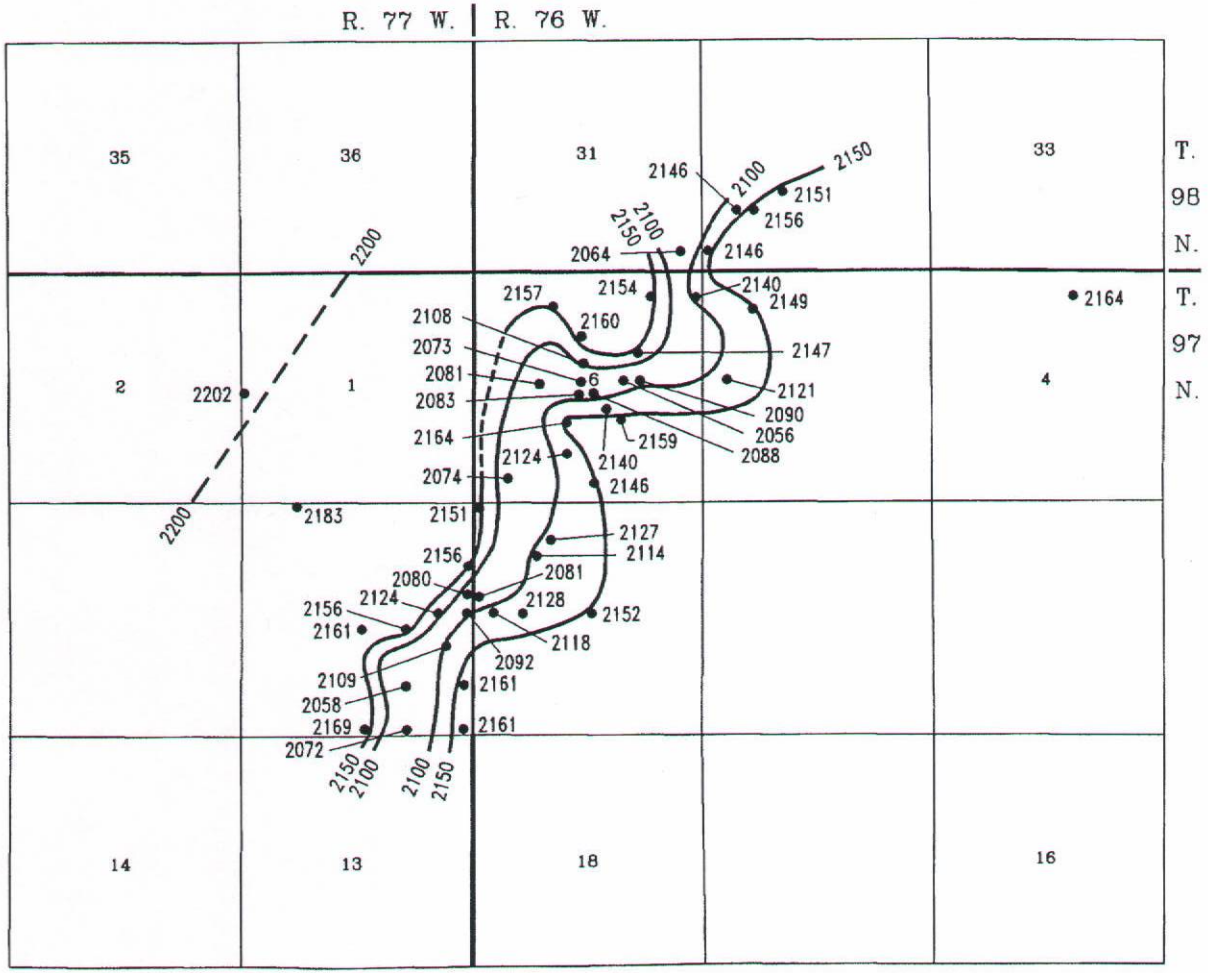


Figure 4. Configuration of the Pierre Shale surface.



2164 — Test hole used to determine the Pierre Shale surface elevation. The number represents the elevation, in feet, above mean sea level.

2150 — Contour line connecting points of equal elevation, in feet, above mean sea level. Contour interval = 50 feet. Dashed where approximate.

Test-hole logs are on file at the Division of Geological Survey.

0 1 Mile

Hydrogeology

The unconsolidated sands and locally cemented sandstones of the Valentine Formation are the primary source of ground water in the region. The Valentine Formation, part of the Ogallala Group, is considered as part of the Ogallala aquifer. Water levels measured in observation wells completed in this formation indicate that the aquifer is generally under unconfined conditions. Table 2 gives the well name, location, depth to water from casing top, and the date the water levels were measured. The saturated thickness of the aquifer is shown on figure 5 and given in table 2. The saturated thickness was calculated by adding the total thickness, in feet, of all sand layers below the static water level. It should be noted that the individual sand layers are not laterally continuous as shown in figure 3. It is assumed, however, that these saturated zones are hydraulically connected given the nature of their deposition. Test well R20–92–27, located near the center of the SE¼ sec. 12, T. 97 N., R. 77 W., has the greatest saturated thickness in the study area at 158 feet. A location near this test well was chosen for a new production well (fig. 6).

Water quality in the Valentine Formation is very good. All concentrations of the parameters that were analyzed were below the primary or secondary drinking water standards set forth by the U.S.

TABLE 2. Depth to water and saturated thickness of the Valentine Formation.

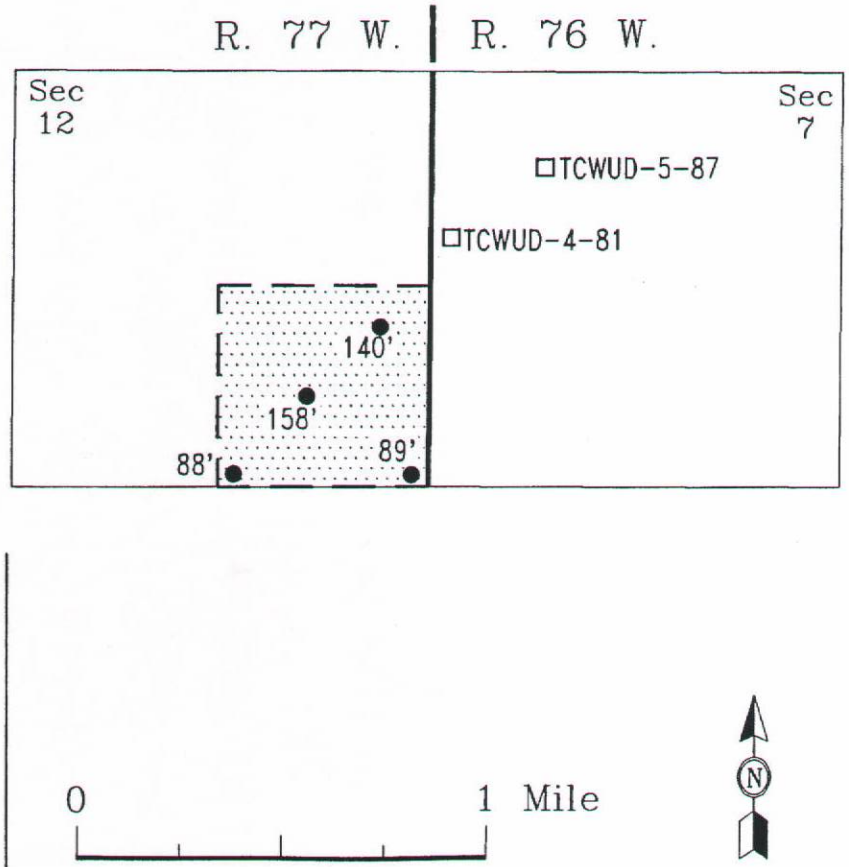
Well Name	Legal Location [1]	Depth to Water [2]	Date Measured	Saturated Thickness [3]
R20-92-31	SW NE NE SE sec. 12, T. 97 N., R. 77 W.	35.81	10/18/93	140
R20-92-27	NE NE SW SE sec. 12, T. 97 N., R. 77 W.	18.88	10/18/93	158
R20-92-30	SW SW SW SE sec. 12, T. 97 N., R. 77 W.	34.64	10/18/93	88
R20-92-29	SE SE SE SE sec. 12, T. 97 N., R. 77 W.	48.01	10/18/93	89

[1] See appendix A for explanation of legal-location format.

[2] Depth to water is presented in feet below casing top.

[3] Saturated thickness was calculated by adding the total thickness, in feet, of all sand layers below the static water level.

Figure 5. Water-sample locations and saturated thickness of the Valentine Formation in the study area.

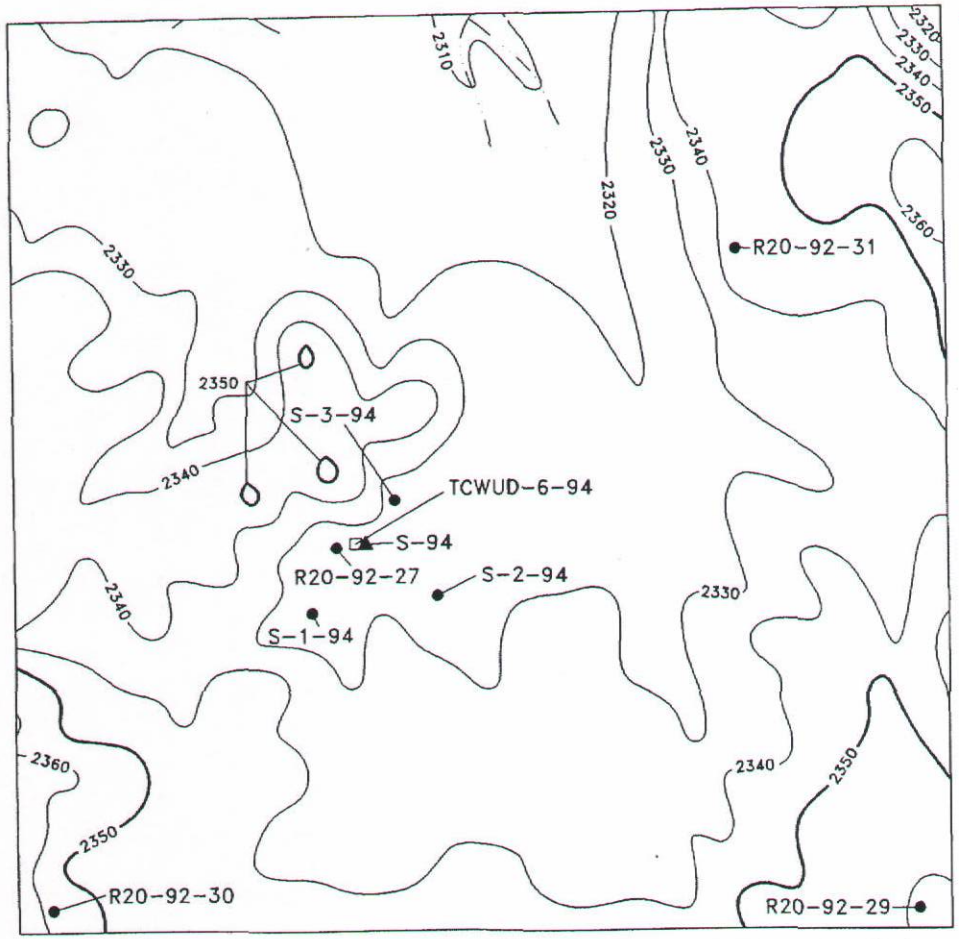


158' ● Observation well constructed and sampled by the Division of Geological Survey for this study. The number is the composite saturated thickness, in feet, of all sand layers below the static water level. Water levels were measured on 10-18-1993. See appendix B for water-chemistry analyses.

TCWUD-4-81 □ Tripp County Water User District production well. The letters and numbers identify the initials of the water district, well number, and year drilled.

Study area for this project.

Figure 6. Location of production well TCWUD-6-94 and observation wells monitored for the Tripp County Water User District aquifer test.



Map digitized from U.S. Department of the Interior Geological Survey (1982).

TCWUD-6-94 □ — Tripp County Water User District production well. The letters and numbers identify the initials of the water district, well number, and year drilled.

S-2-94 ● — Observation well drilled in 1994 by Sargent Irrigation. The letter and numbers identify the first letter of the company's name, observation well number, and year drilled.

S-94 ▲ — Supply well drilled in 1994 by Sargent Irrigation and used to supply water for drilling of the production well. The letter and number identify the first letter of the company's name and year drilled.

R20-92-31 ● — Observation well drilled in 1992 by the Division of Geological Survey. Letter and numbers identify the drilling rig, year drilled, and well number.

2350 — Contour line connecting points of equal elevation in feet above mean sea level. Contour interval = 10 feet.

Map view is the SE1/4 sec. 12, T. 97 N., R. 77 W. See figure 1.

Well locations are approximate.

N

0 250 500 750 1000 Feet

Environmental Protection Agency. Appendix B lists the analytical results of four water samples that were collected for general chemical analysis and figure 5 shows the sample locations.

APPLICATION OF INITIAL FIELD WORK

Based on the information gathered during this study, it was recommended that a production well be drilled and an aquifer test be performed by the Tripp County Water User District in the SE¼ sec. 12, T. 97 N., R. 77 W. Upon this recommendation, the Tripp County Water User District contracted with a private firm to drill additional observation wells and one new production well near the center of the SE¼ sec. 12, T. 97 N., R. 77 W. (fig. 6). An aquifer test was performed, under the supervision of the Division of Geological Survey, at an average pumping rate of 678 gallons per minute for a 24-hour period. The analysis of data shows that the desired pumping rate of 600 gallons per minute could be achieved. All aquifer-test data are on file at the Division of Geological Survey, Department of Environment and Natural Resources, Vermillion, South Dakota.

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_____ 1985b, *National interim primary drinking water regulations-maximum contaminant levels for inorganic chemicals*: Code of Federal Regulations, Title 40, Part 141, Sections 141.11 and 141.15, pp. 523-524.

APPENDIX A

Logs of test holes and observation wells

LEGAL LOCATION and **LOCATION**

The logs are listed by smallest township number, then the smallest range number, the smallest section number and then by quarter section. NE = A; NW = B; SW = C; SE = D. A comparison of **LEGAL LOCATION** and **LOCATION** is as follows. A **LEGAL LOCATION** of SW¼NE¼NE¼SE¼ sec. 12, T. 97 N., R. 77 W. is the same as a **LOCATION** of 097N–77W–12DAAC. If the smallest quarter section in the **LOCATION** is followed by a number, this indicates that more than one log may exist for that particular location.

LATITUDE and **LONGITUDE**

The format is **DD.MMSS** where **D** is degrees, **M** is minutes, and **S** is seconds.

DRILLING COMPANY

SDGS is an abbreviation for South Dakota Geological Survey.

TOTAL DRILL HOLE DEPTH, SCREEN LENGTH, TOTAL CASING AND SCREEN and **CASING STICK-UP**

The numbers are presented in feet.

SCREEN TYPE and **CASING TYPE**

PVC is an abbreviation for polyvinyl chloride. **MFG.** is an abbreviation for manufactured and indicates a product that is commercially available. **SLOT** is the size, in inches, of the openings on the screen.

CASING TOP ELEVATION and **GROUND SURFACE ELEVATION**

The numbers are presented in feet above mean sea level. **T** – the elevation was estimated from a 7.5 minute series topographic map.

CASING DIAMETER

The numbers are presented in inches.

County: TRIPP
Location: 097N-77W-12DAAC
Legal Location: SW NE NE SE sec. 12, T. 97 N., R. 77 W.
Latitude: 43.1358
Longitude: 99.5330
Land Owner: B. MULSO
Project: TRIPP RURAL WATER SYSTEM
Drilling Company: SDGS
Driller: D. IVERSON
Driller's Log:
Geologist: L. SCHULZ
Geologist's Log: X
Date Drilled: 07-28-1992
Drilling Method: ROTARY
Ground Surface Elevation: 2339 T
Total Drill Hole Depth: 239
Test Hole Number: R20-92-26
USGS Hydrological Unit Code: 10140204
Electric Log Information:
Spontaneous Potential: X
Single Point Resistivity: X
Natural Gamma: X
Extra:
Samples:

0	-	1	Topsoil
1	-	19	Sand, brown, fine-grained
19	-	28	Siltstone, green-brown, sandy; some clay
28	-	82	Sand, light-brown, fine-grained; some siltstone in cuttings
82	-	85	Siltstone, light-brown, sandy; some clay
85	-	93	Sand, tan-brown, fine-grained, silty; some clay
93	-	96	Siltstone, light-brown, sandy; some clay
96	-	115	Sand, light-brown, fine-grained, well-rounded; some siltstone and clay in cuttings
115	-	117	Clay, tan-brown, silty, sandy
117	-	118	Sand, brown, fine-grained, silty; some clay
118	-	119	Clay, tan-brown, silty, sandy
119	-	123	Sand, brown, fine-grained, silty; some clay
123	-	129	Clay, tan-brown, silty, sandy
129	-	131	Sand, brown, fine-grained, silty; some clay
131	-	136	Clay, tan-brown, silty, sandy
136	-	140	Sand, brown, fine-grained, silty; some clay
140	-	148	Clay, tan-brown, silty, sandy; some siltstone in cuttings
148	-	174	Sand, light-brown, fine-grained, well-rounded; mainly quartz with some lithic fragments
174	-	178	Siltstone, brown, sandy
178	-	196	Sand, light-brown, fine-grained, well-rounded; mainly quartz with some lithic fragments; some siltstone in cuttings
196	-	218	Clay, tan-brown to orange, silty, very sandy
218	-	229	Sand, light-brown, fine-grained, well-rounded
229	-	230	Clay, white, silty, sandy
230	-	239	Clay, gray to black; greasy (Pierre Shale)

Intervals between 115 and 148 feet were interpreted from the electric log only.

* * * *

County: TRIPP
Location: 097N-77W-12DAAC 1
Legal Location: SW NE NE SE sec. 12, T. 97 N., R. 77 W.
Latitude: 43.1358
Longitude: 99.5330
Land Owner: B. MULSO
Project: TRIPP RURAL WATER SYSTEM
Drilling Company: SDGS
Driller: D. IVERSON
Driller's Log:

Geologist: L. SCHULZ
Date Drilled: 08-12-1992
Ground Surface Elevation: 2339 T
Total Drill Hole Depth: 195
Water Rights Well:
Other Well Name:
Basin: WHITE
Management Unit:
Screen Type: PVC, MFG., SLOT SIZE 0.010 IN.
Casing Type: PVC
Casing Top Elevation: 2341 T
Casing Stick-up: 2.00
Well Maintenance Date:
USGS Hydrological Unit Code: 10140204
Electric Log Information:
Spontaneous Potential:
Natural Gamma:
Samples:

Geologist's Log: X
Drilling Method: ROTARY

Test Hole Number: R20-92-31
SDGS Well Name: R20-92-31

Aquifer: OGALLALA

Screen Length: 30.0
Casing Diameter: 2.0

Total Casing and Screen: 195.0

Single Point Resistivity:
Extra:

Well Information: Total casing and screen = 195 feet. 30-foot screen from 195 to 165 feet below casing top. Filter pack from 195 to 125 feet below casing top. Bentonite grout from 125 feet to land surface. 1 steel well protector installed.

0	-	1	Topsoil
1	-	19	Sand, brown, fine-grained
19	-	28	Siltstone, green-brown, sandy; some clay
28	-	82	Sand, light-brown, fine-grained, well-rounded; some siltstone in cuttings
82	-	85	Siltstone, light-brown, sandy; some clay
85	-	93	Sand, tan-brown, fine-grained, silty; some clay
93	-	96	Siltstone, light-brown, sandy, some clay
96	-	115	Sand, light-brown, fine-grained, well-rounded; some siltstone and clay in cuttings
115	-	117	Clay, tan-brown, silty, sandy
117	-	118	Sand, brown, fine-grained, silty; some clay
118	-	119	Clay, tan-brown, silty, sandy
119	-	123	Sand, brown, fine-grained, silty; some clay
123	-	129	Clay, tan-brown, silty, sandy
129	-	131	Sand, brown, fine-grained, silty; some clay
131	-	136	Clay, tan-brown, silty, sandy
136	-	140	Sand, brown, fine-grained, silty; some clay
140	-	148	Clay, tan-brown, silty, sandy; some siltstone in cuttings
148	-	174	Sand, light-brown, fine-grained, well-rounded; mainly quartz with some lithic fragments
174	-	178	Siltstone, brown, sandy; some light-olive-green sandstone in cuttings
178	-	195	Sand, light-brown, fine-grained, well-rounded; mainly quartz with some lithic fragments; some siltstone in cuttings

Intervals were interpreted from the driller's log and the electric log of R20-92-26. Both holes were drilled only a few feet apart.

* * * *

County: TRIPP
Legal Location: NE NE NW SE sec. 12, T. 97 N., R. 77 W.
Latitude: 43.1403
Land Owner: B. MULSO

Location: 097N-77W-12DBAA

Longitude: 99.5342

Project: TRIPP RURAL WATER SYSTEM
Drilling Company: SDGS
Driller: D. IVERSON
Geologist: L. SCHULZ
Date Drilled: 07-15-1992
Ground Surface Elevation: 2312 T
Total Drill Hole Depth: 167
USGS Hydrological Unit Code: 10140204
Electric Log Information:
Spontaneous Potential: X
Natural Gamma: X
Samples:

Driller's Log:
Geologist's Log: X
Drilling Method: ROTARY

Test Hole Number: R20-92-22

Single Point Resistivity: X
Extra:

0	-	1	Topsoil
1	-	22	Clay, olive-green, silty, very sandy
22	-	44	Sand, brown, fine-grained, well-rounded; mainly quartz with some lithic fragments; some light-green sandstone chips in cuttings
44	-	55	Clay and siltstone interbedded, olive-green clay, buff colored siltstone, sandy
55	-	73	Sand, brown, fine-grained, well-rounded; mainly quartz with some lithic fragments; some light-green sandstone chips in cuttings
73	-	118	Clay, cream-white to light-green, silty, very sandy; some dark-brown to light-pink sandstone in cuttings
118	-	129	Sand, light-brown, fine to medium, well-rounded; mainly quartz with some lithic fragments; some clay layers interbedded
129	-	144	Clay, light-brown, silty, sandy; this interval interpreted from electric log
144	-	156	Sandstone and clay interbedded, dark-brown sandstone, brown clay, silty; much fine sand
156	-	167	Clay, dark-gray to black; greasy (Pierre Shale)

* * * *

County: TRIPP
Legal Location: NW NW NW SE sec. 12, T. 97 N., R. 77 W.
Latitude: 43.1402
Land Owner: B. MULSO
Project: TRIPP RURAL WATER SYSTEM
Drilling Company: SDGS
Driller: D. IVERSON
Geologist: L. SCHULZ
Date Drilled: 07-15-1992
Ground Surface Elevation: 2322 T
Total Drill Hole Depth: 168
USGS Hydrological Unit Code: 10140204
Electric Log Information:
Spontaneous Potential: X
Natural Gamma: X
Samples:

Location: 097N-77W-12DBBB

Longitude: 99.5357

Driller's Log:
Geologist's Log: X
Drilling Method: ROTARY

Test Hole Number: R20-92-21

Single Point Resistivity: X
Extra:

0	-	1	Topsoil
1	-	21	Sand, dark-brown, fine-grained, well-rounded; mainly quartz with some lithic fragments; some small clay layers
21	-	66	Clay, cream-white, silty, very sandy; thin layers of sandstone and unconsolidated sands interbedded throughout
66	-	114	Sand, tan-brown to olive-brown, fine-grained, well-rounded; mostly quartz with some lithic fragments; some small clay layers

114	-	120	Clay, tan-brown to olive-green, silty, sandy
120	-	126	Sandstone, brown; lightly cemented
126	-	156	Clay, tan-brown to olive-green, silty, sandy
156	-	161	Clay, orange-red; greasy, weathered (Pierre Shale)
161	-	168	Clay, dark-gray to black; greasy (Pierre Shale)

* * * *

County: TRIPP
Location: 097N-77W-12DCAA
Legal Location: NE NE SW SE sec. 12, T. 97 N., R. 77 W.
Latitude: 43.1350
Longitude: 99.5342
Land Owner: B. MULSO
Project: TRIPP RURAL WATER SYSTEM
Drilling Company: SDGS
Driller: D. IVERSON
Driller's Log:
Geologist: L. SCHULZ
Geologist's Log: X
Date Drilled: 07-20-1992
Drilling Method: ROTARY
Ground Surface Elevation: 2329 T
Total Drill Hole Depth: 275
Test Hole Number: R20-92-23
USGS Hydrological Unit Code: 10140204
Electric Log Information:
Spontaneous Potential: X
Single Point Resistivity: X
Natural Gamma: X
Extra:
Samples:

0	-	1	Topsoil
1	-	16	Clay, brown to light-brown, silty, very sandy; some fine sand
16	-	69	Sand, brown to light-brown, fine-grained, well-rounded; mainly quartz with some lithic fragments; some clay and silt
69	-	76	Siltstone, dark-olive-green, sandy; some clay and fine sand
76	-	86	Sand, light-brown, fine-grained, well-rounded; mainly quartz with some lithic fragments; some clay
86	-	98	Siltstone, dark-olive-green, sandy; some clay and fine sand
98	-	114	Sand, light-brown, fine-grained, well-rounded; mainly quartz with some lithic fragments; some interbedded clay and siltstone layers
114	-	126	Siltstone, olive-green, sandy; some interbedded sandstone, clay, and unconsolidated fine-grained sand layers
126	-	183	Sand, light-brown to white, fine- to medium-grained, well-rounded; mainly quartz with some lithic fragments; very little clay or silt
183	-	190	Siltstone, dark-olive-green, sandy
190	-	214	Clay, light-olive-green, silty, sandy; some brown sandstone chips in cuttings
214	-	236	Sand and sandstone, light-olive-green, fine sand; some siltstone and clay
236	-	271	Clay, light-pink, silty, sandy
271	-	275	Unknown; hard layer; driller reports gray clay on bit sample (Pierre Shale?)

* * * *

County: TRIPP
Location: 097N-77W-12DCAA 1
Legal Location: NE NE SW SE sec. 12, T. 97 N., R. 77 W.
Latitude: 43.1350
Longitude: 99.5342
Land Owner: B. MULSO
Project: TRIPP RURAL WATER SYSTEM
Drilling Company: SDGS
Driller: D. IVERSON
Driller's Log:
Geologist: L. SCHULZ
Geologist's Log: X

Date Drilled: 07-29-1992
Ground Surface Elevation: 2329 T
Total Drill Hole Depth: 184
Water Rights Well:
Other Well Name:
Basin: WHITE
Management Unit:
Screen Type: PVC, MFG., SLOT SIZE 0.010 IN.
Casing Type: PVC
Casing Top Elevation: 2331 T
Casing Stick-up: 2.50
Well Maintenance Date:
USGS Hydrological Unit Code: 10140204
Electric Log Information:
Spontaneous Potential: X
Natural Gamma: X
Samples:

Drilling Method: ROTARY

Test Hole Number: R20-92-27
SDGS Well Name: R20-92-27

Aquifer: OGALLALA

Screen Length: 25.0
Casing Diameter: 2.0

Total Casing and Screen: 182.5

Single Point Resistivity: X
Extra:

Well Information: Total casing and screen = 182.5 feet. 25 feet of screen from 182.5 to 157.5 feet below casing top. Filter pack from 182.5 to 123 feet below casing top. Bentonite grout from 123 feet to land surface. 1 steel well protector installed.

0	-	1	Topsoil
1	-	15	Clay, tan-brown, silty, sandy
15	-	69	Sand, brown, fine-grained, well-rounded; mainly quartz with some lithic fragments
69	-	76	Siltstone, dark-olive-green, clayey, very sandy
76	-	86	Sand, light-brown, fine-grained, well-rounded; some clay
86	-	98	Siltstone, dark-olive-green, sandy; some clay and fine sand layers interbedded
98	-	114	Sand, light-brown, fine-grained, well- rounded; mainly quartz with some lithic fragments; some interbedded claystone and siltstone layers
114	-	127	Siltstone, dark-olive-green, very sandy; some interbedded sandstone, clay, and unconsolidated sand layers
127	-	184	Sand, light-brown, fine to medium, well-rounded; mainly quartz with some lithic fragments; very little clay or silt

* * * *

County: TRIPP
Legal Location: SW SW SW SE sec. 12, T. 97 N., R. 77 W.
Latitude: 43.1338
Land Owner: B. MULSO
Project: TRIPP RURAL WATER SYSTEM
Drilling Company: SDGS
Driller: D. IVERSON
Geologist: L. SCHULZ
Date Drilled: 07-14-1992
Ground Surface Elevation: 2353 T
Total Drill Hole Depth: 197
USGS Hydrological Unit Code: 10140204
Electric Log Information:
Spontaneous Potential: X
Natural Gamma: X
Samples:

Location: 097N-77W-12DCCC

Longitude: 99.5357

Driller's Log:
Geologist's Log: X
Drilling Method: ROTARY

Test Hole Number: R20-92-20

Single Point Resistivity: X
Extra:

0	-	1	Topsoil

1	-	24	Clay, light-olive-green, silty, very sandy; some fine to medium sand
24	-	34	Clay, light-olive-green, silty, sandy; some interbedded siltstone and sandstone layers
34	-	80	Sand, light-brown to brown, fine-grained, well-rounded; mainly quartz with some lithic fragments; some clay, some lightly cemented siltstone chips in cuttings
80	-	84	Siltstone, dark-olive-green, sandy; much clay
84	-	86	Sandstone, light-olive-green, fine-grained, silty
86	-	89	Siltstone, dark-olive-green, sandy; much clay
89	-	91	Sandstone, light-olive-green, fine-grained, silty
91	-	94	Siltstone, dark-olive-green, sandy; much clay
94	-	106	Sand, brown, fine-grained, well-rounded; mainly quartz with some lithic fragments
106	-	158	Clay and siltstone, light-green clay, light-pink siltstone; some sandstone chips in cuttings; much fine sand
158	-	176	Sand, brown, fine- to medium-grained, well-rounded, silty; mainly quartz with some lithic fragments
176	-	183	Gravel, brown, medium to coarse; mainly lithic fragments of sandstone and siltstone; some quartz sand
183	-	184	Clay, orange-red to brown
184	-	197	Clay, dark-gray to black; greasy (Pierre Shale)

* * * *

County: TRIPP
Location: 097N-77W-12DCCC 1
Legal Location: SW SW SW SE sec. 12, T. 97 N., R. 77 W.
Latitude: 43.1338
Longitude: 99.5357
Land Owner: B. MULSO
Project: TRIPP RURAL WATER SYSTEM
Drilling Company: SDGS
Driller: D. IVERSON
Driller's Log:
Geologist: L. SCHULZ
Geologist's Log: X
Date Drilled: 08-11-1992
Drilling Method: ROTARY
Ground Surface Elevation: 2353 T
Total Drill Hole Depth: 182
Test Hole Number: R20-92-30
Water Rights Well:
SDGS Well Name: R20-92-30
Other Well Name:
Basin: WHITE
Aquifer: OGALLALA
Management Unit:
Screen Type: PVC, MFG., SLOT SIZE 0.010 IN.
Screen Length: 10.0
Casing Type: PVC
Casing Diameter: 2.0
Casing Top Elevation: 2355 T
Casing Stick-up: 2.00
Total Casing and Screen: 183.0
Well Maintenance Date:
USGS Hydrological Unit Code: 10140204
Electric Log Information:
Spontaneous Potential:
Single Point Resistivity:
Natural Gamma:
Extra:
Samples:

Well Information: Total casing and screen = 183 feet. 10-foot screen from 183 to 173 feet below casing top. Filter pack from 183 to 138 feet below casing top. Bentonite grout from 138 feet to land surface. 1 steel well protector installed.

0	-	1	Topsoil
1	-	24	Clay, light-olive-green, silty, very sandy; some fine to medium sand
24	-	34	Clay, light-olive-green, silty, very sandy; some interbedded siltstone and sandstone layers

34	-	80	Sand, light-brown to brown, fine-grained, well-rounded; mainly quartz with some lithic fragments; some clay, some lightly cemented siltstone
80	-	84	Siltstone, dark-olive-green, sandy; much clay
84	-	86	Sandstone, light-olive-green, fine-grained, silty
86	-	89	Siltstone, dark-olive-green, sandy; much clay
89	-	91	Sandstone, light-olive-green, fine-grained, silty
91	-	94	Siltstone, dark-olive-green, sandy; much clay
94	-	106	Sand, light-brown, fine-grained, well-rounded; mainly quartz with some lithic fragments
106	-	158	Clay and siltstone, light-green clay, light-pink siltstone, silty, sandy clay, very sandy siltstone; some sandstone chips in cuttings, much fine sand
158	-	176	Sand, light-brown, fine to medium, well-rounded; mainly quartz with some lithic fragments
176	-	182	Gravel, brown, medium to coarse; mainly lithic fragments of sandstone and siltstone; some quartz sand

Intervals were interpreted from the driller's log and the electric log of R20-92-20. Both holes were drilled only a few feet apart.

* * * *

County: TRIPP
Location: 097N-77W-12DCDD
Legal Location: SE SE SW SE sec. 12, T. 97 N., R. 77 W.
Latitude: 43.1339
Longitude: 99.5341
Land Owner: B. MULSO
Project: TRIPP RURAL WATER SYSTEM
Drilling Company: SDGS
Driller: D. IVERSON
Driller's Log:
Geologist: L. SCHULZ
Geologist's Log: X
Date Drilled: 07-27-1992
Drilling Method: ROTARY
Ground Surface Elevation: 2340 T
Total Drill Hole Depth: 288
Test Hole Number: R20-92-24
USGS Hydrological Unit Code: 10140204
Electric Log Information:
Spontaneous Potential: X
Single Point Resistivity: X
Natural Gamma: X
Extra:
Samples:

0	-	1	Topsoil
1	-	12	Clay, brown to olive-brown, silty, sandy
12	-	63	Sand, light-brown, fine-grained, well-rounded; mainly quartz with some lithic fragments; small clay layer from 25 to 28 feet
63	-	86	Siltstone and sand, dark-brown siltstone, brown sand; some clay
86	-	105	Sand, brown, fine-grained, well-rounded; mainly quartz with some lithic fragments; some dark-brown siltstone in cuttings
105	-	117	Siltstone, dark-brown; some fine sand
117	-	135	Sand, dark-brown, fine-grained, well-rounded; mainly quartz with some lithic fragments
135	-	171	Clay and siltstone, dark-brown, sandy, much fine sand in cuttings
171	-	205	Sand, brown, fine-grained, well-rounded; mainly quartz with some lithic fragments; some sandstone chips in cuttings
205	-	232	Clay, tan-brown to white, silty, very sandy
232	-	252	Sand, brown, fine-grained, well-rounded; mainly quartz with some lithic fragments; some small claystone layers
252	-	263	Clay, tan-brown, silty, very sandy

263	-	268	Clay, orange-red, silty; some sand
268	-	288	Clay, gray; greasy (Pierre Shale)

* * * *

County: TRIPP
Location: 097N-77W-12DDAA
Legal Location: NE NE SE SE sec. 12, T. 97 N., R. 77 W.
Latitude: 43.1350
Longitude: 99.5323
Land Owner: B. MULSO
Project: TRIPP RURAL WATER SYSTEM
Drilling Company: SDGS
Driller: D. IVERSON
Driller's Log:
Geologist: L. SCHULZ
Geologist's Log: X
Date Drilled: 07-28-1992
Drilling Method: ROTARY
Ground Surface Elevation: 2335 T
Total Drill Hole Depth: 188
Test Hole Number: R20-92-25
USGS Hydrological Unit Code: 10140204
Electric Log Information:
Spontaneous Potential: X
Single Point Resistivity: X
Natural Gamma: X
Extra:
Samples:

0	-	1	Topsoil
1	-	8	Clay, brown, silty, sandy
8	-	18	Sand, brown, fine-grained, silty; some clay
18	-	77	Sand and clay interbedded, tan-brown sand, tan-white clay, fine-grained sand, silty, sandy clay; some dark-green siltstone from 45 to 50 feet
77	-	101	Sand, tan-brown, fine-grained, well-rounded; some dark-green siltstone interbedded from 87 to 93 feet
101	-	117	Siltstone and clay, dark-green siltstone, tan clay, very sandy
117	-	157	Sand, light-tan-brown to white, fine- to medium-grained, well-rounded; mainly quartz with some lithic fragments, very little clay
157	-	166	Clay, cream-white, silty, sandy
166	-	174	Clay, reddish-orange-brown
174	-	188	Clay, gray to black; greasy (Pierre Shale)

* * * *

County: TRIPP
Location: 097N-77W-12DDDD
Legal Location: SE SE SE SE sec. 12, T. 97 N., R. 77 W.
Latitude: 43.1338
Longitude: 99.5323
Land Owner: B. MULSO
Project: TRIPP RURAL WATER SYSTEM
Drilling Company: SDGS
Driller: D. IVERSON
Driller's Log:
Geologist: L. SCHULZ
Geologist's Log: X
Date Drilled: 08-10-1992
Drilling Method: ROTARY
Ground Surface Elevation: 2365 T
Total Drill Hole Depth: 212
Test Hole Number: R20-92-28
USGS Hydrological Unit Code: 10140204
Electric Log Information:
Spontaneous Potential: X
Single Point Resistivity: X
Natural Gamma: X
Extra:
Samples:

0	-	1	Topsoil
1	-	6	Clay, tan-brown, silty, sandy
6	-	12	Silt, brown, sandy; some clay
12	-	27	Siltstone, cream-white, very sandy
27	-	38	Sandstone and siltstone interbedded, white sandstone, dark-olive-green siltstone; some clay
38	-	70	Sand, light-brown, fine-grained, well-rounded; some siltstone and clay layers interbedded
70	-	92	Siltstone, dark-olive-green to dark-brown, very sandy; some tan clay, some unconsolidated light-brown sand
92	-	109	Sand, light-brown, fine-grained, well-rounded; mainly quartz with some lithic fragments; some clay in cuttings
109	-	114	Siltstone, dark-olive-green, very sandy; some clay
114	-	120	Sand, light-brown, silty; some clay
120	-	121	Siltstone, dark-olive-green, very sandy; some clay
121	-	128	Sand, light-brown, silty; some clay
128	-	129	Siltstone, dark-olive-green, very sandy; some clay
129	-	136	Sand, light-brown, silty; some clay
136	-	138	Siltstone, dark-olive-green, very sandy; some clay
138	-	166	Sand, light-brown, fine-grained, well-rounded; mainly quartz with some lithic fragments
166	-	200	Clay, tan, silty, sandy; some siltstone in cuttings
200	-	204	Claystone, light-red-pink, silty, sandy
204	-	212	Clay, gray to black; greasy (Pierre Shale)

Intervals from 109 to 138 feet were interpreted from the electric log only.

* * * *

County: TRIPP
Location: 097N-77W-12DDDD 1
Legal Location: SE SE SE SE sec. 12, T. 97 N., R. 77 W.
Latitude: 43.1338
Longitude: 99.5323
Land Owner: B. MULSO
Project: TRIPP RURAL WATER SYSTEM
Drilling Company: SDGS
Driller: D. IVERSON
Driller's Log:
Geologist: L. SCHULZ
Geologist's Log: X
Date Drilled: 08-11-1992
Drilling Method: ROTARY
Ground Surface Elevation: 2365 T
Total Drill Hole Depth: 167
Test Hole Number: R20-92-29
Water Rights Well:
SDGS Well Name: R20-92-29
Other Well Name:
Basin: WHITE
Aquifer:
Management Unit:
Screen Type: PVC, MFG., SLOT SIZE 0.010 IN.
Screen Length: 10.0
Casing Type: PVC
Casing Diameter: 2.0
Casing Top Elevation: 2367 T
Casing Stick-up: 2.00
Total Casing and Screen: 167.0
Well Maintenance Date:
USGS Hydrological Unit Code: 10140204
Electric Log Information:
Spontaneous Potential:
Single Point Resistivity:
Natural Gamma:
Extra:
Samples:

Well Information: Total casing and screen = 167 feet. 10-foot screen from 167 to 157 feet below casing top. Filter pack from 167 to 128 feet below casing top. Bentonite grout from 128 feet to land surface. 1 steel well protector installed.

0	-	1	Topsoil
1	-	6	Clay, tan-brown, silty, sandy
6	-	12	Silt, brown, sandy; some clay
12	-	27	Silt, cream-white, sandy; some tan clay
27	-	38	Sandstone and siltstone interbedded, white sandstone, dark-olive-green siltstone; some clay
38	-	70	Sand, light-brown, fine-grained, well-rounded; some siltstone and clay layers interbedded
70	-	92	Siltstone and clay, dark-olive-green siltstone, tan clay; some unconsolidated fine-grained sand layers
92	-	109	Sand, light-brown, fine-grained, well-rounded; mainly quartz with some lithic fragments
109	-	114	Siltstone, dark-olive-green, very sandy; some clay
114	-	120	Sand, light-brown, silty; some clay
120	-	121	Siltstone, dark-olive-green, very sandy; some clay
121	-	128	Sand, light-brown, silty; some clay
128	-	129	Siltstone, dark-olive-green, very sandy; some clay
129	-	136	Sand, light-brown, silty; some clay
136	-	138	Siltstone, dark-olive-green, very sandy; some clay
138	-	167	Sand, light-brown, fine-grained, well-rounded; mainly quartz with some lithic fragments

Intervals were interpreted from the driller's log and the electric log of R20-92-28. Both holes were drilled only a few feet apart.

* * * *

Appendix B. Chemical analyses of water samples

Legal Location	Well Name	Date Sampled	Well Depth[2]	Conductivity[3]	Field pH[4]	Concentrations in milligrams per liter[1]													
						TDS	Hardness as $CaCO_3$	Alk-T	HCO_3	Ca	Cl	F	Fe	K	Mg	Mn	Na	NO_3-N + NO_2-N	SO_4
						500[5]	----	-----	----	--	250[5]	2.4[6]	0.3[6]	----	----	0.05[5]	----	10[6]	250[5]
Valentine Formation (Ogallala aquifer)																			
SW NE NE SE sec. 12, T. 97 N., R. 77 W.	R20-92-31	9-01-92	193	169	7.40	145	77	84	102	26	0.9	0.19	<0.05	4.7	2.9	<0.05	3.9	0.70	2.0
NE NE SW SE sec. 12, T. 97 N., R. 77 W.	R20-92-27	8-31-92	182	194	7.54	160	81	92	112	27	0.9	0.24	<0.05	5.6	3.3	<0.05	7.5	1.22	4.4
SW SW SW SE sec. 12, T. 97 N., R. 77 W.	R20-92-30	8-31-92	183	214	7.92	164	86	106	129	27	0.8	0.42	<0.05	7.1	4.6	<0.05	9.8	0.77	3.3
SE SE SE SE sec. 12, T. 97 N., R. 77 W.	R20-92-29	8-31-92	167	301	7.59	227	140	152	185	48	1.9	0.18	<0.05	7.0	5.9	<0.05	7.0	0.94	5.3
		AVERAGE		219	7.61	174	97	109	132	32	1.1	0.26	<0.05	6.1	4.2	<0.05	7.1	0.91	3.8

[1] **TDS** - total dissolved solids; **Hardness as $CaCO_3$** - hardness as calcium carbonate; **Alk-T** - total alkalinity; **HCO_3** - bicarbonate; **Ca** - calcium; **Cl** - chloride; **F** - fluoride; **Fe** - iron; **K** - potassium; **Mg** - magnesium; **Mn** - manganese; **Na** - sodium; **NO_3-N + NO_2-N** - nitrate-nitrogen plus nitrite-nitrogen; **SO_4** - sulfate

[2] Well depth is presented in feet below ground surface and represents depth to bottom of screen.

[3] Conductivity is presented in μmhos/cm (micromhos per centimeter).

[4] Field pH is on unfiltered sample.

[5] U.S. Environmental Protection Agency, 1985a.

[6] U.S. Environmental Protection Agency, 1985b.

3-82c

Data Request:

Please describe each of the HCAs that have the potential to be affected by the pipeline (name of town, etc.)?

Response:

Table 3-82c HCAs that have the potential to be affected by the Project CL

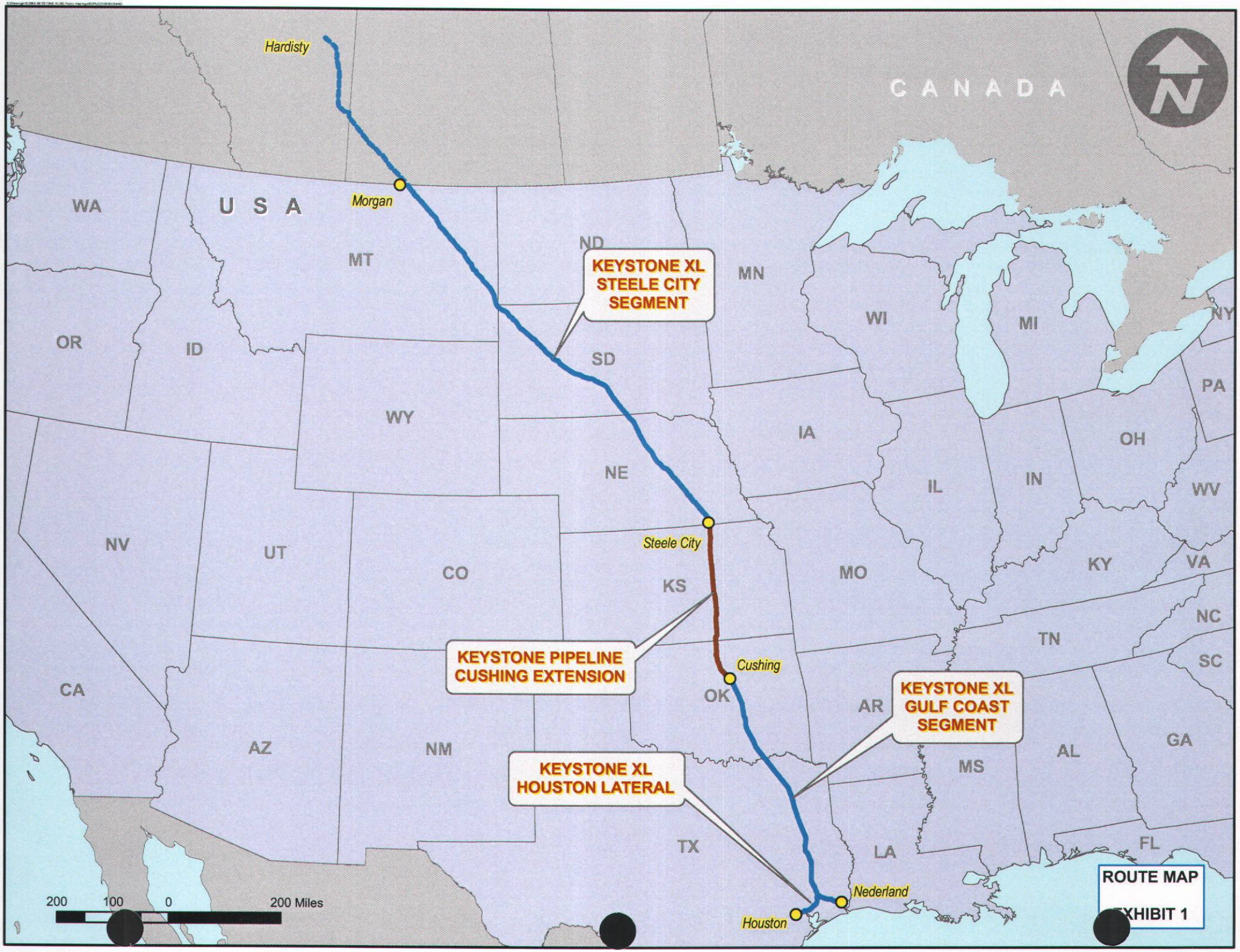
CPS/HCA ID	HCA	Mode of Transport	Transport Distance to HCA (miles)	CPS (Mileposts)	Length of CPS (miles)
SD-1	Little Missouri River Eco USA	Downstream transport along tributary leading to Boxelder Creek	2.7	282.6 – 284.6	2
SD-2	Little Missouri River Eco USA	Downstream transport along Little Missouri River and its tributaries	0.0	289.4 – 289.6; 290.5 – 290.7; 291.9 – 293.0; 294.8 – 295.4; 297.4 – 297.6	1.4
SD-3	Buffalo PA and GW USA	Overland or subsurface transport	0.2	314.7 – 316.2	1.5
SD-4	Cheyenne River Eco USAs	Downstream transport along Cheyenne River	0.0	418.0 – 427.0; 427.6– 429.7	10.9
SD-5	Midland PA	Overland transport and downstream transport along	0.9	478.3– 479.6	1.3

Response prepared by: Meera Kothari, Keystone

CPS/HCA ID	HCA	Mode of Transport	Transport Distance to HCA (miles)	CPS (Mileposts)	Length of CPS (miles)
		Mitchell Creek			
SD-6	White River SW USA and Eco USA	Downstream transport along White River and its tributaries (including Little Dog and Cottonwood creeks)	1.6	536.8–537.0; 538.8–540.5; 541.0 – 545.3	6.2
SD-7	Winner PA	Downstream transport along Dog Ear Creek	2.2	565.2 – 565.9; 566.1 – 566.3;	
SD-8	Colome SWPA	Subsurface transport	0.0	574.6 – 575.0	0.4
SD-9	Terrestrial Eco USA	Overland flow	0.3	582.5 – 585.3	2.8
SD-10	Terrestrial Eco USA	Overland flow	0.6	585.5 – 587.9	2.4
SD-11	Terrestrial Eco USA	Overland flow or downstream transport	0.1	590.3 – 593.2	2.9
SD-12	Terrestrial Eco USA	Overland flow or downstream transport	0.0	594.2 – 598.0	3.8

HCA Type:
SW – Surface water
GW – Ground water
ECO – Ecological Sensitive Area
PA – Populated Area

Response prepared by: Meera Kothari, Keystone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Morgan
Steele City
Cushing
Houston
Nederland
CANADA
U S A
WA
OR
CA
ID
NV
MT
WY
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CO
NM
ND
SD
NE
KS
OK
TX
MN
IA
MO
AR
LA
WI
IL
MS
MI
IN
KY
TN
AL
OH
WV
GA
FL
SC
NC
VA
PA
NY
KEYSTONE XL STEELE CITY SEGMENT
KEYSTONE PIPELINE CUSHING EXTENSION
KEYSTONE XL GULF COAST SEGMENT
KEYSTONE XL HOUSTON LATERAL
200 100 0 200 Miles
ROUTE MAP
EXHIBIT 1

Saskatchewan

Manitoba

N
W
E
S

MP 0.00

Spread 1
Length: 81.18 mi
Construction Year: 2012

Phillips

Valley

MP 81.18, Old Smokey Rd

Spread 2
Length: 82.02 mi
Construction Year: 2011

Garfield

McCone

MP 163.20, HWY 211

Dawson

Spread 3
Length: 83.73 mi
Construction Year: 2011

MT

Prairie

Wibaux

Custer

MP 246.93, RD 322

Fallon

Spread 4
Length: 86.11 mi
Construction Year: 2012

Carter

Harding

MP 333.04, J B Rd

Perkins

Spread 5
Length: 81.91 mi
Construction Year: 2011

Butte

Ziebach

MP 414.95, El Rancho Rd

Meade

Spread 6
Length: 84.60 mi
Construction Year: 2012

ND

SD

Stanley

Haakon

MP 499.55, Van Metre Rd

Pennington

Spread 7
Length: 78.54 mi
Construction Year: 2011

Jones

Lyman

Jackson

Mellette

WY

MP 578.10, 322nd Ave

Tripp

Gregory

Spread 8
Length: 84.23 mi
Construction Year: 2012

Keya Paha

Boyd

Rock

Holt

MP 662.33, 477th Ave

Garfield

Wheeler

Spread 9
Length: 94.61 mi
Construction Year: 2011

Valley

Boone

Greeley

Nance

Howard

MP 756.94, N W Rd & E 29th Rd

Merrick

Polk

York

Seward

Hamilton

NE

CO

Fillmore

Saline

Spread 10
Length: 93.32 mi
Construction Year: 2012

Thayer

Jefferson

Gage

MP 850.26, Romeo Rd

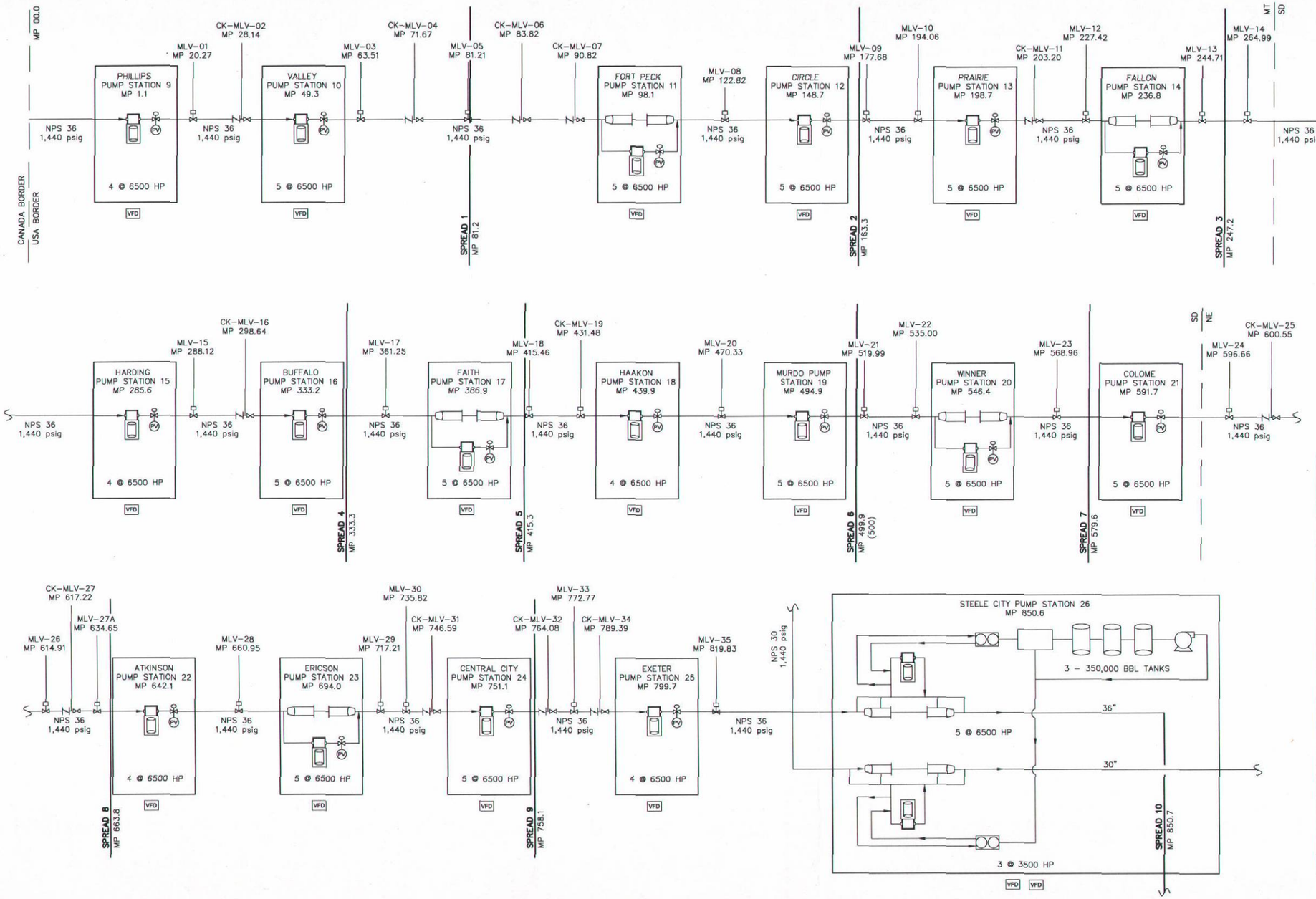
KS

0 30 60 120 Miles

SPREAD BREAK MAP

EXHIBIT 2

X:\Drawings\50386X KEYSTONE XL\SD Public Hearings\SDPUC20090803\MXD\EXHIBIT 2rev1



AREAS SUBJECT TO MOP 1.600 psig

PUMP STATION NUMBER	PUMP STATION [MP]	MP OF 1600 MOP PIPE SECTION MP [START]	MP [END]
0	0.000	0	0
PS 9 TO 10	1.123	1.178	2.900
PS 10 TO 11	49.274	49.274	53.561
	49.274	54.926	56.018
PS 11 TO 12	98.105	98.105	101.546
PS 12 TO 13	148.694	148.694	148.850
PS 13 TO 14	198.679	199.619	203.679
PS 14 TO 15	236.793	236.929	237.100
PS 15 TO 16	286.595	285.595	285.672
PS 16 TO 17	333.226	333.226	333.284
	333.226	333.284	334.493
	333.226	337.495	338.752
PS 17 TO 18	386.896	386.896	388.243
PS 18 TO 19	439.940	439.996	443.853
PS 19 TO 20	494.851	494.851	494.940
	494.851	497.137	497.299
PS 20 TO 21	546.365	546.365	548.028
PS 21 TO 22	591.686	591.686	600.063
PS 23 TO 24	642.127	693.387	696.563

LEGEND

- NEW PIPE, EQUIPMENT AND MATERIALS
- MAIN LINE PUMP
- SCRAPER LAUNCHER/RECEIVER
- METER
- TANK
- NPS 36 / 1,440 psig — NOMINAL PIPE SIZE / PUMP DISCHARGE PRESSURE
- 5 @ 6500 HP — OPERATING PUMPS
- BOOSTER PUMP
- CONTROL VALVE
- VFD — VARIABLE FREQUENCY DRIVE
- MANIFOLD
- MOTOR OPERATED VALVE
- CHECK AND MANUAL VALVE
- MLV-XX — MOTOR OPERATED VALVE DESIGNATION
- CK-MLV-XX — CHECK AND MANUAL VALVE DESIGNATION

REFERENCE DRAWINGS

DRAWING No	TITLE

REVISION

REV No	DATE	DESCRIPTION
0	01-12-09	ISSUED FOR REVIEW
1	02-07-09	UPDATED PER TRANSCANADA REQUEST
2	02-17-09	ADDED VALVES
3	05-13-09	REVISED MILE POSTS AND ADDED SPREADS
4	06-11-09	ADDED MILE POSTS AT SPREADS; CHANGED DWG. NO.; ADDED TABLE

APPROVAL

PROJECT CODE	DRAFTER	DRAFTING CHECKER	DESIGNER	DESIGN CHECKER	PROJECT MANAGER	COMPANY
	CB	TW	RB	GR	JP	TROW/UEI
	CB	TW	RB	GR	JP	TROW/UEI
	CB	TW	RB	GR	JP	TROW/UEI
	CB	TW	RB	GR	JP	TROW/UEI
	CB	TW	RB	GR	BW	TROW/UEI

PROFESSIONAL ENGINEER/RPT — PERMIT/ ENG. APPROVAL — DATE

REV. NO. | DATE | PERMIT NUMBER:

TransCanada — In business to deliver | ConocoPhillips | UNIVERSAL ENERGY, INC.

FIA # 1399 | CHAINAGE: | DISCIPLINE # 01

KEYSTONE XL PROJECT
EXHIBIT 3: MECHANICAL FLOW SCHEMATIC
UNITED STATES STEELE CITY SEGMENT

SCALE N.T.S. | DRAWING No 1399-01-ML-0S-700 | REV 4

TC_UD_BR.DWG 22X34

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DESIGNFILE: G:\20000\ontlingen\GIS\CADFiles\Drawings\VibrationDrawings\KEYSTONEXL\KEYSTONE_XL_SCHEMATIC.dwg

Exhibit 4 Plot Plan for Pump Station with Pig Launcher and Receiver

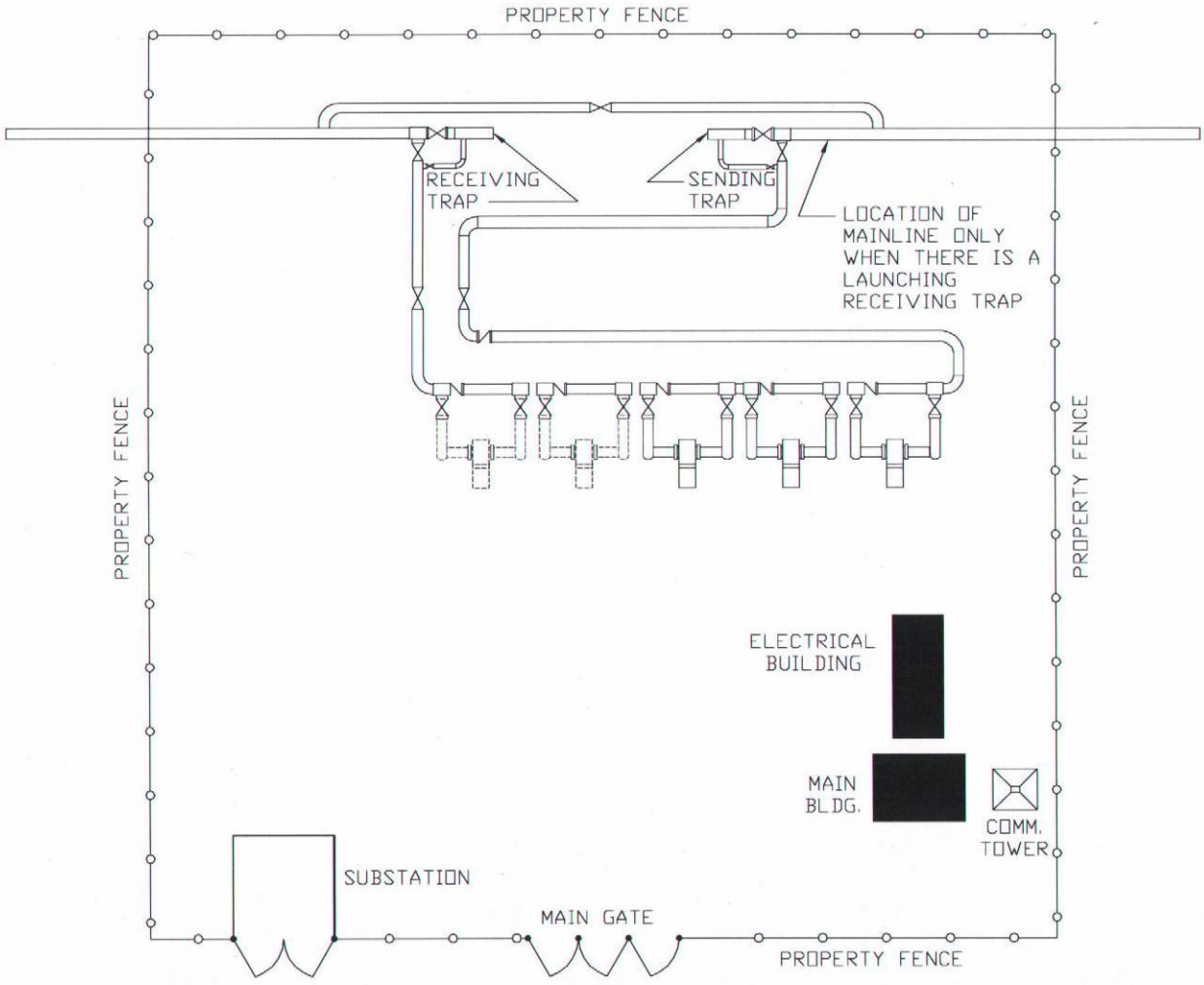
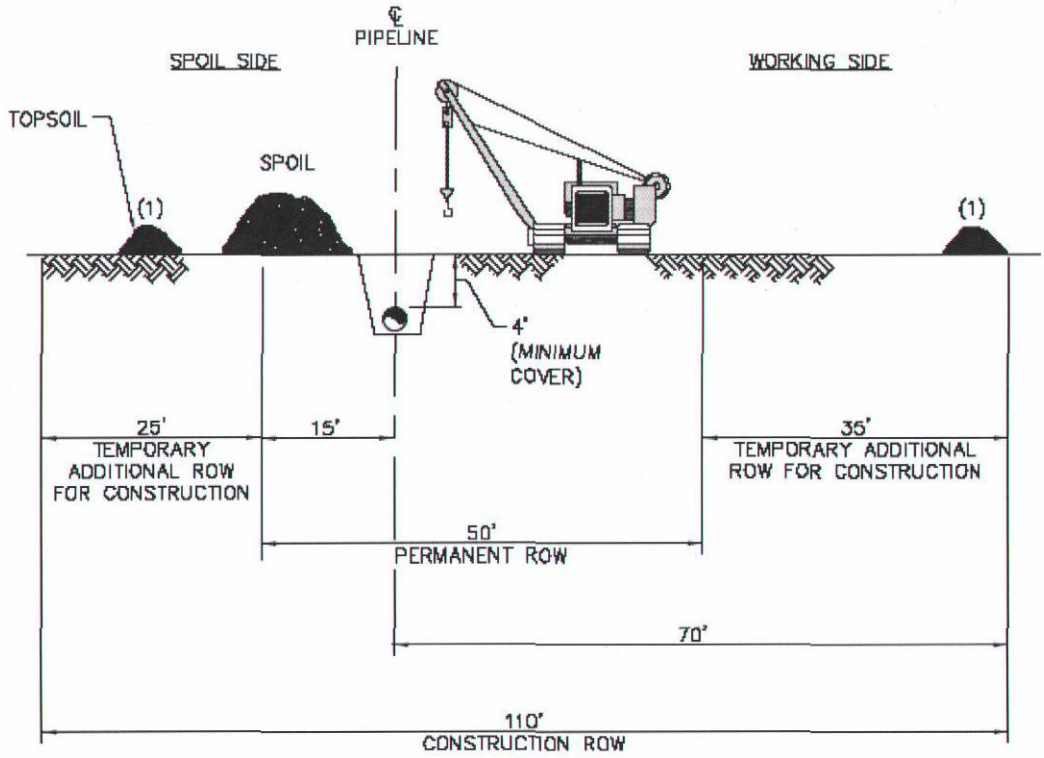
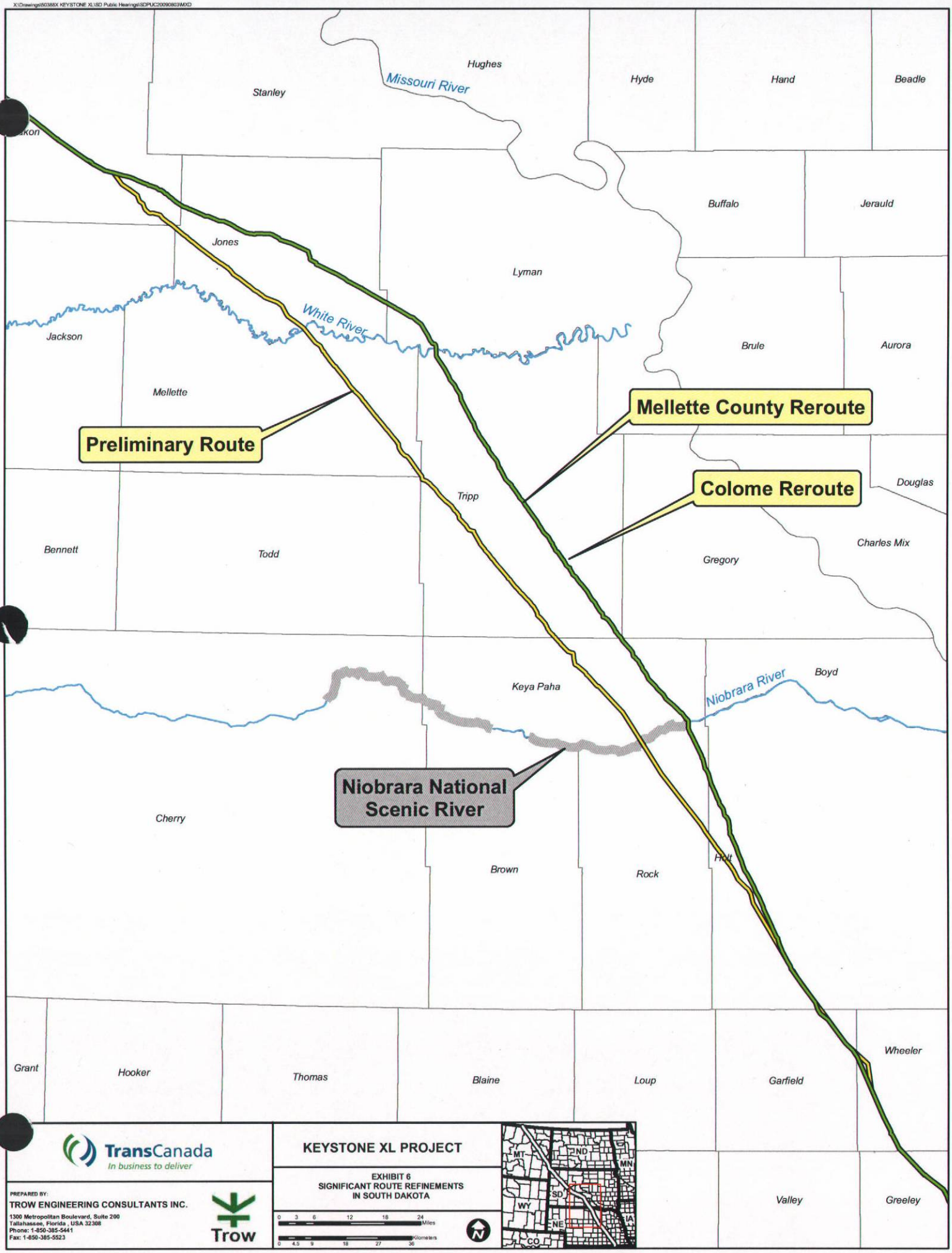


Exhibit 5 **Typical 110-foot Construction ROW with Topsoil Removal Only Over Trench Line (not to scale)**



(1) ALTERNATE TOPSOIL PLACEMENT LOCATIONS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Stanley
Missouri River
Hyde
Hand
Beadle
Buffalo
Jerauld
Jones
Lyman
White River
Jackson
Brule
Aurora
Mellette
Mellette County Reroute
Preliminary Route
Colome Reroute
Douglas
Tripp
Bennett
Todd
Gregory
Charles Mix
Keya Paha
Niobrara River
Boyd
Niobrara National Scenic River
Cherry
Brown
Rock
Holt
Grant
Hooker
Thomas
Blaine
Loup
Garfield
Wheeler
Valley
Greeley
TransCanada
In business to deliver
KEYSTONE XL PROJECT
EXHIBIT 6
SIGNIFICANT ROUTE REFINEMENTS
IN SOUTH DAKOTA
PREPARED BY:
TROW ENGINEERING CONSULTANTS INC.
1300 Metropolitan Boulevard, Suite 200
Tallahassee, Florida , USA 32308
Phone: 1-850-385-5441
Fax: 1-850-385-5523
Trow
0 3 6 12 18 24 Miles
0 4.5 9 18 27 36 Kilometers
MT
ND
MN
SD
WY
NE
IA
CO