APPENDIX A

LIST OF ENERGY PROJECTS IN NORTH DAKOTA
(Department Of Commerce 5/29/09)

APPENDIX A - ENERGY PROJECTS

Energy Project Tracking - Completed and Proposed (DRAFT)

Facility	City	Capacity	Units	Cost	PSC	Notes
Biodiesel						
Completed						
ADM Biodiesel Plant (Archer Daniels Midland Co)	Velva	85,000,000.00	Gallons Annually	$ 34,000,000		
Northwood Agri-Biodiesel LLP (Northwood Mills LLLP)	Northwood	3,000,000.00	Gallons Annually	$ 3,300,000		Currently not operating - Was using soybeans for feedstock but are considering switching to canola - Have increased output to 7 million gallons per year
Subtotals		**88,000,000.00**		**$ 37,300,000**		
Proposed						
Subtotals		**0.00**		**$ -**		
All Biodiesel Total		**88,000,000.00**		**$ 37,300,000**		
Coal Gasification						
Completed						
Dakota Gasification Company	Beulah	160,000,000.00	Cubic Feet Daily			
Subtotals		**160,000,000.00**				
Proposed						
Great Northern Power Development	South Heart	100,000,000.00	Cubic Feet Daily	$ 2,100,000,000		Contact Richard Voss 701-223-8783
Subtotals		**100,000,000.00**		**$ 2,100,000,000**		rvoss@gr-northern.com
All Coal Gasification Total		**260,000,000.00**		**$ 2,100,000,000**		
Coal - Other Projects						
Proposed						
Basin/Powerspan - CO2 sequester	Beulah			$ 300,000,000		
Subtotals				**$ 300,000,000**		
Under Construction						
GTL - coal beneficiation	Underwood			$ 12,000,000		Shouldn't be any water usage in process. They extract water from the coal.
Great American Energy - beneficiation	Underwood			$ 20,000,000		Contact Al Christianson 701-220-4881 achristianson@grenergy.com
Subtotals				**$ 32,000,000**		
All Coal - Other				***$ 332,000,000***		

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Facility	City	Capacity	Units	Cost	PSC	Notes
Coal Liquefaction						
Proposed						
American Lignite Energy	Underwood	32,000.00	Barrels Daily	$	4,000,000,000	Contact David Straley 701-222-7596 david.straley@falkirk.com
Subtotals		***32,000.00***		***$***	***4,000,000,000***	
All Coal Liquefaction Total		***32,000.00***		***$***	***4,000,000,000***	
Coal-fired electrical station						
Completed						
Antelope Valley Station (Basin Electric Power Cooperative)	Beulah	900.00	Megawatts			Includes two units each rated at 450 megawatts
Coal Creek Station	Underwood	1,100.00	Megawatts			Includes two units each rated at 550 megawatts
Coyote Station(Otter Tail Power Company)	Beulah	414.00	Megawatts			
Heskett Station (Montana Dakota Utilities Resources Group)	Mandan	100.00	Megawatts			Included two units, one rated at 25 megawatts and the other at 75 megawatts.
Leland Olds Station (Basin Electric Power Cooperative)	Stanton	650.00	Megawatts			Includes two units, one rated at 210 megawatts and the other at 440 megawatts.
Milton R Young Units 1 & 2 (Minnkota Power Cooperative)	Center	705.00	Megawatts			Includes two units, one rated at 250 megawatts and the other at 455 megawatts.
Stanton Station	Stanton	202.00	Megawatts			
Subtotals		***4,071.00***				
All Coal-fired Total		**4,071.00**				

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Facility	City	Capacity	Units	Cost	PSC	Notes
Ethanol						
Completed						
ADM Corn Processing (Archer Daniels Midland Co)	Walhalla	25,000,000.00	Gallons Annually			
Alchem Ltd LLLP	Grafton	10,000,000.00	Gallons Annually			Currently not operating
Blue Flint Ethanol	Underwood	50,000,000.00	Gallons Annually	$ 85,000,000		Uses waste heat from adjoining coal-fired generating station.
Red Trail Energy, LLC	Richardton	50,000,000.00	Gallons Annually	$ 75,200,000		
Tharaldson Ethanol Plant I LLC	Casselton	100,000,000.00	Gallons Annually	$ 180,000,000		
VeraSun Hankinson LLC (Gold Energy)	Hankinson	100,000,000.00	Gallons Annually	$ 145,000,000		Just started running in the Fall of 2008
Subtotals		**335,000,000.00**		**$ 485,200,000**		
Proposed						
Buffalo Creek Energy LLC	New England	55,000,000.00	Gallons Annually	$ 190,000,000		Unsure of Status of Project
Lakota Biofuels LLC	Lakota	55,000,000.00	Gallons Annually	$ 171,000,000		Unsure of Status of Project
Spirit Ethanol	Jamestown	100,000,000.00	Gallons Annually	$ 169,000,000		Unsure of Status but something similar will be in its place. Contact Al Christianson 701-220-4881 achristianson@grenergy.com
Yellowstone Ethanol LLC	Williston	60,000,000.00	Gallons Annually	$ 120,000,000		Mike Daly 701-752-4542 mike@yellowstoneethanol.com
Subtotals		**270,000,000.00**		**$ 650,000,000**		
Under Construction						
Subtotals		**0.00**		**$ -**		
All Ethanol Total		**605,000,000.00**		**$ 1,135,200,000**		

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Facility	City	Capacity	Units	Cost	PSC	Notes
Hydro						
Completed						
Garrison Dam and Powerplant (Western Area Power Administration)	Riverdale	515.00	Megawatts			
Subtotals		**515.00**				
All Hydro Total		**515.00**				
Lignite-fired Electric Generation						
Under Construction						
Spiritwood Energy LLC	Jamestown	99.00	Megawatts	$ 300,000,000		Contact Al Christianson 701-220-4881
Subtotals		**99.00**		**$ 300,000,000**		
All Lignite-fired Total		**99.00**		**$ 300,000,000**		
Natural Gas Processing & Pipeline						
Completed						
4 new natural gas plants completed	Western ND	50 million cubic feet		$ 96,000,000		
3 gas plant expansions - completed	Western ND			$ 54,000,000		
Subtotals				**$ 150,000,000**		
Under Construction						
EOG - expansion under const.	Stanley	NA		$ 35,000,000		
Subtotals				**$ 35,000,000**		
Proposed						
EOG natural gas pipeline	Stanley to Velva			$ 80,000,000		
Subtotals				**$ 80,000,000**		
All Natural gas				**$ 265,000,000**		

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Facility	City	Capacity	Units	Cost	PSC	Notes
Refining						
Under Construction						
Tesoro Low Sulfer Diesel Expansion		2,000 barrels per day		$ 125,000,000		
Subtotals				**$ 125,000,000**		
Proposed						
Northwest Refining	Williston	100,000 bpd		$ 3,000,000,000		Melvin Falcon 701-572-8527 (no email found)
Dakota Oil Processing	Trenton	20,000 bpd		$ 29,000,000		Mike Wavra (contact unknown)
Three Affiliated Tribes	Makoti	15,000 barrels per day		$ 360,000,000		(701) 627-4399 Unsure of direct contact info
Subtotals				**$ 360,000,000**		
All Refining				**$ 485,000,000**		
Crude Oil Pipeline						
Completed						
Enbridge Phase V		20,000 bpd increase		$ 80,000,000		
Belle Fouche (True pipeline)		pipeline expansion		$ 10,000,000		
Subtotals				**$ 90,000,000**		
Under Construction						
Keystone Pipeline		435,000 bpd		**$ 277,000,000**		
Proposed						
Enbridge Phase VI crude pipeline expansion		51,000 bpd increase		$ 120,000,000		
Belle Fouche (True pipeline)		10,000 bpd increase		$ 2,000,000		
Subtotals				**$ 122,000,000**		
All Crude Oil Pipelines				**$ 489,000,000**		

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Facility	City	Capacity	Units	Cost	PSC	Notes
Wind						
Completed						
Fort Totten Wind Project	Ft Totten	0.10	Megawatts	$	200,000	Capacity is 0.1 megawatts
Grafton Technical College Wind Project	Grafton	0.10	Megawatts	$	200,000	Rated capacity is 0.065 megawatts
Ashtabula Wind Project (FPL Energy Operating Services Inc)	Valley City	200.00	Megawatts	$	500,000,000	Will use 2.5 megawatt turbines (≈ estimated total cost)
Langdon Wind Project (FPL Energy Operating Services Inc)	Langdon	159.00	Megawatts	$	318,000,000	≈ estimated total cost
Langdon Wind Project II (FPL Energy Operating Services Inc)	Langdon	40.50	Megawatts	$	73,000,000	Additional 27 turbines to be added to original Langdon Wind Project
ND Wind Energy Center I (FPL Energy Operating Services Inc)	Edgeley	40.50	Megawatts	$	64,800,000	
ND Wind Energy Center II (FPL Energy Operating Services Inc)	Kulm	21.00	Megawatts	$	33,600,000	
Oliver II Wind Energy Center (FPL Energy Operating Services Inc)	Center	48.00	Megawatts	$	120,000,000	≈ estimated total cost
Oliver Wind Energy Center (FPL Energy Operating Services Inc)	Center	50.60	Megawatts	$	101,200,000	≈ estimated total cost
Petersburg Wind Project (Minnkota Power Cooperative)	Petersburg	0.90	Megawatts	$	1,440,000	
Prairie Winds (Basin Electric Power Cooperative)	Minot	2.60	Megawatts	$	4,160,000	
Richardton Abbey Wind Project	Richardton	0.10	Megawatts	$	200,000	Rated capacity is 0.125 megawatts
Tatanka Wind Power LLC (Acciona Wind Energy USA, LLC)	Forbes	90.00	Megawatts	$	190,500,000	$7.3 million dollar transmission line being constructed in tandem
Turtle Mountain Wind Project	Belcourt	0.10	Megawatts	$	200,000	≈ estimated total cost
Valley City Wind Project (Minnkota Power Cooperative)	Valley City	0.90	Megawatts	$	1,440,000	
Velva Windfarm LLC (Acciona Wind Energy USA, LLC)	Velva	12.00	Megawatts	$	10,000,000	
Wilton Wind Energy Center (FPL Energy Operating Services Inc)	Wilton	49.50	Megawatts	$	74,250,000	≈ estimated total cost
Subtotals		**715.90**		**$**	**1,493,190,000**	
Announced - have NOT filed letter of intent with PSC						
BP Alternative Energy	Wishek	300.00	Megawatts	$	750,000,000	≈ estimated total cost
Frey Winds LLC	Berthold	100.00	Megawatts	$	250,000,000	≈ estimated total cost
Peak Wind Development, LLC	Valley City	200.00	Megawatts	$	250,000,000	
Roughrider Wind (Green Wing Energy)	Stanley	300.00	Megawatts	$	750,000,000	≈ estimated total cost
Ashtabula Wind Project II (FPL Energy)	Valley City	120.00	Megawatts	$	300,000,000	≈ estimated total cost **[not yet publicly announced]**
Wilton Wind Energy Center II (FPL Energy Operating Services Inc)	Wilton	49.50	Megawatts	$	123,750,000	≈ estimated total cost **[details not publicly known]**
Subtotals		**1,070**		**$**	**2,423,750,000**	

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Facility	City	Capacity	Units	Cost	PSC	Notes
Proposed - Have filed letter of intent with PSC						
Merricourt Wind Project	Dickey & McIntosh	150.00	Megawatts	$ 400,000,000	✓	enXco builds, Xcel will purchase the farm
Bison 1 Wind Project (Minnesota Power)	Oliver County	125.00	Megawatts	$ 333,000,000	✓	≈ estimated total cost. Filing Letter to PSC 11/5/2008
Bison 1 Wind Project (Minnesota Power)		75.90	Megawatts	$ 189,750,000		≈ estimated total cost
Dickey County Wind (FPL Energy Operating Services Inc)	Ellendale	150.00	Megawatts	$ 375,000,000	✓	≈ estimated total cost
Rhame Wind Farm (Montana-Dakota Utilities Co.)	Rhame	19.50	Megawatts	$ 48,750,000		≈ estimated total cost. **<100MW, No PSC jurisdiction**
Hartland Wind Farm Phase One (Denali Companies, Inc.)	Kenmare	1,000.00	Megawatts	$ 2,500,000,000	✓	≈ estimated total cost
Hartlland Wind Farm Phase Two (Denali Companies, Inc.)	Kenmare	1,000.00	Megawatts	$ 2,500,000,000	✓	≈ estimated total cost
Gascoyne I Wind Park (Crownbutte Wind Power LLC)	Gascoyne	20.00	Megawatts	$ 50,000,000	✓	≈ estimated total cost
Gascoyne II Wind Park (Crownbutte Wind Power LLC)	Gascoyne	200.00	Megawatts	$ 500,000,000	✓	≈ estimated total cost
Just Wind LLC	Napoleon	368.00	Megawatts	$ 920,000,000	✓	≈ estimated total cost
Emmons County Wind Farm (Just Wind LLC)	Strasburg	900.00	Megawatts	$ 2,300,000,000	✓	= cost in letter of intent filed with PSC
M-Power LLC (Griggs-Steele Empowerment Zone)	Luverne	157.00	Megawatts	$ 300,000,000	✓	≈ estimated total cost
Oliver-Morton Wind Project (FPL Energy Operating Services Inc)		1,000.00	Megawatts	$ 2,000,000,000	✓	Planned 667 wind turbines for Oliver and Morton counties
Border Winds (Sequoia Energy)	Rolla	150.00	Megawatts	$ 375,000,000	✓	≈ estimated total cost
Prairiewinds ND 1, Inc. (Basin Electric Power Cooperative)	Minot	115.50	Megawatts	$ 240,000,000	✓	Proposed 115.5 megawatt windfarm to be constructed south of Minot. Will consist of 77 GE 1.5sle turbines.
Subtotals		**5,430.90**		**$ 13,031,500,000**		
Under Construction						
PPM Rugby Wind Farm (PPM Energy)	Rugby	149.10	Megawatts	$ 372,750,000	✓	≈ estimated total cost
Subtotals		**149.10**		**$ 372,750,000**		
All Wind Total		**7,365.40**		**$ 17,321,190,000**		

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Facility	City	Capacity	Units	Cost	PSC	Notes

Grand Total All Completed	$	2,255,690,000
Grand Total All Under Construction	$	864,750,000
Grand Total All Proposed (does not include announced wind projects that haven't filed with the PSC)	$	20,643,500,000
Grand Total All Categories	*$*	*23,763,940,000*
Grant Total - Renewables	$	16,069,940,000
Grand Total - Traditionals	$	7,971,000,000

APPENDIX B

AQUIFER LITHOLOGIES
(***From the Section: Shallow Glaciofluvial Aquifers***)

APPENDIX B - LITHOLOGY

Figure B.1.1.1. Grenora aquifer lithology.

Location	15910306DDD	Date Drilled	06/23/1964
County	Williams	Land Surface	2000.46
Aquifer	Grenora	Total Depth	346
Purpose	Observation Well	Bedrock Depth	320

Unit	Description	Begin Int	End Int	Thickness
SOIL	Black, sandy and gravelly	0	1	1
CLAY	Light olive-gray, sandy	1	5	4
TILL	Moderate olive-brown, silty to sandy, oxidized	5	36	31
SAND	Olive-gray, clayey, fine to medium, calcareous	36	44	8
SAND	Fine to medium	44	94	50
SAND	Fine to coarse; contains thin clay layers	94	99	5
SILT	Olive-gray, clayey, carbonaceous; contains thin very fine sand and dark carbonaceous laminae	99	140	41
GRAVEL	Fine to coarse, moderately sorted, subangular to subrounded	140	166	26
CLAY	Olive-gray, very sandy, calcareous	166	190	24
TILL	Olive-gray, silty	190	210	20
CLAY	Olive-gray, silty; contains thin lenses of very fine sand	210	288	78
CLAY	Dark greenish gray, sandy, calcareous, slightly micaceous; had strong hydrogen sulfide odor	288	300	12
GRAVEL	Dark brown, fine to coarse, generally subrounded; pebbles are predominantly chert and iron-oxide stained limestone	300	320	20
SHALE	Light olive-gray, silty to sandy; contains some lignite (Fort Union Group)	320	346	26

Figure B.1.1.2. Grenora aquifer lithology.

Location	15910310CAA1	Date Drilled	06/03/2004
County	Williams	Land Surface	2033.46
Aquifer	Grenora	Total Depth	260
Purpose	Observation Well	Bedrock Depth	229

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Dark brownish gray, clayey	0	2	2
SAND & GRAVEL	More gravel than sand, primarily silicates, some tan carbonates, some sandstone. Oxidized to about 23 feet, coarser at 30-31 feet	2	31	29
CLAY	Olive gray, about 1/3 clay, with silt, sand & gravel, moderately cohesive, silt lens at 38 feet, sand lens at 52 feet (till)	31	58	27
SILT	Slightly sandy, clayey, detrital lignite at 71 feet, gravelly shale at 76-78 feet	58	84	26
CLAY	Olive gray, silty, sandy, gravelly (clayey till)	84	97	13
CLAY	Olive gray, smooth, fast drilling	97	103	6
CLAY	Olive gray, silty, sandy, as above (clayey till), granite rock at 117 feet	103	146	43
SAND	Fine to medium grained, poorly sorted, primarily quartzose, with lignite, some clay lenses as at 149-151 & 155 feet	146	168	22
CLAY	Olive gray, silty, sandy, gravelly (till)	168	188	20
CLAY	As above, slower, quieter drilling, more clay (clayey till)	188	203	15
SAND	With lignite, poor recovery	203	206	3
CLAY	As above (clayey till)	206	222	16
SAND & GRAVEL	More gravel than sand, primarily very coarse sand and gravel granules in cuttings, somewhat weathered	222	229	7
CLAY	Light gray and greenish gray, smooth, slow drilling (bedrock)	229	238	9
SANDSTONE	No recovery	238	240	2
CLAY	As above, primarily greenish gray (bedrock)	240	260	20

Figure B.1.1.3. Grenora aquifer lithology.

Location	16010320CBA	Date Drilled	06/29/2001
County	Divide	Land Surface	2041.9
Aquifer	Grenora	Total Depth	180
Purpose	Irrigation Well	Bedrock Depth	161

Unit	Description	Begin Int	End Int	Thickness
TILL	sandy, yellow	0	17	17
TILL	very sandy	17	43	26
SAND	fine to medium	43	85	42
TILL	olive grey	85	110	25
CLAY	grey	110	133	23
SAND	medium to coarse	133	138	5
SAND & GRAVEL	coarse	138	161	23
CLAYSTONE	light grey	161	180	19

Figure B.1.2.1. Little Muddy aquifer lithology.

08/31/2009

Location	15510009BBB	Date Drilled	06/11/2002
County	Williams	Land Surface	1914.4
Aquifer	Little Muddy	Total Depth	80
Purpose	Domestic Well	Bedrock Depth	72

Unit	Description	Begin Int	End Int	Thickness
TILL	yellow	2	17	15
CLAY	olive gray	17	38	21
SAND & GRAVEL	coarse sand	38	72	34
CLAYSTONE	light gray	72	80	8

Figure B.1.2.2. Little Muddy aquifer lithology.

Location	15610021CCC	Date Drilled	07/29/1998
County	Williams	Land Surface	1917.9
Aquifer	Little Muddy	Total Depth	80
Purpose	Observation Well	Bedrock Depth	0

Unit	Description	Begin Int	End Int	Thickness
CLAY	Dark yellowish brown, 30%, with silt, sand & gravel (oxidized till)	1	10	9
CLAY	Dark yellowish brown, 30%, with silt, sand, & gravel (oxidized till)	12	14	2
CLAY	Dark yellowish brown, 30%, with silt, sand, & gravel (oxidized till)	23	35	12
CLAY	Olive gray, 30%, with silt, sand, & gravel (till), rock at 50 feet and 52 feet	35	53	18
SAND & GRAVEL	20% gravel, primarily very coarse sand, silicates, carbonates, lignite, taking water with drilling	53	73	20
CLAY	Olive gray, plastic (lacusterine)	73	80	7

Figure B.1.2.3. Little Muddy aquifer lithology.

Location	15810007DDD	Date Drilled	07/17/1996
County	Williams	Land Surface	1963.15
Aquifer	Little Muddy	Total Depth	100
Purpose	Observation Well	Bedrock Depth	0

Unit	Description	Begin Int	End Int	Thickness
SAND	Medium grained, fair sorting	1	5	4
CLAY	Olive gray, 25%, with silt & sand, (sandy, oxidized till)	5	11	6
SAND	As above	11	16	5
CLAY	Olive gray 30% with silt, sand, & gravel (till)	16	57	41
SAND & GRAVEL	30% gravel, well graded, silicates, lignite, shale, carbonates	57	87	30
CLAY	Olive gray 30% with silt, sand, & gravel (till)	87	94	7
CLAY	Olive gray, cohesive	94	100	6

Figure B.1.3.1. Ray aquifer lithology.

Location	15809719AAA	Date Drilled	06/11/1965
County	Williams	Land Surface	2235
Aquifer	Ray	Total Depth	200
Purpose	Observation Well - Destroy	Bedrock Depth	186

Unit	Description	Begin Int	End Int	Thickness
CLAY	Yellowish gray, sandy	0	4	4
TILL	Dusky yellow, sandy, oxidized	4	16	12
TILL	Moderate olive-brown, silty and sandy	16	86	70
SAND	Gray, medium, moderately well sorted, subrounded	86	94	8
CLAY	Olive-gray, silty	94	99	5
SAND	Fine to coarse, subangular to subrounded	99	102	3
TILL	Olive-gray, silty	102	137	35
SAND	Gray, medium, well sorted, subrounded	137	150	13
SAND	Brown, gravelly, subangular to subrounded; predominantly chert and quartz	150	186	36
CLAY	Light gray, light greenish gray, greenish gray, brownish black, silty, calcareous, locally carbonaceous (Fort Union Group)	186	200	14

Figure B.1.3.2. Ray aquifer lithology.

Location	15809807DDD	Date Drilled	06/17/1965
County	Williams	Land Surface	2226
Aquifer	Ray	Total Depth	304.5
Purpose	Observation Well	Bedrock Depth	284

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	black	0	1	1
TILL	Till, dusky yellow (5Y6/4) to yellowish gray (5Y6/2), holds together, mod. soft, silty, crumbles a bit, sh, qtz, lignite(?), dol, lms, at top most fragments are less than 0.5 mm in size, downwards till becomes gravelly oxid., slightly calcareous, contains pockets of Fe stained material, fragments are ang. to rounded	1	42	41
TILL	dark greenish gray (5GY3/1) to olive gray (6-Y3/1), holds together, mod. hard, qtz, sh, igneous xline, dol, lms, ranging from 1 to 2 mm, ang. to subrounded, calcareous, unoxid.	42	56	14
GRAVEL	fine medium to coarse, about 0.25 fine medium to coarse sand	56	65	9
GRAVEL	sand poorly sorted, angular to rounded, qtz, dol, lms, sh, igneous xline, sed. very, size varies greatly	65	69	4
TILL	olive gray (5Y4/1) to dark greenish gray (5GY4/1), holds together, mod. hard to mod. soft, dol, sh, qtz, lignite, ranges from silt size to about 2 mm, ang. to rounded, calcareous, unoxid.	69	84	15
SILT	dark greenish gray (5GY45/1), clayey, holds together, mod. soft, crumbly, highly calcareous, unoxid.	84	95	11
CLAY	silty, ranges from dark greenish gray (5GY5/1) to dusky yellow (5Y6/4) to dusky yellow green (5GY5/2), holds together, mod. hard, highly calcareous, unoxid.	95	100	5
TILL	(?), clayey, mod., yellowish brown (10YR5/4) to dark yellowish orange (10YR6/6), holds together, mod. soft, plastic, sh., dol, and pockets of finely powdered lignite, frag. are not very abundant and vary greatly in size, calcareous, oxid., contains much gypsum in places, frag. becomes more abundant downwards	100	145	45

Figure B.1.3.3. Ray aquifer lithology.

Location	15810017ABC	Date Drilled	04/05/1966
County	Williams	Land Surface	1992.2
Aquifer	Ray	Total Depth	100
Purpose	Observation Well - Destroy	Bedrock Depth	94

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	black	0	1	1
SAND	fine to coarse, some fine gravel, yellowish brown, poorly sorted	1	7	6
CLAY	silty to very sandy, some gravel size material, moderately hard and brittle, yellowish brown (till)	7	27	20
CLAY	silty to sandy, some fine gravel, poorly plastic and cohesive, dark olive gray (till)	27	42	15
SAND	very fine to medium, angular to subangular, moderately well sorted, drills very easy	42	80	38
GRAVEL	fine to coarse, about 40% medium to coarse sand, poorly sorted, subangular to subround, some coal in places, drills easy and fast, taking quite a bit of water, used 850 gal. to 90'	80	90	10
CLAY	olive gray, slightly silty, quite cohesive and plastic, drills soft	90	94	4
CLAY	bright, bluish gray, hard, (Tongue River) NOTE: The contact between the sand and the gravel was graduational between approximately 79' and 82'	94	100	6

Figure B.1.4.1. Wildrose aquifer lithology.

Location	16009713BBB	Date Drilled	05/08/1963
County	Divide	Land Surface	2257
Aquifer	Wildrose	Total Depth	156
Purpose	Observation Well	Bedrock Depth	134

Unit	Description	Begin Int	End Int	Thickness
SAND	Very coarse	2	7	5
SAND	Silty, very fine	7	20	13
SILT	Dark greenish gray	20	45	25
CLAY	Shaley, Dark greenish gray	45	51	6
SILT	Dark greenish gray	51	58	7
SAND AND GRAVEL	Fine sand to medium gravel, subrounded, poorly sorted	58	78	20
TILL	Dark greenish gray	78	105	27
TILL	Dark greenish gray	108	115	7
SILT	Sandy, dark gray and olive-gray, calcareous, few fossil fragments, (dark gray color due to organic matter)	115	122	7
TILL	Dark yellowish orange, oxidized; few limestone and s;hale grains	122	139	17
SAND	Silty, very fine, oxidized, calcareous (Tongue River Formation)	139	146	7
SILT	Dark yellowish orange, oxidized, (grading downward into) silty, lignitic, dark greenish gray to brownish black (Tongue River Formation)	146	158	12
LIMESTONE	(Tongue River Formation)	158	160	2

Figure B.1.4.2. Wildrose aquifer lithology.

Location	16009736BCB	Date Drilled	05/10/1963
County	Divide	Land Surface	2210
Aquifer	Wildrose	Total Depth	320
Purpose	Observation Well	Bedrock Depth	293

Unit	Description	Begin Int	End Int	Thickness
CLAY	Silt, and sand, light olive-brown, unsorted	2	14	12
CLAY	Silty, dark greenish gray, slightly calcareous; few selenite crystals	14	34	20
TILL	Gravelly, dark greenish gray	34	78	44
GRAVEL	Fine and medium sand, subrounded to well-rounded pebbles, predominantly quartz and limestone, with some lignite	78	98	20
TILL	Gravelly, dark greenish gray	98	121	23
TILL	Gravelly, dark greenish gray	123	141	18
SILT	Dark greenish gray, very calcareous	141	143	2
TILL	Dark greenish gray	146	150	4
TILL	Dark greenish gray	151	167	16
TILL	Dark greenish gray	168	244	76
SAND	Very fine to very coarse, and dark greenish gray silty, abundant lignite particles, calcareous; apparently interbedded	244	273	29
SAND	Very fine, and silt, some clay; interbedded	273	288	15
GRAVEL	Granule, sandy, rounded; abundant brownish pebbles	288	294	6
CLAY	Sandy, bluish gray, hard (Tongue River Formation)	294	320	26

Figure B.1.5.1. Yellowstone Buried Channel aquifer lithology.

Location	16009929BBB	Date Drilled	05/15/1959
County	Divide	Land Surface	2100
Aquifer	Yellowstone Buried Channe	Total Depth	420
Purpose	Test Hole	Bedrock Depth	0

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	black	0	2	2
CLAY	smooth, brown	2	11	9
CLAY	Brownish-yellow to dark-yellowish-orange, mottled, oxidized w/ fine gravel (till)	11	33	22
CLAY	gray (till)	33	75	42
GRAVEL	Fine sand to medium pebbles	75	83	8
TILL	Gray	83	98	15
GRAVEL	Or several small rocks (drilling action)	98	103	5
CLAY	Light gray	103	189	86
CLAY	gray clay, fine gravel, shale pebbles and coal, a rock at 328 ft., thinned mud out at 346 ft., hard drilling from 368 ft. to 390. (till)	189	394	205
CLAY	Sandy gray to light brown	394	415	21
CLAY	Carbonaceous, lignitic, contains some coarse sand grains	415	420	5

Figure B.1.5.2. Yellowstone Buried Channel aquifer lithology.

Location	16009904AAA1	Date Drilled	06/10/1963
County	Divide	Land Surface	2055
Aquifer	Yellowstone Buried Channe	Total Depth	590
Purpose	Observation Well	Bedrock Depth	560

Unit	Description	Begin Int	End Int	Thickness
FILL	Road fill	0	7	7
SILT	dark yellowish orange to medium yellowish brown, clay to fine sand, calcareous, oxidized	7	10	3
CLAY	moderately yellowish brown, clay through gravel, abundant shale, calcareous, oxidized (till)	11	17	6
CLAY	dark yellowish brown, clay though gravel, abundant shale and limestone, calcareous, part., oxidized (till)	17	30	13
SILT	dark greenish gray, clay, some areas of fine sand, highly calcareous	30	40	10
CLAY	dark greenish gray, clay though gravel, unsorted, composition varied with abundant shale and some limestone and lignite (till)	40	72	32
SILT	olive to bluish gray, sandy-greatly resembles clayey-sand, Fort Union? bedrock-mica flakes, lignite chips, slightly calcareous	72	75	3
SANDSTONE	Sandstone, bluish gray, noncalcareous, shale, quartz, etc., a few lignitic areas	76	92	16
CLAY	olive gray-black (5Y3/1), clay through gravel, composition varied, limestone, shale, granite, lignite, etc.; solid, hard calcareous (till)	92	100	8
SAND	predominantly fine to coarse sand, subrounded, composition varied but predominantly quartz, fine at base	100	154	54
CLAY	as above, with bedrock and calcareous olive gray clay, till, olive gray-black, clay through gravel, composition varied, Tongue River bedrock, oxidized and unoxidized, noncalcareous sandstone and lignite, clay, olive gray, silty, calcareous vary hard (till)	154	204	50
SILT	with sand layers, olive gray, clay, slightly cohesive calcareous, (samples quit at 220 feet, mud is getting thicker, drills fairly easy, soft silt)	204	253	49

Figure B.1.5.3. Yellowstone Buried Channel aquifer lithology.

Location	16309715ABB	Date Drilled	06/12/1971
County	Divide	Land Surface	1916.29
Aquifer	Yellowstone Buried Channe	Total Depth	540
Purpose	Observation Well	Bedrock Depth	502

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Sandy loam, dark brown	0	1	1
SAND	Medium to very coarse, gravelly, assorted, generally subrounded, loose, iron-stained, oxidized	1	10	9
SILT	Clayey, sandy, pebbly, yellowish gray, soft, slightly cohesive, laminated, oxidized (till?)	10	22	12
CLAY	Very silty, sandy, pebbly, cobbles, olive gray, moderately soft to slightly hard, very cohesive, stiff, tightly compacted (till)	22	69	47
CLAY	Silty, sandy, pebbly, moderate olive brown, moderately soft, slightly crumbly to slightly brittle, partially oxidized (till)	69	82	13
SAND	Coarse, reddish brown, sorted, generally subangular, loose, iron-stained	82	87	5
CLAY	Very silty and sandy, pebbly, dusky yellow, soft to moderately soft, slightly crumbly, compacted, oxidized (till)	87	102	15
CLAY	Silty, sandy, pebbly, cobbles, occasional coarse sand lenses, olive gray, moderately soft;, cohesive, moderately stiff (till)	102	135	33
CLAY	Silty, olive gray, slightly hard, cohesive, stiff, smooth, tight	135	155	20
SAND	Fine and medium, light brown, sorted, subrounded, loose; thin clay layers	155	169	14
CLAY	Silty, sandy, pebbly, cobbles, variegated but predominantly moderate olive brown, moderately soft, cohesive to slightly crumbly, oxidized to partially oxidized (till)	169	224	55
CLAY	Silty, sandy, pebbly, olive gray, slightly hard, cohesive, stiff (till)	224	239	15
SAND	Medium and coarse, very gravelly, lenticular	239	266	27
CLAY	Silty, sandy, pebbly, olive gray, moderately soft, very cohesive, stiff (till); sand and gravel lenses	266	289	23

Figure B.1.6.1. Crosby aquifer lithology.

Location	16209701CCC1	Date Drilled	12/01/1971
County	Divide	Land Surface	1970
Aquifer	Crosby	Total Depth	460
Purpose	Observation Well - Destroy	Bedrock Depth	428

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Pebbly clay loam, dark brown	0	1	1
CLAY	Silty, sandy, pebbly, dusky reddish yellow, soft to moderately soft, cohesive, moderately plastic, oxidized (till)	1	13	12
CLAY	Silty, slightly sandy, numerous pebbles and occasional cobbles, reddish brown to moderate olive brown, moderately soft, cohesive, slightly plastic, oxidized (till)	13	28	15
CLAY	Silty to slightly sandy, pebbly, occasional cobbles and boulders, olive gray, moderately soft, slightly stiff and brittle (till)	28	39	11
SAND	Very fine to fine, thin silty to clayey lenses, light olive to olive gray but partially oxidized in upper few feet, loose to slightly cohesive, predominantly quartz laminated with fine lignite particles and carbonaceous material	39	80	41
CLAY	Silty, sandy, pebbly granite boulders at 130 and 137 feet, olive gray, cohesive, tough (till)	80	150	70
SAND	Predominantly fine, medium in upper part, very fine in lower part, well-sorted and uniform, quartzose, subrounded, loose, clean	150	175	25
CLAY	Silty, sandy, pebbly, olive gray, moderately soft to slightly hard, tight (till)	175	238	63
SAND	Coarse to very coarse, some fine gravel, moderately well-sorted, subangular to rounded, loose, clean	238	283	45
CLAY	silty, sandy, pebbly, occasional cobbles, olive gray, moderately soft, cohesive, fairly stiff (till)	283	308	25
CLAY	Silty, sandy, pebbly, and cobbles, olive to dark olive gray, slightly hard, tightly compacted, stiff and moderately brittle (till)	308	325	17
SAND	Very fine to fine slightly clayey, light gray to light olive gray, moderately soft, chunky, crumbly, calcareous (till?); occasional thin layers of marl-like clay	325	350	25

Figure B.1.6.2. Crosby aquifer lithology.

Location	16309726DDD	Date Drilled	06/14/1972
County	Divide	Land Surface	1942.16
Aquifer	Crosby	Total Depth	380
Purpose	Observation Well	Bedrock Depth	373

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Pebbly, silty loam; black	0	1	1
CLAY	Silty, sandy, pebbly, dark brown, moderately soft, very cohesive, slightly plastic, oxidized (till)	1	10	9
CLAY	Silty, sandy, pebbly, moderate olive brown to light reddish brown, soft to moderately soft, moderately cohesive, oxidized (till); lenses of loose, medium grained sand	10	37	27
CLAY	Silty to sandy, dark olive gray, moderately soft, slightly friable, laminated	37	49	12
CLAY	Silty, sandy, pebbly, cobbles, olive gray, slightly hard, stiff, brittle, compacted (till)	49	94	45
SILT	Clayey, sandy, light olive gray, moderately soft, slightly cohesive to friable, laminated, partially oxidized	94	103	9
SILT	Clayey to very sandy, gravel lenses, light olive and olive gray to light brown, laminated, soft and slightly cohesive to loose	103	186	83
CLAY	Silty, sandy, pebbly, cobbles, olive gray, moderately soft, cohesive, stiff (till); gravel lenses	186	274	88
SAND	Very fine to medium, interbedded silt and sandy clay, loose to slightly cohesive	274	298	24
CLAY	And silty clay, olive to dark olive gray, moderately soft to slightly hard, stiff, brittle, smooth, tight	298	315	17
CLAY	Very silty, sandy, pebbly, cobbles, olive gray, slightly hard, stiff, compacted (till)	315	322	7
SAND	Medium to very coarse, yellowish brown, sorted but lenticular, subrounded, loose	322	337	15
SILT	Clayey, very sandy, olive gray, laminated, soft to moderately soft, slightly cohesive; interbedded with fine gravel	337	351	14
SAND	Medium to coarse, brown, subangular and subrounded, sorted, loose, clean	351	360	9

Figure B.2.1.1. Columbus aquifer lithology.

02/26/2010

Location	16208833AAA	Date Drilled	06/01/1977
County	Burke	Land Surface	1888
Aquifer	Columbus	Total Depth	400
Purpose	Observation Well	Bedrock Depth	379

Unit	Description	Begin Int	End Int	Thickness
CLAY	Sandy, silty, pebbly, slightly gravelly with a few boulders, moderate yellowish brown, moderately tight to tight, cohesive, very slightly plastic (till) oxidized	0	23	23
CLAY	As above, medium dark to olive gray, tight, cohesive (till)	23	115	92
SAND & GRAVEL	Sand is fine to very coarse, predominantly coarse to very coarse, subrounded to rounded, 70% quartz, 20% carbonates, 10% granitics and shale, well sorted, gravel, fine, subangular to subrounded, predominantly carbonates with some quartz, interbedded with till after 135'	115	131	16
CLAY	Sandy, silty, pebbly with occasional boulders, medium dark to olive gray, tight, cohesive (till)	131	286	155
SAND	Fine to very coarse, predominantly medium to very coarse, subangular to rounded, well sorted, 60% quartz, 30% carbonates, 10% shale with abundant detrital lignite, some gravel and rocks, predominantly carbonates and shale gravel with abundant lignite after 330' with some interbedded clays	286	379	93
SAND	Fine grained, very clayey, medium light gray to bluish green, tight, cohesive, friable (Tongue River)	379	400	21

Figure B.2.1.2. Columbus aquifer lithology.

02/26/2010

Location	16208903BBB	Date Drilled	08/18/1966
County	Burke	Land Surface	1918
Aquifer	Columbus	Total Depth	280
Purpose	Observation Well	Bedrock Depth	236

Unit	Description	Begin Int	End Int	Thickness
CLAY	Silty and sandy with pebbles and interbedded sand and gravel lenses, dusky yellow to reddish brown, soft, loose to moderately cohesive, oxidized (till)	0	26	26
CLAY	Silty with sand grains, pebbles occasional rocks and gravel stringers, olive gray, moderately soft, cohesive (till) some samples are pure clay, silt or very fine sandy clay without pebbles	26	84	58
CLAY	Silty with sand grains, pebbles, occasional large rocks, olive gray, slightly hard, very cohesive	84	127	43
SAND	Medium to coarse, light gray, slightly clayey, generally subrounded, lignitic, tight drilling	127	136	9
TILL	As above, tight and tough, occasional large rocks	136	176	40
SAND	Medium to coarse, clayey and carbonaceous, dark brown	176	182	6
SAND	Fine to very coarse and fine to very coarse gravel, dark brown, poorly sorted, subangular and subrounded (preglacial outwash type)	182	218	36
CLAY	Sandy, soft, light gray, chalky, fairly tight	218	226	8
SAND & GRAVEL	As above with more coarser gravel and much rougher drilling, dark brownish stain, various types of varigated rocks, many siliceous rocks, also volcanics or metamorphics	226	236	10
SHALE	Light to medium gray to black with beds of lignite, much gravel in cuttings, and much lignite chips in the mud	236	254	18
SHALE	Very sandy, light greenish gray with carbonaceous inclusions	254	264	10
LIMESTONE	Tan, very hard	264	269	5
SHALE	Medium gray, slightly hard and brittle, tight drilling	269	280	11

Figure B.2.2.1. Kenmare aquifer lithology.

02/26/2010

Location	16009113ACD1	Date Drilled	06/30/1966
County	Burke	Land Surface	2240
Aquifer	Kenmare	Total Depth	360
Purpose	Observation Well	Bedrock Depth	0

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Silty loam, black	0	1	1
CLAY	Silty and sandy with pebbles, yellowish gray, soft, moderately cohesive, oxidized (till)	1	5	4
CLAY	Silty to sandy, dusky yellow to moderate olive brown with a reddish tint, soft, cohesive, moderately plastic, fairly tight	5	24	19
CLAY	Silty and sandy with pebbles and rocks, moderate olive brown, moderately soft, cohesive, oxidized (till)	24	47	23
CLAY	Silty with sand grains, pebbles, occasional rocks and numerous gravel stringers, olive gray, moderately soft, cohesive (till) gravel is mostly limestone particles	47	68	21
SAND	Medium, light brownish gray, very well sorted, subrounded, mostly quartz with feldspar and limestone, small amount of shale and lignite	68	82	14
CLAY	Silty with sand grains, pebbles, occasional rocks and a few sand lenses, olive gray, moderately soft, cohesive (till)	82	111	29
SAND	Medium, light olive gray, loose, well sorted, subrounded	111	115	4
CLAY	Silty with sand grains and pebbles, occasional glacial erratics, olive gray, moderately soft, cohesive (till)	115	164	49
SAND	Medium and coarse, light pinkish gray, well sorted, generally subrounded, predominantly quartz, feldspar and limestone, some shale and lignite	164	173	9
CLAY	Silty and sandy with numerous pebbles and medium to coarse gray sand lenses, olive gray	173	196	23
SAND	Medium and coarse with fine gravel, moderately well sorted, subrounded, mostly quartz, feldspar, limestone and shale	196	243	47

Figure B.2.2.1. Kenmare aquifer lithology (continued).

02/26/2010

Unit	Description	Begin Int	End Int	Thickness
CLAY	Silty and sandy with pebbles, olive gray, moderately soft to slightly hard, moderately cohesive (till)	243	261	18
SAND	Coarse, light gray, quartzose, subangular and subrounded	261	265	4
CLAY	As above (till)	265	270	5
CLAY	Silty and sandy with numerous pebbles and occasional rocks, olive gray to dark olive gray, slightly hard, tightly compacted, slightly brittle (till)	270	298	28
GRAVEL	Fine to coarse, sandy and numerous cobbles, poorly sorted, subangular and subrounded, mostly granitic rocks and limestone	298	309	11
CLAY	Sandy, white, chalky, soft, highly calcareous	309	313	4
SAND	Medium to very coarse with fine and medium gravel, getting coarser with depth, well sorted, subrounded, mostly quartz and granitic derivatives and limestone	313	347	34
GRAVEL	Fine to coarse, sandy with cobbles and possibly boulders, poorly sorted, subangular and subrounded, mostly granitics and limestone	347	359	12
ROCK	No description	359	360	1

APPENDIX B - LITHOLOGY

Figure B.2.3.1. Shell Creek aquifer lithology.

02/26/2010

Location	15909423DDC	Date Drilled	07/08/1966
County	Burke	Land Surface	2195
Aquifer	Shell Creek	Total Depth	110
Purpose	Observation Well	Bedrock Depth	95

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Sandy loam, black	0	1	1
SILT	Clayey to very sandy with pebbles, yellowish gray to moderately olive brown, soft, slightly cohesive, oxidized	1	7	6
CLAY	Silty with sand grains and pebbles, olive gray, soft to moderately soft, cohesive (till)	7	21	14
GRAVEL	Fine and medium, sandy, brown, sorted, generally subrounded	21	41	20
CLAY	Very silty to sandy with pebbles and occasional rock, light olive gray to olive gray, moderately soft to slightly hard, very cohesive (till)	41	95	54
SAND	Fine, light greenish gray to greenish gray, moderately soft, moderately friable, quartzose and micaceous	95	110	15

Figure B.3.1.1. Denbigh aquifer lithology.

Location	15607717DCC	Date Drilled	06/28/2004
County	McHenry	Land Surface	1504.45
Aquifer	Denbigh	Total Depth	100
Purpose	Observation Well	Bedrock Depth	87

Unit	Description	Begin Int	End Int	Thickness
SILT	Dark yellowish-brown	1	9	8
SILT	Olive gray	9	15	6
SAND	Medium grained, moderate sorting, subrounded, quartzose, some lignite	15	40	25
SAND	Coarse grained, as above, grading coarser, shale noticed in wasings	40	60	20
SAND & GRAVEL	As above, very coarse, with a little gravel	60	87	27
SAND	Fine grained, quartzose, with greenish-gray matrix clay (bedrock - Fox Hills Formation)	87	100	13

Figure B.3.2.1. Glenburn aquifer lithology.

Location	15908224ADA	Date Drilled	08/10/1977
County	Bottineau	Land Surface	1535
Aquifer	Glenburn	Total Depth	220
Purpose	Observation Well	Bedrock Depth	190

Unit	Description	Begin Int	End Int	Thickness
CLAY	Silty, sandy, pebbly, reddish-yellow stringers, oxidized (till)	0	18	18
CLAY	As above, olive gray (till)	18	40	22
SAND & GRAVEL	Predominantly sand, predominantly medium grain size, subangular to rounded, 50% to 60% quartz, calcareous, lignitic (glacio fluvial), caving, taking water, added 1 bag mud	40	45	5
TILL	Possibly silty sand, very poor sample recovery, above sand caving, drills softer than above till, retrieved 1 small sample of a greenish gray silty sand	45	138	93
SAND & GRAVEL	Poor sample analysis due to above caving of sand and addition of mud, coarser than above, more gravel portion, fair to poor sorting, angualr to rounded (glacio-fluvial)	138	190	52
SANDSTONE	First contact appears weathered, light gray to green, very fine to fine, silty, clayey, slightly calcareous, with depth color changes to greenish-gray, not weathered	190	220	30

Figure B.3.3.1. Lake Souris aquifer lithology.

Location	15407618CBB	Date Drilled	06/04/1993
County	McHenry	Land Surface	1533.09
Aquifer	Lake Souris	Total Depth	60
Purpose	Observation Well	Bedrock Depth	0

Unit	Description	Begin Int	End Int	Thickness
SAND	Coarse grained, poorly sorted, quartz, etc., oxidized to 11 feet	1	47	46
SAND & GRAVEL	25% gravel, poorly sorted, quartz, dark silicates, carbonates, shale, lignite (as above, grading coarser)	47	56	9
CLAY	Olive gray, 30%, with silt, sand & gravel (till)	56	60	4

Figure B.3.3.2. Lake Souris aquifer lithology.

Location	15507816DDD	Date Drilled	10/13/1970
County	McHenry	Land Surface	1518
Aquifer	Lake Souris	Total Depth	100
Purpose	Observation Well	Bedrock Depth	76

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Very sandy, silty, brownish black	0	1	1
SAND	Slightly silty, very fine- to very coarse-grained (mostly medium- to coarse-grained), subangular to rounded, well sorted, some pebble-sized, detrital lignite fragments (iron-stained on outside surface), about 70% quartz and feldspar, 15% carbonates, 15% shale and siliceous rock fragments, lignitic, oxidized to about 10 ft. below land surface	1	20	19
CLAY	Silty, slightly sandy, pebbly, olive gray, cohesive, plastic, calcareous (till)	20	25	5
SAND	Slightly gravelly, fine- to very coarse-grained, subangular to rounded, moderately well sorted, mostly quartz, slightly lignitic	25	28	3
CLAY	Silty, slightly sandy, pebbly, olive gray, very cohesive, plastic, calcareous (till)	28	76	48
SHALE	Moderately clayey, slightly sandy to sandy, medium bluish gray to grayish brown, bedded, noncalcareous, moderately indurated, a few small brownish concretions (Hell Creek Formation)	76	100	24

Figure B.3.4.1. New Rockford aquifer lithology.

Location	15207520CCC	Date Drilled	10/02/1970
County	McHenry	Land Surface	1594.45
Aquifer	New Rockford	Total Depth	300
Purpose	Observation Well	Bedrock Depth	288

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	sandy, silty, pebbly, brownish black	0	1	1
CLAY	very silty, sandy, pebbly, a few cobbles, dusky yellow, slightly cohesive, moderately plastic, oxidized, (TILL)	1	9	8
SAND	slightly gravelly, (slightly oxidized), fine to very coarse grained, (mostly medium grained), subangular to rounded, moderately well sorted, mostly quartz, lignitic, taking some water	9	35	26
CLAY	silty, slightly sandy, pebbly, occasional cobbles, medium dark gray, moderately cohesive, moderately plastic, calcareous, (TILL)	35	65	30
SAND	(slightly clayey), very slightly gravelly, fine to very coarse grained (mostly medium grained), subangular to rounded, moderately well sorted, about 60% quartz and feldspar, 20% shale, 20% carbonates, granitic fragments, and lignite; taking some water, not caving in	65	86	21
CLAY	very silty, (occasional detrital lignite fragments), slightly sandy, olive gray with light olive gray laminations, very cohesive, slightly plastic, highly calcareous, (fluvial sediment)	86	116	30
CLAY	same as above, with thin sand lenses (fluvial sediment)	116	136	20
SAND	slightly clayey, silty, very fine to medium grained, subangular, moderately well sorted, mostly quartz, shale, and lignite, dirty looking samples	136	139	3
CLAY	sandy, very silty, interbedded with sand lenses, medium dark gray with light olive gray laminations, slightly cohesive, moderately plastic, highly calcareous, (fluvial sediment), some detrital lignite chips	139	182	43
CLAY	very sand, silty, pebbly, occasional cobbles, occasional thin sand lenses, medium dark gray, cohesive, moderately plastic, calcareous, (TILL)	182	238	56

Figure B.3.5.1. Voltaire aquifer lithology.

10/26/2009

Location	15207816CBA	Date Drilled	11/16/1977
County	McHenry	Land Surface	1560
Aquifer	Voltaire	Total Depth	80
Purpose	Observation Well - Pluggec	Bedrock Depth	60

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Brownish-black	0	1	1
CLAY	Yellowish-brown, silty, oxidized	1	8	7
SAND	Fine to medium, subangular to subrounded	8	45	37
CLAY	Brownish-gray, very silty; interbedded with lenses of fine to medium sand	45	54	9
CLAY	Medium-dark-brown, silty to sandy (glacial till)	54	60	6
SHALE	Brownish-gray, silty, carbonaceous	60	80	20

Figure B.4.1.1. Munich aquifer lithology.

Location	16106329BBB	Date Drilled	08/28/1970
County	Cavalier	Land Surface	1619
Aquifer	Unknown	Total Depth	160
Purpose	Observation Well	Bedrock Depth	133

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Fine sandy loam, very dark brown	0	1	1
CLAY	Silty to sandy with pebbles, yellowish gray to dusky yellow, soft, slightly to moderately cohesive, leached in upper 6' or 7', oxidized (till)	1	23	22
CLAY	Silty to sandy with pebbles, olive gray, moderately soft, cohesive, slightly plastic (till)	23	30	7
SAND	Very fine to medium, interbedded with silt and sandy clay, lenticular, predominantly gray color, loose to moderately cohesive, sand mostly quartz, easy drilling	30	65	35
SAND	Coarse to very coarse, moderately well sorted and uniform, subangular to subrounded, predominantly quartz with shale and carbonates, clean, taking some water	65	78	13
GRAVEL	Fine to coarse, very little sand, sorted but very lenticular - some lenses practically 100% shale, others about 50% shale and 50% carbonates, some silicates and a trace of granitics, generally subrounded, drills good, taking water but no mud necessary, clean, really nice	78	133	55
SHALE	Black, hard, brittle, siliceous, contains clayey layers	133	160	27

Figure B.4.1.2. Munich aquifer lithology.

Location	16206321BBB	Date Drilled	09/01/1970
County	Cavalier	Land Surface	1594
Aquifer	Unknown	Total Depth	80
Purpose	Observation Well	Bedrock Depth	51

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Silty loam, black	0	1	1
CLAY	Silty, yellowish gray, soft, moderately cohesive, leached, very alkaline	1	5	4
SILT	Clayey to sandy, yellowish gray to dusky yellow, contains occasional pebbles and sand lenses, soft, loose to slightly cohesive, oxidized	5	16	11
CLAY	Silty to sandy with occasional pebbles, olive gray, moderately soft, cohesive, stiff (till)	16	23	7
SAND	Medium to coarse, some finer sand and a little gravel, assorted to poorly sorted, subangular to subrounded, mostly quartz and carbonates with a little shale, clean, except for clayey layer from 32'-36'	23	51	28
SHALE	Black, hard, brittle, siliceous, solid	51	80	29

Figure B.4.2.1. Rolla aquifer lithology.

Location	16306902BBB	Date Drilled	11/05/1980
County	Rolette	Land Surface	1803
Aquifer	Rolla	Total Depth	181
Purpose	Observation Well	Bedrock Depth	154

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Dark brown, silty	0	1	1
TILL	Yellow-brown, oxidized, silty and sandy, calcareous, moderately cohesive	1	14	13
TILL	Dusky yellow-brown, oxidized, silty, clayey, gravelly, calcareous, moderately cohesive, boulder at 18 ft.	14	24	10
TILL	Dark olive gray, silty, pebbly, gravelly, calcareous, moderately cohesive, boulder at 40 ft.	24	41	17
TILL	Yellow-brown, oxidized, sandy, calcareous, moderately cohesive	41	55	14
SAND	Fine sand to fine gravel, predominantly very coarse sand, angular to rounded, predominantly angular, oxidized stain, predominantly carbonates	55	63	8
TILL	As above, interbedded with gravel	63	82	19
SAND	Fine grain, well sorted, angular to rounded, predominantly subrounded, oxidized, predominantly quartz	82	92	10
TILL	As above	92	99	7
SAND	Fine grain, well sorted, angular to rounded, predominantly subrounded, predominantly quartz, approximately 15 %, detrital shale	99	112	13
CLAY	Olive gray, poor sample	112	122	10
SAND	No sample	122	142	20
SILT	Olive gray, clayey, cohesive	142	154	12
SHALE	Dark gray, calcareous, very cohesive	154	181	27

Figure B.4.3.1. Spiritwood aquifer lithology (Ramsey and Towner Counties).

Location	15506609AAA	Date Drilled	08/15/1974
County	Ramsey	Land Surface	1447.27
Aquifer	Spiritwood	Total Depth	180
Purpose	Observation Well	Bedrock Depth	145

Unit	Description	Begin Int	End Int	Thickness
SILT	Clayey, pale yellowish orange to grayish orange, oxidized	0	10	10
CLAY	Silty, sandy, pebbly, moderate yellowish brown to reddish brown; contains a few thin gravel lenses (till)	10	17	7
CLAY	Silty, sandy, pebbly, dark gray (till)	17	23	6
CLAY	Very sandy, silty, pebbly, dark gray (till)	23	32	9
CLAY	Very sandy, silty, pebbly, dark gray; contains numerous sand and gravel lenses (till)	32	58	26
CLAY	Very silty, sandy, pebbly, dark gray, soft (till)	58	63	5
SAND	Medium, medium dark gray, lignitic	63	83	20
SAND	Gravelly, medium dark gray	83	106	23
SAND	Gravelly, partly silty	106	145	39
SHALE	Clayey, dark gray, partly brittle (Pierre Formation)	145	180	35

Figure B.4.3.2. Spiritwood aquifer lithology (Ramsey and Towner Counties).

Location	15806630BBB	Date Drilled	06/16/1980
County	Towner	Land Surface	1481
Aquifer	Spiritwood	Total Depth	322
Purpose	Observation Well - Record	Bedrock Depth	290

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Brownish black	0	1	1
CLAY	Yellowish brown, cohesive, oxidized	1	13	12
TILL	Dark gray, silty, thin gravel streaks	13	52	39
GRAVEL	Fine to coarse, subrounded, mostly carbonates, granitic and shales, sandy	52	58	6
TILL	Dark gray, silty to sandy, boulder at 63'	58	66	8
TILL	Dark gray, silty, pebbly with very thin lenses of gravel	66	76	10
TILL	Dark gray to black, pebbly, silty, sandy	76	84	8
GRAVEL	Fine to coarse, angular to rounded, mostly carbonates and detrital shale	84	86	2
TILL	Dark grayish black, silty, pebbly with thin lenses of silt	86	106	20
SILT	Dark gray, very clayey	106	125	19
TILL	Dark grayish to black, silty, pebbly	125	134	9
SILT	Medium gray, clay, sandy lenses	134	150	16
TILL	Dark grayish black, silty, sandy, reworked into a fluvial deposit	150	178	28
SAND	Very silty, very fine to coarse, predominantly subrounded to rounded	178	224	46
GRAVEL	Coarse sand to medium gravel, predominantly coarse sand and fine gravel, angular to rounded, predominantly rounded, predominantly detrital shale and some carbonates, becomes coarser and more angular with depth to predominantly coarse, angular carbonate gravel	224	234	10
TILL	Brownish gray, very sandy, pebbly, moderate to very cohesive, calcareous with intercalated gravel lenses	234	274	40

Figure B.4.4.1. Starkweather aquifer lithology (Ramsey and Towner Counties).

Location	15506325AAA	Date Drilled	08/01/1973
County	Ramsey	Land Surface	1476.3
Aquifer	Starkweather	Total Depth	385
Purpose	Observation Well	Bedrock Depth	0

Unit	Description	Begin Int	End Int	Thickness
LOAM	Clayey, silty, grayish black (topsoil)	0	1	1
CLAY	Very silty, moderate yellowish brown, oxidized (lacustrine sediment)	1	5	4
CLAY	Moderately sandy, silty, pebbly, moderate yellowish brown, oxidized (till)	5	18	13
CLAY	Slightly sandy, pebbly, cobbly, olive-gray, calcareous (till)	18	20	2
SAND	Fine to very coarse; consists of about 60 percent shale particles	20	28	8
CLAY	Sandy, pebbly, gravelly, cobbly, bouldery, olive-gray, calcareous (till)	28	76	48
SILT	Clayey, dark greenish gray to medium dark gray; laminated light olive-gray (glaciofluvial sediment)	76	172	96
GRAVEL	Fine to coarse, sandy; consists of about 90 percent shale particles; contains a few thin clay layers	172	192	20
SILT	Clayey, sandy, medium gray, highly calcareous (glaciofluvial sediment)	192	196	4
GRAVEL	Fine to coarse, clayey, slightly cobbly; consists of about 80 percent shale particles	196	246	50
CLAY	Sandy, moderately silty, pebbly, gravelly, bouldery, slightly calcareous (till)	246	383	137
BOULDERS	Granite, and limestone; very rough drilling	383	385	2

Figure B.5.1.1. Icelandic aquifer lithology.

Location	16105534BAA	Date Drilled	05/10/1968
County	Pembina	Land Surface	1005
Aquifer	Icelandic	Total Depth	470
Purpose	Test Hole	Bedrock Depth	340

Unit	Description	Begin Int	End Int	Thickness
GRAVEL	Sandy or sand, gravelly, oxidized fine sand to pebbles, limestone, shale, quartz, granitics, etc., poorly sorted, rounded to well rounded	0	22	22
SILT	Olive gray, very soft, cohesive, highly calcareous, particularly that portion containing lighter colored laminations, moderately olive brown from 100'-110'	22	100	78
CLAY	Olive gray, very cohesive, very slightly calcareous except for the white highly calcareous spots	100	125	25
SILT	Olive gray, cohesive, highly calcareous with very highly clcareous light colored laminae, soft. Seems to have clayey areas and the silt is somewhat clayey	125	232	107
TILL	Clay through granules, cohesive to non-cohesive, olive gray (light olive gray to olive black) shale and limestone grains predominant but some granitics present, some of the till is silty, some sandy, all highly calcareous. Limestone boulder at 254', till beneath boulder is the light olive gray highly calcareous, till with numerous boulders and cobbles, turns olive gray with fewer rocks at 300'-305'	232	324	92
SHALE	Olive black, non-calcareous, silty with occasional light colored silt to very fine sand laminae which are only very slightly calcareous, hard	324	330	6
TILL	Light olive gray (occasional olive gray) hard, cohesive, highly calcareous rocky	330	340	10
SAND	Coarse, very coarse, quartz, angular to subangular, clear and frosted grains, pyrite, (Dakota). Shale, brownish to olive black, leaves mud brownish to purplish, non-calcareous	340	370	30
SAND	Fine to very fine, quartz, subrounded to well rounded, well sorted, pyrite, becomes coaser with depth. Shale, very poor samples, soft looks like some organic material, silty, non-calcareous	370	470	100

Figure B.5.2.1. Pembina River aquifer lithology.

Location	16305622CCB3	Date Drilled	09/01/1983
County	Pembina	Land Surface	935
Aquifer	Pembina River	Total Depth	40
Purpose	Observation Well	Bedrock Depth	0

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Silty, black	0	1	1
CLAY	Sandy, silty, yellowish brown, It's about 40% sand	1	3	2
SAND	Fine, medium to coarse	3	9	6
CLAY	Silty, medium gray	9	10	1
GRAVEL	Fine, medium to coarse, It's about 40% sand	10	21	11
SAND	Fine, medium to coarse, bluish gray	21	35	14
CLAY	Sandy, silty, olive gray	35	40	5

Figure B.5.2.2. Pembina Delta aquifer lithology.

Location	16305634DDC	Date Drilled	05/19/1971
County	Pembina	Land Surface	1010
Aquifer	Pembina Delta	Total Depth	120
Purpose	Observation Well	Bedrock Depth	0

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Very sandy, silty, clayey, brownish black	0	1	1
SAND	Slightly gravelly, very fine to very coarse grained, grain size becomes finer with increasing depth, subangular to rounded, well sorted, much shale gives material grayish black color, taking some water, not caving	1	58	57
SILT	Very clayey, occasional shale pebbles, detrital lignite fragments, and sand grains, medium dark gray with occasional light olive gray laminae, slightly cohesive, highly plastic (Glacio Fluvial Sediment)	58	98	40
CLAY	Very silty, olive gray, moderately cohesive, highly plastic, moderately calcareous, (Glacio Lacustrine Sediment	98	120	22

Figure B.6.1.1. Bennie Peer aquifer lithology.

Location	14810536DCD	Date Drilled	10/15/1979
County	McKenzie	Land Surface	2002
Aquifer	Undefined	Total Depth	182
Purpose	Observation Well - Destroy	Bedrock Depth	146

Unit	Description	Begin Int	End Int	Thickness
CLAY	Silty, slightly sandy, dark yellowish brown	0	22	22
SAND AND GRAVEL	Fine to coarse; predominantly scoria with dark gray clay layers	22	34	12
CLAY	Silty, slightly sandy, olive-gray to medium dark gray, lignitic, soft	34	80	46
SAND	Fine to medium, lignitic; a few medium gray to dark gray clay layers	80	96	16
SANDSTONE	Very silty, very fine, light bluish gray to medium gray (Tongue River member of Fort Union Formation)	146	153	7
SILTSTONE	Sandy, light gray (Tongue River member of Fort Union Formation)	153	157	4
CLAYSTONE	Dark gray, organic (Tongue River member of Fort Union Formation)	157	172	15
LIGNITE	(Tongue River member of Fort Union Formation)	172	176	4
CLAYSTONE	Dark greenish gray, organic (Tongue River member of Fort Union Formation)	176	182	6

Figure B.6.2.1. Charbonneau aquifer lithology.

Location	15110108DAA	Date Drilled	10/09/1979
County	McKenzie	Land Surface	1988
Aquifer	Charbonneau	Total Depth	202
Purpose	Observation Well - Destroy	Bedrock Depth	165

Unit	Description	Begin Int	End Int	Thickness
CLAY	Silty, sandy, dark yellowish brown, interbedded sand	0	16	16
SAND & GRAVEL	Silty layers	16	21	5
CLAY	Very sandy, silty, dark yellowish brown (till?)	21	42	21
SAND	Fine, lost circulation, no samples	42	122	80
SAND	Layers of gravel	122	161	39
CLAY	White, soft, sticky	161	165	4
SAND	Silty, greenish gray & shale (bedrock)	165	202	37

Figure B.6.3.1. Tobacco Garden aquifer lithology.

Location	15009902CCD	Date Drilled	09/17/1980
County	McKenzie	Land Surface	2105.8
Aquifer	Tobacco Garden Creek	Total Depth	160
Purpose	Observation Well	Bedrock Depth	137

Unit	Description	Begin Int	End Int	Thickness
CLAY	Olive gray, silty	1	41	40
SAND & GRAVEL	Fine sand to pebbles of gravel, subrounded to subangular, 30% carbonates, 70% silicates, some locally derived material, clay lenses at 52', 63', 68'	41	71	30
CLAY	Olive gray, sandy	71	102	31
SAND & GRAVEL	Fine sand to granules of gravel, gubrounded, silicates & carbonates, some lignite	102	137	35
CLAY	Light gray to medium dark gray, to greenish gray, consoliated (bedrock)	137	160	23

Figure B.6.3.2. Tobacco Garden aquifer lithology.

09/17/2009

Location	15209811DCC	Date Drilled	05/06/1981
County	McKenzie	Land Surface	1956
Aquifer	Tobacco Garden Creek	Total Depth	180
Purpose	Observation Well - Destroy	Bedrock Depth	167

Unit	Description	Begin Int	End Int	Thickness
SILT	Dark yellowish brown, argillaceous	0	19	19
SILT	Yellowish brown	19	22	3
SAND AND GRAVEL	Lignitic	22	38	16
CLAY	Silty, sandy, olive-gray	38	60	22
SAND	Fine to very coarse	78	116	38
SANDSTONE	Fine to medium (Sentinel Butte and Tongue River members, undifferentiated, of Fort Union Formation)	167	180	13

Figure B.6.4.1. Yellowstone Buried Channel aquifer lithology.

Location	15010420CCC1	Date Drilled	10/23/1966
County	McKenzie	Land Surface	1890
Aquifer	Yellowstone Buried Channe	Total Depth	100
Purpose	Observation Well - Destroy	Bedrock Depth	0

Unit	Description	Begin Int	End Int	Thickness
SILT	Dark yellowish brown	0	2	2
SAND	Fine to medium, gray, well-sorted, very lignitic	2	10	8
CLAY	Very silty to sandy, light olive-gray	10	18	8
SAND	Slightly clayey, fine, gray	18	29	11
CLAY	Silt and very fine gray sand; interbedded	29	51	22
GRAVEL	Fine to coarse, poorly sorted; lenses of clay and silt and some cobbles	51	92	41
CLAYSTONE	Medium gray, smooth, very tight (Tongue River member of Fort Union Formation)	92	100	8

Figure B.6.4.2. Trenton aquifer lithology.

Location	15210308BBB	Date Drilled	05/19/1965
County	Williams	Land Surface	1901
Aquifer	Trenton	Total Depth	220.5
Purpose	Observation Well - Destroy	Bedrock Depth	178

Unit	Description	Begin Int	End Int	Thickness
SOIL	Black	0	1	1
CLAY	Dusky yellow, silty, calcareous, much fine lignite	1	53	52
GRAVEL	Sandy, poorly sorted, angular	53	76	23
SAND	Very fine, or silt (no sample)	76	83	7
GRAVEL	Sandy, poorly sorted, maximum size 40 millimeter	83	99	16
SAND	Fine to coarse, poorly sorted, much lignite	99	110	11
GRAVEL	Sandy, poorly sorted, subrounded to rounded, predominant size about 10 millimeters	110	115	5
CLAY	Olive-black, sandy; color due to abundant lignite particles	115	126	11
GRAVEL	Sandy, poorly sorted; size ranged from about 0.25 to 12 millimeters, predominant sizes are 1 and 10 millimeters	126	137	11
CLAY	Olive-gray to greenish gray, sandy and silty, calcareous	137	148	11
SAND	Fine to coarse, poorly sorted, angular	148	173	25
GRAVEL	Fine, much lignite	173	178	5
CLAY	Light gray to brownish gray, sandy and silty (Fort Union Group)	178	220	42

Figure B.7.1.1. Goodman Creek aquifer lithology.

Location	14509021AAA1	Date Drilled	05/08/1969
County	Mercer	Land Surface	0
Aquifer	Goodman Creek	Total Depth	240
Purpose	Observation Well	Bedrock Depth	208

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Sandy, gravelly, silty, moderate yellowish brown to brownish black	0	1	1
CLAY	Very silty, dusky yellow to light brownish gray, cohesive, plastic, very calcareous, occasional laminations (Alluvium)	1	20	19
SAND	Very fine to medium grained, subangular to subrounded, moderately well sorted, interbedded throughout with clay lenses (Alluvium)	20	34	14
CLAY	Very silty, slightly sandy, bluish-black, laminated, carbonaceous, calcareous (Alluvium)	34	38	4
SAND	Very slightly gravelly, very fine to coarse grained (mostly medium grained) subangular to rounded, fair sorting, mostly quartz, some shale, lignite and sandstone, taking water	38	80	42
SILT	Clayey, slightly sandy, (interbedded with fine grained sand) olive gray to medium dark gray with numerous light olive gray laminations, very plastic, slightly cohesive, numerous detrital lignite chips, calcareous (Alluvium)	80	180	100
SAND	Slightly gravelly, very fine to coarse grained, subangular to rounded, moderately well sorted, mostly quartz and shale, lignitic	180	190	10
GRAVEL	Sandy, (approximately 20-40% fine to very coarse grained sand) fine to medium, angular to subrounded, moderately well sorted, mostly western-source rocks and local derivatives, some limestone, dolostone and granitics, taking water, lignitic	190	208	18
SHALE	Very silty, clayey, medium bluish-gray to brownish gray, bedded, moderately indurated, non-calcareous, (Sentinel Butte Formation)	208	240	32

Figure B.7.2.1. Killdeer aquifer lithology.

Location	13908926CCD	Date Drilled	06/16/1975
County	Morton	Land Surface	0
Aquifer	Killdeer	Total Depth	320
Purpose	Unknown	Bedrock Depth	293

Unit	Description	Begin Int	End Int	Thickness
CLAY	Moderate yellowish brown, very silty, slightly sandy, slightly plastic oxidized and iron stained, soft, small amount of lignite	0	60	60
CLAY	As above, medium gray to medium dark gray, harder	60	86	26
SAND	Very fine to medium, predominantly fine, angular to subrounded, mostly quartz, considerable amount of lignite, small amount of carbonates nd igneous, well sorted	86	149	63
GRAVEL	Medium to very coarse, angular to subangular, mostly granitics, small amount of carbonates and igneous and lignite	149	152	3
CLAY	Medium dark gray, very silty, moderately sandy, tight, slightly plastic, moderate amount of lignite	152	232	80
CLAY	Dark gray, silty, sandy, pebbly, very slightly plastic, moderately hard (till)	232	293	61
SAND	Fine to medium, very rocky the first few feet, grayish green (Tongue River)	293	320	27

Figure B.7.2.2. Killdeer aquifer lithology.

Location	14109130DAD	Date Drilled	06/18/1974
County	Stark	Land Surface	0
Aquifer	Killdeer	Total Depth	245
Purpose	Observation Well - Destroy	Bedrock Depth	237

Unit	Description	Begin Int	End Int	Thickness
SAND	Silty, very fine to fine, subrounded, light brown staining, oxidized, moderately well sorted	0	6	6
SILT	Clayey, very sandy, sand lenses, dark yellowish brown with olive gray mottling and laminae, slightly cohesive, soft, crumbly, oxidized (Colluvium)	6	20	14
CLAY	Very silty, interbedded with gravelly sand lenses, olive gray with greenish gray and light olive gray, mottling, cohesive to highly plastic, calcareous, angular, lignite fragments	20	36	16
SAND	Numerous clay lenses, very fine to very coarse, mostly fine to medium, slightly gravelly, subangular to subrounded, fair sorting, small amount of detrital lignite	36	58	22
SILT	Very sandy, clayey, sand lenses, olive gray, slightly cohesive, crumbly, calcareous	58	88	30
CLAY	Silty, olive gray to dark greenish gray, very cohesive, sticky, highly calcareous, small amount of detrital lignite, occasional interbedded sand lenses	88	158	70
SAND	Very fine to very coarse (mostly medium to coarse), very slightly gravelly, subangular to rounded, well sorted, 75% quartz, 10% shale, 15% feldspar, lignite, scoria, a few thin clay layers	158	206	48
SILT	Clayey, sandy, sand lenses, olive gray to medium dark gray, slightly cohesive, soft, crumbly, detrital lignite fragments, a large amount of reworked bedrock - sandstone, siltstone and shale	206	237	31
SANDSTONE	Light gray to grayish white, very fine, hard and cemented, highly calcareous, limey	237	245	8

Figure B.7.2.3. Killdeer aquifer lithology.

Location	14109404BAA	Date Drilled	06/11/1974
County	Dunn	Land Surface	0
Aquifer	Killdeer	Total Depth	220
Purpose	Observation Well - Pluggec	Bedrock Depth	196

Unit	Description	Begin Int	End Int	Thickness
CLAY	Very silty, sandy, moderate yellowish brown, moderately cohesive, plastic, oxidized (Colluvium)	0	30	30
CLAY	Silty, moderate yellowish brown, plastic, very cohesive, sticky, oxidized (Lake Sediment)	30	48	18
CLAY	Same as above, only olive gray (Lake Sediment)	48	66	18
SAND	Occasional clay layers, very fine to coarse, mostly fine to medium, very slightly gravelly, subrounded, moderately well sorted, a large amount of detrital lignite, used water	66	168	102
GRAVEL	Very sandy, fine to coarse, angular to rounded, fair sorting, approximately 40% brownish western silicates, 40% local sandstone, siltstone and limestone, 20% carbonates, shale and granitics, small amount of detrital lignite	168	184	16
CLAY	Silty, medium light gray to lignite gray, highly calcareous, stiff	184	194	10
GRAVEL	Clayey, sandy, large amount of detrital lignite, fine to very coarse, mostly local sandstone and siltstone, brownish western silicates, poorly sorted	194	196	2
SILTSTONE	Siliceous, medium gray to medium dark gray with light greenish gray to brownish gray mottling, moderately indurated, non-calcareous, small amount of thin sandy claystone bedding	196	220	24

Figure B.7.3.1. Knife River aquifer lithology.

Location	14209114BBB	Date Drilled	06/19/1974
County	Dunn	Land Surface	0
Aquifer	Knife River	Total Depth	160
Purpose	Observation Well - Pluggec	Bedrock Depth	140

Unit	Description	Begin Int	End Int	Thickness
CLAY	Very silty, sandy, moderately yellowish brown, slightly cohesive, crumbly, oxidized (Colluvium)	0	12	12
SAND	Clayey and silty, fine to coarse, stained reddish brown, fair sorting, oxidized	12	22	10
SAND	Slightly clayey, very fine to very coarse, mostly medium to coarse, subangular to rounded, fair to good sorting, containing scoria and lignite	22	60	38
SILT	Clayey, occasional thin sand layers, medium light gray to olive gray, soft, moderately plastic to crumbly, highly calcareous, small amount of detrital lignite	60	116	56
CLAY	Silty, olive gray, very cohesive, highly plastic, calcareous, small amount of detrital lignite (Tongue River Formation)	116	140	24
LIMESTONE	Medium gray to light gray, hard, microcrystalline	140	145	5
SILTSTONE	Light gray to grayish white, moderately indurated, moderately calcareous, sandy	145	150	5
LIMESTONE	Medium dark gray, very hard, microcrystalline	150	153	3
SILTSTONE	Light gray, sandy, highly calcareous, moderately indurated	153	160	7

Figure B.7.4.1. Missouri River aquifer lithology.

Location	13708024ABC	Date Drilled	09/15/1961
County	Burleigh	Land Surface	1627
Aquifer	Missouri River	Total Depth	126
Purpose	Observation Well	Bedrock Depth	115

Unit	Description	Begin Int	End Int	Thickness
CLAY	Pale yellowish brown, silty, slightly cohesive, strongly effervescent	0	11	11
CLAY	Light olive gray, silty, very cohesive, blackish lignitic or organic areas, strongly effervescent	11	21	10
SAND	Very fine to coarse, unsorted, subrounded to rounded, predominantly quartz, abundant lignite fragments, purple colored wood fragments, very sparse snail shell fragment	21	81	60
GRAVEL	Fine to medium, sandy, unsorted, subangular to subrounded, abundant quartz and abundant brownish grains and pebbles, lignite fragments	81	90	9
GRAVEL	Fine to coarse sandy, subrounded to well rounded, brownish pebbles, predominantly lignite fragments	90	104	14
SAND	Medium to very coarse, gravelly, subrounded, predominantly quartz with abundant brownish grains, fine to coarse gravel, lignite fragments (Hell Creek)	104	115	11
CLAY	Grayish blue silty (Hell Creek)	115	126	11

Figure B.7.4.2. Missouri River aquifer lithology.

Location	14408221CDD	Date Drilled	07/07/1969
County	Oliver	Land Surface	1675
Aquifer	Missouri River	Total Depth	140
Purpose	Observation Well	Bedrock Depth	111

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Black sandy, silty loam	0	1	1
SILT	Silt, sandy, clayey, yellowish gray	1	20	19
SAND	Medium to very coarse grained, some gravel, abundant lignite	20	40	20
GRAVEL	Sandy, lignitic, clay beds in lower part	40	80	40
SILT	With sand, medium to coarse grained, lignitic, dark gray	80	84	4
SAND	Medium to coarse grained, lignitic	84	111	27
CLAYSTONE	Silty, sandy, brown, to light olive gray (bedrock - Cannonball or Ludlow Fm.)	111	140	29

Figure B.7.5.1. White Shield aquifer lithology.

Location	14908924AAA	Date Drilled	07/13/1970
County	McLean	Land Surface	1955.67
Aquifer	White Shield	Total Depth	380
Purpose	Observation Well	Bedrock Depth	342

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Pebbly loam, black	0	1	1
CLAY	Silty with sand grains and pebbles, dusky yellow to moderate olive brown, moderately soft, cohesive, moderately plastic, oxidized (till) yellowish gray, leached and jointed to 4' below toposoil	1	18	17
SAND	Fine and medium, brownish, loose, sorted, subrounded, mostly quartz and carbonates with block siliceous shale, carbonates, heavily iron stained	18	26	8
CLAY	Silty and sandy, light olive to olive gray, soft, slightly to moderately cohesive, slightly plastic	26	36	10
SHALE	Greenish gray, slightly hard, slightly brittle to very stiff, smooth, tight, bentonitic	36	44	8
SAND	Coarse to fine to coarse again, dark gray, 50% quartz and 50% dark siliceous shale and lignite, generally subangular	44	52	8
SILT	Very light gray to light greenish gray, moderately soft, slightly cohesive, calcareous, occasional pebble	52	68	16
SAND	Very fine and silty, light greenish to greenish gray, soft to moderately soft, non to cohesive, occasional pebble	68	78	10
SAND	Coarse, brownish gray, sorted, angular to subrounded, mostly iron stained, limestone and siltstone with concretion chips and lignite	78	85	7
CLAY	Silty to sandy with pebbles, very dark brown, moderately soft, cohesive, chunky, tight (till)	85	96	11
SAND	Fine to very coarse with interbedded lenses of clay, silt and occasionally fine gravel, thinly interbedded and very variable	96	185	89
CLAY	Silty to sandy with pebbles, olive gray, moderately soft, cohesive, stiff (till)	185	193	8

Figure B.7.5.2. White Shield aquifer lithology.

Location	15109234DAA	Date Drilled	08/06/1966
County	Mountrail	Land Surface	1891
Aquifer	White Shield	Total Depth	200
Purpose	Observation Well - Destroy	Bedrock Depth	170

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Sandy loam, black	0	1	1
SAND	Fine and medium, slightly clayey, dusky yellow, loose to slightly cohesive, oxidized	1	21	20
CLAY	Silty with sand grains and pebbles, moderate olive brown, soft to moderately soft, cohesive, fairly tight, oxidized (till)	21	49	28
CLAY	As above, olive gray, unoxidized, very few cobbles and boulders (till)	49	60	11
GRAVEL	Fine and medium, some sand, moderately well sorted, generally subrounded, mostly limestone with granitic rocks	60	66	6
CLAY	Olive gray, soft, smooth, plastic, tight	66	70	4
GRAVEL	As above, slightly rusty tint to limestone pebbles	70	74	4
SAND	Fine and medium, well sorted, subrounded, mostly quartz and very lignitic	74	83	9
CLAY	Sandy, very fine, light olive gray, soft, moderately cohesive	83	87	4
SAND	Fine and medium, light gray, not as lignitic as sand above	87	99	12
SILT	Light olive gray, soft, slightly cohesive	99	105	6
SAND	Fine, some medium, gray, well sorted, subrounded, quartzose	105	109	4
CLAY	Silty and very sandy, light olive gray to olive gray, soft, moderately cohesive	109	124	15
GRAVEL	Fine and medium, sandy, dark brown, mostly siliceous rocks and heavily iron stained limestone and shale	124	141	17
CLAY	Olive gray with bluish tint, moderately soft to slightly hard, very cohesive and tight	141	145	4
GRAVEL	As above, dark brown, fine to coarse with lenses of clay and sand	145	170	25

Figure B.8.1.1. Lake Nettie aquifer lithology.

Location	14607830DDD	Date Drilled	05/13/1971
County	Sheridan	Land Surface	1895
Aquifer	Lake Nettie	Total Depth	500
Purpose	Observation Well - Destroy	Bedrock Depth	495

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	silty, clayey, sandy, grayish black	0	1	1
clay	silty, sandy, pebbly, dusky yellow to moderate yellowish brown, moderately cohesive and plastic, oxidized; TILL	1	35	34
clay	silty, moderately sandy, pebbly, olive gray, cohesive, moderately plastic, calcareous; cobbles; TILL	35	105	70
shale block	very, sandy, dark greenish gray, indurated, slightly calcareous	105	115	10
clay	silty, moderately sandy, pebbly, gravelly, olive gray, cohesive, moderately plastic, calcareous; TILL	115	225	110
clay	very silty, olive gray to medium dark gray, very cohesive, highly plastic, calcareous; scattered light olive gray laminations (fluvial)	225	251	26
clay	silty, moderately sandy, pebbly, olive gray, cohesive, moderately plastic, calcareous; a few cobbles; TILL	251	272	21
gravel	very clayey, moderately sandy, fine to medium, angular to subrounded, poorly sorted; 50% carbonates, 30% igneous and metamorphic and 20% siliceous rock fragments (shale, siltstone and detrital lignite); (no water loss)	272	336	64
clay	very sandy, silty, cohesive, slightly plastic, moderately calcareous, scattered pebbles; olive gray with scattered dark greenish gray streaks; TILL	336	376	40
sand	gravelly, moderately clayey, very fine to very coarse, mostly fine to medium, subangular to rounded, moderately well sorted, moderately lignitic; mostly quartz and feldspar with some carbonate grains; (no appreciable water loss with thin mud)	376	485	109
gravel	and cobbles; sandy, fine to coarse, angular to well rounded, fairly sorted; (taking some water)	485	495	10

Figure B.8.1.2. Lake Nettie aquifer lithology.

Location	14808034DCC	Date Drilled	08/10/1970
County	McLean	Land Surface	1867.5
Aquifer	Lake Nettie	Total Depth	360
Purpose	Observation Well	Bedrock Depth	335

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	sandy, pebbly, black	0	1	1
CLAY	very silty and sandy, pebbly, yellowish gray to moderate olive-brown; with gravelly sand lenses (till)	1	25	24
GRAVEL	fine to medium, with some sand, subrounded	25	37	12
CLAY	silty, olive-gray; scattered sand, pebbles and lignite fragments (till)	37	66	29
GRAVEL	fine to coarse, subangular to subrounded; till layers 70-72 ft and 80-82 ft	66	80	14
SAND	very fine to medium, silty, lignitic	80	100	20
SAND	fine to coarse, silty; with gravel and detrital lignite lenses	100	163	63
CLAY	silty, sandy, pebbly, lignitic, olive gray (till)	163	190	27
SAND	medium, subrounded, dark-gray; scattered gravel-size lignite fragments	190	198	8
GRAVEL	coarse, subrounded; abundant cobbles and boulders	198	214	16
CLAY	silty, smooth, gray	214	219	5
GRAVEL	coarse, subrounded; abundant cobbles and boulders; interbedded with silty clay lenses	219	240	21
CLAY	silty, olive-gray, smooth, laminated	240	266	26
SAND	very fine to medium, lignitic, subrounded, medium gray	266	300	34
SILT	clayey, olive-gray	300	311	11
SAND	very fine to fine, lignitic, medium gray	311	322	11
SAND	medium, lignitic, medium-gray	322	335	13
SANDSTONE	very fine to fine, hard, calcareous, light gray (Fort Union Group)	335	338	3

Figure B.8.2.1. Lost Lake aquifer lithology.

Location	14308102BBCB1	Date Drilled	11/06/1985
County	McLean	Land Surface	1731.9
Aquifer	Lost Lake	Total Depth	236
Purpose	Observation Well	Bedrock Depth	234

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	No description	0	1	1
SAND	Coarse, oxidized	1	4	3
SILT	Dark yellowish orange, oxidized, slightly clayey	4	8	4
SAND	Coarse sand to fine gravel, predominantly very coarse sand	8	14	6
SILT	As above	14	20	6
SAND	Very fine grading to coarse	20	32	12
GRAVEL	Coarse sand to gravel 1" diameter, predominantly 1/4" to 1/2" diameter, rounded, oxidized	32	47	15
TILL	Olive gray, silty, sandy, gravel 62' to 65', a few cobbles at 82'	47	100	53
CLAY	Olive gray (Lacustrine)	100	124	24
SAND	Fine to medium, rounded, quartz and lignite clay lenses at 132', 137', 142' to 145', 148' to 152', clay lense at 158', sand predominantly very coarse at 160', moderately well rounded, below 200' predominantly coarse sand, thin interbedded clay 205' to 211'	124	234	110
BEDROCK	Shale, brown, tight, waxy	234	236	2

Figure B.8.3.1. Butte aquifer lithology.

Location	15107821CBB1	Date Drilled	08/11/1978
County	McHenry	Land Surface	1620
Aquifer	Butte	Total Depth	240
Purpose	Observation Well - Pluggec	Bedrock Depth	213

Unit	Description	Begin Int	End Int	Thickness
CLAY	Silty, sandy, pebbly; light olive-brown, oxidized, compact and cohesive clay; very silty, sandy, and moderately pebbly	0	7	7
GRAVEL	Sandy; fine-coarse gravel, very fine-very coarse sand (15% medium and coarse gravel, 30% fine gravel), (40% coarse and very coarse sand) (15-20% medium sand, fine and very fine sand); carbonates 30-40%, quartz 30%, shale 20%, igneous and metamorphic rocks 10%; fair sorting; subangular to rounded; oxidized	7	36	29
SILT	Sandy; brown-black silty with 30% very fine-fine sand; poor sample return (for thick mud) with 10% lignite fragments, coarse sand	36	68	32
SILT	Sandy, pebbly; dark gray silty with 20-30% very fine sand and 10-20% medium-very coarse sand with 10-20% pebbles, sand is very lignitic	68	144	76
SAND	Silty; very fine-medium sand with 20-30% silt; predominantly quartz (40%), carbonates (30-40%), shale (20%); well sorted	144	156	12
SAND	Silty, very fine-very coarse sand; with 20-30% silt; sand, predominantly coarse 40-50%, 20% very coarse, 30% medium, 5-10% fine and very fine); fairly well sorted to fair sorting, predominantly quartz	156	178	22
CLAY	Silty, sandy; medium grey, moderately compact and cohesive; very silty and sandy	178	182	4
GRAVEL	Sandy; fine-medium gravel, very fine-very coarse sand; 30-40% fine gravel, 10-20% medium gravel; 20-30% medium-very coarse sand, 10% very fine-fine sand; fair sorting to fairly well sorted; predominantly carbonaceous 30-40%, quartz 20-30%, shale 20-30%; subrounded-rounded; with clay stringers at 196-198 and 204-206 ft.	182	213	31

Figure B.8.3.2. Martin aquifer lithology.

Location	15107615ADC	Date Drilled	08/25/1966
County	McHenry	Land Surface	1600
Aquifer	Martin	Total Depth	105
Purpose	Observation Well - Destroy	Bedrock Depth	78

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Brownish-black	0	2	2
SAND	Fine to medium grained, subangular to subrounded, oxidized	2	15	13
SAND	Medium grained, subrounded to subangular	15	35	20
SAND	Medium to coarse grained, subangular to subrounded	35	45	10
SAND	Very coarse to coarse grained, subrounded	45	55	10
SAND	Very fine to medium grained, silty, subangular	55	73	18
GRAVEL	Fine to medium, subangular to angular	73	78	5
SILTSTONE	Dark-greenish-gray, clayey, moderately indurated (bedrock - Hell Creek Formation)	78	105	27

Figure B.8.5.1. Strawberry Lake aquifer lithology.

Location	15008024DCC	Date Drilled	11/02/1982
County	McLean	Land Surface	1997.75
Aquifer	Strawberry Lake	Total Depth	120
Purpose	Observation Well	Bedrock Depth	105

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	No description	0	1	1
SAND & GRAVEL	Coarse sand to coarse gravel predominantly very coarse sand, angular to rounded, predominantly rounded, carbonates, medium to coarse sand with detrital lignite, oxidized	1	25	24
GRAVEL	Fine to very coarse, predominantly medium, angular to rounded, predominantly subangular, carbonates, oxidized	25	44	19
SILT	Yellow brown, oxidized, slightly clayey	44	49	5
GRAVEL	Fine to coarse, predominantly fine, angular to rounded, carbonates, oxidized, interbedded with silt, below 60' there is equal proportions of shale and carbonates , non-oxidized, silts are olive gray becoming very coarse at 75'	49	78	29
SAND	No description	78	82	4
GRAVEL	Very coarse	82	83	1
TILL	Olive gray, silty and pebbly, moderately cohesive and plastic	83	105	22
SANDSTONE	Yellowish green, oxidized, fine grain, well sorted, subangular and angular, slightly argillaceous, carbonaceous, poorly indurated	105	120	15

Figure B.8.6.1. Turtle Lake aquifer lithology.

Location	14708128ADD	Date Drilled	07/31/1967
County	McLean	Land Surface	1836.93
Aquifer	Turtle Lake	Total Depth	120
Purpose	Observation Well	Bedrock Depth	85

Unit	Description	Begin Int	End Int	Thickness
Topsoil	Clay silty, grayish black.	0	1	1
Clay	silty, sandy, dusky yellow (till).	1	10	9
Clay	silty, gravelly, olive-gray (till).	10	26	16
Sand	very fine to fine, clayey.	26	41	15
Clay	silty, sandy, olive gray (till).	41	61	20
Gravel	fine, sandy, angular to subrounded.	61	85	24
Sandstone	fine to medium, noncalcareous, bluish gray.	85	120	35

Figure B.8.6.2. Weller Slough aquifer lithology.

Location	14608315CCC	Date Drilled	07/07/1970
County	McLean	Land Surface	1958
Aquifer	Weller Slough	Total Depth	460
Purpose	Observation Well - Pluggec	Bedrock Depth	408

Unit	Description	Begin Int	End Int	Thickness
SILT	pebbly, black, (topsoil)	0	1	1
CLAY	silty, moderate olive brown; scattered sand and pebbles, (TILL)	1	65	64
CLAY	silty, olive gray; scattered sand and pebbles, (TILL)	65	101	36
SAND	fine to very fine, silty, clayey, subangular to subrounded	101	128	27
CLAY	silty, calcareous, gray	128	258	130
CLAY	silty, sandy, gravelly, olive gray; scattered pebbles and lignite chips, (TILL)	258	273	15
GRAVEL	fine to medium, sandy, angular to subrounded	273	292	19
SILT	and very fine sand, clayey, dark gray, organic rich in spots, slightly cohesive; poor sample return - cuttings wash out in drilling fluid (drills fast and easy)	292	408	116
SAND	very fine to fine, clayey, micaceous, calcareous, greenish gray (Fort Union Group, bedrock)	408	460	52

Figure B.8.6.3. Wolf Creek aquifer lithology.

Location	14708312CCC	Date Drilled	06/26/1985
County	McLean	Land Surface	1854.3
Aquifer	Wolf Creek	Total Depth	86
Purpose	Observation Well	Bedrock Depth	46

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	dark reddish brown, silty and sandy	0	1	1
CLAY	slightly silty, light gray to grayish white; crumbly, soft	1	4	3
CLAY	silty to very silty, yellowish brown; soft, moderately cohesive, slightly plastic, oxidized	4	8	4
SAND & GRAVEL	very fine sand to medium gravel, mostly medium sand to fine gravel; poorly sorted, subangular to subrounded; predominantly carbonates, shale, and quartz	8	10	2
CLAY	silty, slightly sandy and gravelly with very fine sand to fine gravel, yellowish brown to dark yellowish brown; moderately soft, moderately cohesive, slightly to moderately plastic, gritty, somewhat stiff, (TILL)	10	24	14
SAND & GRAVEL	very fine sand to fine gravel, mostly fine to medium sand, moderately well sorted; mostly shale, carbonates, and quartz	24	46	22
CLAYSTONE	dark maroon gray and dark brownish gray interbedded; lignite layers; moderately firm, slightly indurated and compact, moderately to very friable; some layers slightly soft to slightly firm, nonindurated; with greenish gray and brownish gray layers 70-80 ft	46	80	34

Figure B.9.1.1. Cherry Lake aquifer lithology.

Location	14906313BAAB1	Date Drilled	08/12/1987
County	Eddy	Land Surface	1497.37
Aquifer	Cherry Lake	Total Depth	160
Purpose	Observation Well	Bedrock Depth	124

Unit	Description	Begin Int	End Int	Thickness
CLAY	Very silty, soft, plastic	3	7	4
SAND	Fine to coarse, predominantly medium to coarse, subrounded to rounded, predominantly quartz	7	12	5
GRAVEL	Sandy, medium sand to pebbles, predominantly subangular to rounded, limestone and shale granules	13	14	1
CLAY	Silty	14	21	7
CLAY	Silty	23	25	2
CLAY	Very silty, very sandy, pebbly, soft, slightly crumbly, olive gray (till)	26	43	17
GRAVEL	Rounded, shale pebbles	43	45	2
CLAY	Slightly silty, slightly sandy, very pebbly, firm, waxy (till), rock at 84 ft.	45	96	51
GRAVEL	Very sandy, coarse sand and fine pebbles, predominantly very coarse sand and fine and medium granules; 30% coarse sand to very coarse sand, subangular to rounded, 1/2 quartz, 1/2 shale and limestone, 50% granules, subangular and rounded, limestone and shale, 20% rounded shale pebbles	96	101	5
TILL	As above	101	124	23
SHALE	Nonsilty, poorly to moderately indurated, waxy, dark gray to black, some is very fissile	124	160	36

Figure B.9.2.1. Eastman aquifer lithology.

Location	14506216DDD	Date Drilled	11/14/1991
County	Foster	Land Surface	1503.56
Aquifer	Eastman	Total Depth	180
Purpose	Observation Well	Bedrock Depth	171

Unit	Description	Begin Int	End Int	Thickness
CLAY	Clay, medium yellowish brown, 25%, with silt, sand, & gravel, (oxidized till)	2	4	2
SILT	Medium to dark yellowish brown, argillaceous	4	9	5
CLAY	Clay, dark yellowish brown, 25%, with silt, sand, & gravel, sandy to argillaceous, somewhat rocky, drills slow, rock at 24', (oxidized till)	9	24	15
CLAY	Clay, olive gray, 30%, moderately cohesive, with silt, sand, & gravel, rocks at 33', 35'	24	103	79
SAND	Coarse grained, poorly sorted, some gravel (15%), subangular to subrounded, silicates, carbonates, shale, lignite	103	133	30
SAND & GRAVEL	25% gravel, graded, lithology as 'sand', above, rocks at 144'	133	171	38
CLAY	Olive gray, still, (bedrock - Pierre Formation)	171	180	9

Figure B.9.3.1. Manfred aquifer lithology.

Location	14807213ACD1	Date Drilled	06/28/1988
County	Wells	Land Surface	1617.06
Aquifer	Manfred	Total Depth	210
Purpose	Observation Well - Pluggec	Bedrock Depth	191

Unit	Description	Begin Int	End Int	Thickness
CLAY	yellow to yellow brownish gray, moderately to very soft, weathered and oxidized sand and gravel inclusions, silty, (TILL)	1	4	3
SAND & GRAVEL	poorly sorted, highly oxidized	4	7	3
CLAY	oxidized Till, as above	7	14	7
CLAY	medium gray, moderately firm, unoxidized, sand and gravel inclusions, (TILL)	14	21	7
SAND	fine to coarse, predominantly medium, moderately well sorted, rounded to subangular, mainly rounded to subrounded, 50-60% quartz, 20% carbonates, 10% shale, 10% rock fragments	21	33	12
SILT	sandy silt to clayey silty sand, drilled slightly tighter, cuttings are soft and break apart easily	33	42	9
SAND & GRAVEL	fine to very coarse to 3 mm gravel, moderate sorting, mainly coarse sand, rounded to subangular, same lithology as above sand	42	56	14
SILT	sandy silt to clayey silty very fine sand, drilled slightly tighter, lignitic form 74-84 ft	56	84	28
SAND & GRAVEL	fine to 5 mm gravel, mainly coarse sand, moderate sorting, 50% quartz, 20% carbonates, 20% igneous and metamorphic rock fragments, 10% shale and lignite	84	104	20
SILT	sandy clayey silt to silty clayey to fine sand, drills moderately fast drilling	104	120	16
SAND & GRAVEL	as above, generally medium to coarse sand; 1-2 ft layers of clay 144-159 ft interbedded	120	159	39
SILT	clayey silts to silty very fine sand, smooth texture, moderately tight drilling, (TILL?) (lacustrine)	159	171	12
CLAY	medium gray, moderately firm, sand and gravel inclusions, silty, (TILL)	171	191	20

Figure B.9.4.1. New Rockford aquifer lithology.

Location	14906913BCC	Date Drilled	08/28/1986
County	Wells	Land Surface	1577.9
Aquifer	New Rockford	Total Depth	260
Purpose	Observation Well	Bedrock Depth	244

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	No description	0	2	2
CLAY	Very silty, very sandy (very fine), pebbly, soft, slightly plastic to slightly friable, oxidized, yellow brown mottled with dark yellow orange and reddish brown (till)	2	16	14
CLAY	Very silty, very sandy, pebbly, soft, more plastic, unoxidized, olive gray (till)	16	21	5
SAND	Very fine to coarse predominantly very fine to fine (90%) 10% medium to coarse, subrounded to rounded, 90% quartz, 10% limestone	21	22	1
CLAY	Silty (less than above) slightly sandy, pebbly, slightly firm, plastic to slightly brittle, olive gray (till) rock at 35'	22	35	13
GRAVEL	Coarse pebble, round to subrounded, limestone and shale	35	36	1
TILL	As above	36	136	100
SAND	Gravelly, medium sand to fine pebbles, 80% coarse to very coarse sand, 10% medium sand, 10% gravel angular to rounded, predominantly subrounded to round (90%) 85% quartz, predominantly as sand, 15% shale and limestone pebbles, some chert fragments	136	156	20
CLAY	Gray, plastic	156	158	2
SAND	Slightly gravelly, medium sand to fine pebbles, predominantly coarse sand, angular to rounded, predominantly subrounded to rounded, coarse sand, predominantly quartz with some limestone, gravel, limestone and shale, increasing detrital lignite	158	182	24

Figure B.9.4.2. New Rockford aquifer lithology.

Location	14506104DAD1	Date Drilled	11/04/1970
County	Griggs	Land Surface	1470
Aquifer	New Rockford	Total Depth	166
Purpose	Observation Well - Record	Bedrock Depth	0

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Silty, clayey, moderately sandy, grayish-black	0	1	1
CLAY	Silty, moderately sandy, pebbly, occasional cobbles and boulders, dusky yellow to moderate yellowish-brown, cohesive, slightly plastic, oxidized (till)	1	18	17
CLAY	Silty, moderately sandy, pebbly, occasional cobbles and boulders, olive gray, cohesive, slightly plastic, calcareous (till)	18	40	22
SAND	Interbedded with thin silty clay lenses, very fine – to medium-grained, subangular to rounded, moderately well-sorted, about 60% quartz and feldspar, 30% shale and lignite, 10% carbonates and siliceous rock fragments, taking some water, not caving in	40	82	42
CLAY	Silty, moderately sandy, pebbly, a few cobbles, olive gray, moderately cohesive, plastic, calcareous (till)	82	96	14
SAND	Very fine – to medium-grained, subangular to rounded, moderately well-sorted, mostly quartz, poor samples	96	98	2
CLAY	Very silty, very sandy, pebbly, olive gray, cohesive, plastic, highly calcareous (till)	98	101	3
SAND	Interbedded with a few thin silty clay lenses, very fine – to very coarse-grained (mostly medium-grained, becomes more coarse from 130' to 135'), subangular to rounded, well-sorted, about 70% quartz and feldspar, 15% shale and lignite, 15% carbonates and siliceous rock fragments, small water loss	101	160	59

Figure B.9.4.3. New Rockford aquifer lithology.

Location	15107328CCC	Date Drilled	05/28/1970
County	Pierce	Land Surface	1632
Aquifer	New Rockford	Total Depth	190
Purpose	Observation Well - Pluggec	Bedrock Depth	185

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Brown, silty to sandy	0	1	1
TILL	Dusky yellow to moderate-yellowish-brown, very silty, sandy, oxidized	1	16	15
TILL	Olive-gray, moderately silty	16	32	16
SAND	Very fine to medium, subangular to rounded, silty, well sorted, mostly quartz and detrital lignite	32	49	17
TILL	Olive-gray, silty	49	67	18
GRAVEL	Fine to coarse, angular to subrounded, slightly sandy, poorly sorted, mostly carbonates and detrital shale	67	71	4
TILL	Olive-gray, silty	71	148	77
GRAVEL	Fine to coarse, subrounded, slightly sandy, poorly sorted, about 40 percent carbonates, 30 percent detrital shale, 30 percent granitics, siliceous, rocks, and detrital lignite	148	163	15
TILL	Olive-gray, silty, occasional thin lenses of sand and gravel	163	168	5
GRAVEL	Fine to coarse, angular to subrounded, slightly sandy, some cobbles, fair sorting, about 40 percent carbonates, 30 percent detrital shale, 30 percent granitics, metamorphics, siliceous rocks, and detrital lignite, occasional thin clay lenses	168	181	13
TILL	Olive-gray, silty	181	185	4
SANDSTONE	Medium gray, moderately silty, noncalcareous (Fox Hills Formation)	185	190	5

Figure B.9.5.1. Pipestem Creek aquifer lithology.

Location	14506810BCC	Date Drilled	10/12/1965
County	Wells	Land Surface	1630
Aquifer	Pipestem Creek	Total Depth	52.5
Purpose	Observation Well	Bedrock Depth	30

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Sandy loam, black	0	1	1
GRAVEL	Fine and medium with medium to very coarse sand, subangular and subrounded, moderately well sorted, brown, predominantly limestone and granitic with lots of shale, iron-stained. Drills fast - slightly rough in spots, took some water	1	10	9
SAND	Medium to very coarse with fine and medium gravel, about same as above only greater percentage of finer material	10	30	20
SHALE	Olive gray to olive black, silty, moderately soft to slightly hard and brittle, noncalcareous, Pierre Shale	30	53	23

Figure B.9.6.1. Spiritwood aquifer lithology in Benson County.

Location	15106227DDDA	Date Drilled	09/01/1983
County	Benson	Land Surface	1463.95
Aquifer	Spiritwood	Total Depth	220
Purpose	Observation Well	Bedrock Depth	197

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	dark brown, sandy,	0	1	1
SAND	yellowish brown, fine to medium, oxidized	1	10	9
SAND	gray, fine, to coarse unoxidized	10	12	2
TILL	olive gray, pebbly clay loam, sticky, cohesive, plastic, moderately hard	12	24	12
CLAY	dark gray, slightly silty clay, massive, cohesive plastic, sticky, hard	24	53	29
CLAY	olive gray, sandy, pebbly loam, cohesive, plastic	53	69	16
SAND	gray, slightly silty, fine to medium sand, lignite layers	69	85	16
CLAY	slightly silty, gray, whitish gray bentonitic clay, drills smooth, very hard, looks like bedrock, massive, lake clay?	85	112	27
SAND	gray, silty, very fine to fine sand, abundant lignite layers	112	148	36
SAND & GRAVEL	medium sand to granule gravel, largely coarse sand, moderately well sorted, 60% silicates, rounded, 30% shale and lignite, angular, and 10% carbonates, subrounded	148	184	36
SAND & GRAVEL	very coarse sand to medium gravel, largely fine gravel, moderately well sorted except for large fragments of shale and lignite, 50% silicates, 30% shale and lignite, and 20% carbonates	184	197	13
SHALE	black to dark gray shale, hard, interbedded with dark gray clay and whitish gray bentonitic clay, Pierre Shale, bedrock	197	220	23

Figure B.9.6.2. Spiritwood aquifer lithology in Griggs County.

Location	14806018BBA	Date Drilled	08/25/1971
County	Griggs	Land Surface	1495
Aquifer	Spiritwood	Total Depth	160
Purpose	Observation Well - Destroy	Bedrock Depth	135

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Pebbly silt loam, black	0	1	1
SAND	Fine to coarse, silty, dirty, assorted, subangular and subrounded, heavily iron-stained	1	5	4
SILT	Clayey to sandy, interbedded, yellowish gray to dusky yellow, soft, slightly to moderately cohesive, non to slightly plastic, oxidized	5	22	17
SAND	Fine, yellowish gray, loose, sorted, subrounded, quartzose	22	27	5
SILT	Clayey, olive gray, soft, moderately cohesive, nonplastic	27	42	15
SAND	Medium, varies slightly from fine to coarse, well-sorted and uniform, subrounded, loose, clean, mostly quartz	42	58	16
SILT	As above, soft	58	66	8
CLAY	Very silty and sandy with coarse sand grains and pebbles, olive gray, moderately soft, cohesive, moderately stiff (till)	66	80	14
SAND	Medium to coarse, well-sorted and uniform, clean, generally subrounded, mostly granitics and carbonates, nice	80	108	28
SAND	As above, interbedded with silt and clay	108	135	27
SHALE	Silty, medium dark gray to black, hard, very tight, brittle, bentonitic	135	160	25

Figure B.9.6.3. Spiritwood aquifer lithology in Griggs County.

Location	15406517AAA	Date Drilled	08/12/1974
County	Ramsey	Land Surface	1467.78
Aquifer	Spiritwood	Total Depth	160
Purpose	Observation Well	Bedrock Depth	139

Unit	Description	Begin Int	End Int	Thickness
CLAY	Silty, sandy, pebbly, dark yellowish orange, oxidized (till)	0	5	5
CLAY	Silty, sandy, pebbly, dark yellowish brown, oxidized (till)	5	18	13
CLAY	Silty, sandy, pebbly, dark gray; contains numerous sand and gravel lenses (till)	18	30	12
CLAY	Silty, sandy, pebbly, medium dark gray; contains numerous sand and gravel lenses (till)	30	48	18
CLAY	Silty, very sandy, pebbly, dark gray (till)	53	83	30
CLAY	Very silty, sandy, pebbly, dark gray (till)	83	93	10
SAND	Very fine to coarse, medium dark gray	93	120	27
GRAVEL	Fine to medium, and very coarse sand	120	139	19
SHALE	Dark gray, hard, brittle (Pierre Formation)	139	160	21

Figure B.9.7.1. Tokio aquifer lithology.

Location	15106406CCC2	Date Drilled	11/04/1986
County	Benson	Land Surface	1583.5
Aquifer	Tokio	Total Depth	80
Purpose	Observation Well	Bedrock Depth	0

Unit	Description	Begin Int	End Int	Thickness
GRAVEL	sandy, unoxidized,	0	0	0
GRAVEL	sandy, oxidized, 70 % shale, well rounded to subrounded, rocky	1	4	3
CLAY	yellowish brown to gray, oxidized	4	7	3
GRAVEL	as above, oxidized	7	53	46
CLAY	olive gray, silty, sandy with pebbles, till	53	56	3

Figure B.9.8.1.Warwick aquifer lithology.

Location	15006204BBA	Date Drilled	07/22/1977
County	Eddy	Land Surface	1471.23
Aquifer	Warwick	Total Depth	70
Purpose	Observation Well	Bedrock Depth	0

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	SILTY BLACK	0	0.5	0.5
SAND	FINE, MEDIUM TO COARSE	0.5	21	20.5
SAND	FINE, MEDIUM TO COARSE 10% GRAVEL	21	37	16
SAND	FINE MEDIUM TO COARSE 35% GRAVEL LOTS OF SHALE GRAVEL	37	56	19
CLAY	SANDY, SILTY,OLIVE GRAY	56	70	14

Figure B.9.8.2.Warwick aquifer lithology.

Location	15106336CCC	Date Drilled	01/01/1968
County	Benson	Land Surface	1468
Aquifer	Warwick	Total Depth	82
Purpose	Observation Well	Bedrock Depth	0

Unit	Description	Begin Int	End Int	Thickness
SAND	Fine to medium, uniformly sorted	0	28	28
SAND	Fine to medium; predominantly quartz; uniformly sorted; silty to clayey in places	28	81	53
TILL	Olive gray, sandy	81	82	1

Figure B.10.2.1.McVille aquifer lithology.

Location	14705827BBB	Date Drilled	11/10/1970
County	Griggs	Land Surface	1325
Aquifer	McVille	Total Depth	120
Purpose	Observation Well	Bedrock Depth	81

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Very sandy, silty, brownish-black	0	1	1
SAND	Silty, slightly clayey, fine to coarse grained, subangular to rounded, moderately well-sorted, mostly quartz and carbonates, well oxidized	1	9	8
CLAY	Very silty, sandy, moderate yellowish-brown to dark yellowish-brown, slightly cohesive, moderately plastic, oxidized (Alluvium)	9	23	14
SAND	Slightly gravelly, fine to very coarse grained, subangular to rounded, well sorted, about 60% quartz and feldspar, 20% shale and 20% siliceous rocks, taking some water, appears slightly oxidized, mixed 1 bag bentonite	23	50	27
GRAVEL	Moderately sandy, fine to coarse, angular to well rounded, about 70% shale, 15% carbonates and 15% siliceous rock, taking some water, not caving in	50	69	19
CLAY	Very silty, sandy, a few thin sand lenses, medium dark gray, slightly cohesive, plastic, highly calcareous (Glacio-Fluvial Sediment)	69	78	9
GRAVEL	Sandy, boulders, cobbles, rough drilling, poorly sorted	78	81	3
SHALE	Moderately clayey, medium light gray, numerous small white specks and rod-like brownish concretions, well indurated, highly calcareous, bedded, (Niobrara Formation)	81	120	39

Figure B.11.3.1. Central Dakota aquifer in Stutsman County.

02/23/2010

Location	14106809BBB1	Date Drilled	07/12/2007
County	Stutsman	Land Surface	1878.19
Aquifer	Central Dakota	Total Depth	460
Purpose	Observation Well	Bedrock Depth	402

Unit	Description	Begin Int	End Int	Thickness
SAND	Medium to coarse, trace fine to coarse gravel, subrounded to rounded, diverse petrology	0	11	11
CLAY	Soft, dark yellowish brown (10YR 4/2) from 11-12 ft, olive gray (5Y 4/1) from 12 -29 ft, high plasticity, trace fine sand to fine gravel (mostly carbonates) -- oxidized till	11	29	18
SAND & GRAVEL	Medium sand to fine gravel, rounded to well rounded, diverse petrology	29	34	5
CLAY	Soft, olive gray (5Y 4/1), high plasticity, trace fine sand to fine gravel (mostly carbonates) -- reduced till	34	40	6
SAND & GRAVEL	Medium sand to fine gravel, rounded to well rounded, diverse petrology	40	44	4
CLAY	Medium stiff from 44-60 ft, soft from 60-103 ft, olive gray (5Y 4/1), high plasticity, trace fine sand to fine gravel (mostly carbonates), rocks from 98-101 ft -- till	44	103	59
SAND	Medium to coarse, subangular to rounded, little fine gravel, predominantly shale and lignite; clay from 121-122 ft	103	142	39
SILT	Medium stiff, dark gray (5YR 4/1) to olive gray (5Y 4/1), low plasticity, little fine to medium sand (mostly carbonates and shale) -- till	142	169	27
CLAY	Soft, olive gray (5Y 4/1), medium to high plasticity	169	184	15
CLAY	Soft, olive gray (5Y 4/1), medium to high plasticity, little to few fine to medium sand -- till	184	193	9
SAND	Medium; subangular to rounded; mostly shale, lignite, and carbonates; trace coarse sand to fine gravel from 193-200 ft; clay lens from 200-202 ft; little to few coarse sand to fine gravel from 202-222 ft	193	222	29
CLAY	Soft, 5Y 3/2, high plasticity, few fine to medium sand (mostly shale) -- till; loose, medium sand to coarse gravel from 225-229 ft; rocks from 245-246 ft	222	247	25

Figure B.11.3.2. Central Dakota aquifer in Kidder County.

02/23/2010

Location	14207333AAA	Date Drilled	08/17/1999
County	Kidder	Land Surface	1784
Aquifer	No Obs Well Installed	Total Depth	180
Purpose	Test Hole	Bedrock Depth	161

Unit	Description	Begin Int	End Int	Thickness
SAND	Fine to Medium, Brown	0	12	12
SAND	Fine to Medium, Gray	12	40	28
CLAY	Silty, Medium Dark Gray	40	51	11
CLAY	Silty, Sandy, Olive Gray	51	54	3
SAND	Fine to Coarse, Gray	54	62	8
CLAY	Silty, Sandy, Olive Gray	62	133	71
CLAY	Sandy, Gray, Shale Fragments, Rocks at 160-161 ft	133	161	28
SILTSTONE	Soft, Dark Gray- Bedrock	161	180	19

Figure B.11.3.3. Central Dakota aquifer in Kidder County.

02/23/2010

Location	14307016BBB1	Date Drilled	10/17/2007
County	Kidder	Land Surface	1889.47
Aquifer	Central Dakota	Total Depth	317
Purpose	Observation Well	Bedrock Depth	307

Unit	Description	Begin Int	End Int	Thickness
CLAY	Soft, light olive gray (5Y 5/2) to moderate olive brown (5Y 4/4), medium plasticity, trace fine to coarse sand (mostly carbonates and shale); reddish brown, orange, and gray mottles. Oxidized till	1	15	14
CLAY	Medium stiff to stiff, olive gray (5Y 3/2), high plasticity, trace fine sand to fine gravel (shale and carbonates). Reduced till	15	102	87
SAND & GRAVEL	Clean, fine sand to coarse gravel, subrounded to rounded, mostly carbonates and shale.	102	114	12
CLAY	Soft, olive gray (5Y 3/2), medium plasticity, few fine sand to fine gravel (mostly carbonates and shale). Till	114	122	8
SAND & GRAVEL	Clean, fine sand to coarse gravel, subrounded to rounded, mostly carbonates and shale. Till from 133-134 ft.	122	138	16
INTERBEDDED	Clean, fine sand to coarse gravel, subrounded to rounded, mostly carbonates and shale; and soft, olive gray (5Y 3/2), medium plasticity clay with few fine sand to fine gravel. Unit is approximately 50% sand and gravel and 50% clayey till.	138	180	42
SAND & GRAVEL	Clean, fine sand to coarse gravel, subrounded to rounded, mostly carbonates and shale.	180	203	23
GRAVEL	Clean, fine to coarse gravel, subrounded to rounded, some medium to coarse sand, mostly cobbles/boulders from 232-236 ft.	203	236	33
CLAY	Medium stiff, olive gray (5Y 3/2), high plasticity, little fine to coarse sand (shale and carbonates). Till	236	272	36
CLAY	Medium stiff, olive gray (5Y 4/1), high plasticity, massive.	272	307	35

Figure B.11.3.4. Central Dakota aquifer in Stutsman County.

Location	13807725DDD	Date Drilled	07/26/1978
County	Burleigh	Land Surface	1714.2
Aquifer	Long Lake	Total Depth	20
Purpose	Observation Well - Pluggec	Bedrock Depth	172

Unit	Description	Begin Int	End Int	Thickness
SAND	Very fine to fine, well sorted, light brown, in part pale grayish white, moderately clayey and with some light brown and pale gray clay layers	0	8	8
CLAY	Medium olive brown and medium gray somewhat variegated, slightly to moderately silty, moderately soft, cohesive, slightly to moderately sticky, tight, some iron oxide mottles 8' to 12' Oxidized Lacustrine	8	16	8
CLAY	Medium gray slightly olive and light olive gray, slightly to moderately silty, slighty sandy with very fine to fine sand, moderately soft, cohesive, slightly to moderately sticky moderately tight, slightly lignitic with small fragments, contains some very thin layers of fine to coarse sand, contains some layers of soft, cohesive, moderately to very sticky, moderately tight medium to very clayey silt, occasional fine to medium gravel 95' to 98', 147' to 148' Lacustrine	16	155	139
SAND & GRAVEL	Very fine sand to medium gravel, mostly fine sand to very coarse sand, 5% gravel, poorly sorted, subangular to rounded, mostly subangular, contains silty clay layers 152' to 163', quartz, much shale and limestone, some igneous, occasional meta fragments, rock at 170'	155	172	17
SAND	Very fine to fine, well sorted, medium bluish gray, slightly silty, slightly to moderately indurated, moderate to very friable, contains some layers of light brownish gray, moderately indurated and friable clay and silt Bedrock	172	200	28

Figure B.12.1.1. Elm Creek aquifer lithology.

Location	13508416AAA1	Date Drilled	06/06/1974
County	Morton	Land Surface	1893
Aquifer	Elm Creek	Total Depth	360
Purpose	Observation Well - Destroy	Bedrock Depth	333

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	no description	0	1	1
SAND	dirty, oxidized	1	6	5
SILT	with very fine sand, moderately yellowish brown, dark yellowish and very pale orange, variegated, highly calcareous, oxidized	6	20	14
SAND	mostly medium, 15-18 slot, predominantly quartz, subangular to rounded, very nice, abundant lignite	20	100	80
SILT	olive gray, clayey, cohesive, slightly calcareous	100	114	14
SAND	fine to medium, 10-15 slot, predominantly quartz, subangular, good, abundant lignite	114	126	12
SILT	sandy, olive gray, fairly solid with sandy streaks	126	134	8
SILT	clayey, olive gray, cohesive	134	160	26
SILT	sandy, olive gray with sandy zones to sand streaks	160	200	40
GRAVEL	granule, sandy to clayey, dirty?, angular to subangular, shale, limestone, quartz, etc. and abundant lignite	200	240	40
SILT	sandy as above	240	260	20
SAND	fine to coarse, 15-18 slot, pred. quartz, shale, shell fragments, subrounded, lignite lenses	260	316	56
SILT	olive gray, cohesive	316	333	17
SILTSTONE	olive gray, solid, non-calcareous, sandstone, medium bluish gray to olive gray, variegated, thin bedded, sandstone and shale	333	360	27

Figure B.12.2.1. Little Heart aquifer lithology.

Location	13508033DDA	Date Drilled	09/12/1973
County	Morton	Land Surface	0
Aquifer	Little Heart	Total Depth	200
Purpose	Observation Well - Destroy	Bedrock Depth	177

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Clayey, fine sand loam, dark brown	0	2	2
SAND	Very fine and fine, silty and clayey, dusky yellow, yellowish gray and moderate olive brown, soft, loose to slightly cohesive, lenticular, dry, oxidized	2	10	8
SAND	Medium to very coarse with fine gravel, rusty brown, loose, sorted but lenticular, subrounded with subangular, iron stained, oxidized	10	21	11
SILT	Including sandy clay, light olive gray with dark laminations, soft, slightly to moderately cohesive, lenticular	21	32	11
GRAVEL	Fine with coarse sand, well sorted, loose, subrounded	32	39	7
SILT	Clayey to sandy (very fine to medium), predominantly olive gray but laminated, soft and slightly to moderately cohesive, layers of moderately soft plastic clay and lenses of loose non-cohesive sand, soft	39	84	45
CLAY	Dark olive gray, moderately soft, cohesive, plastic, sticky, smooth, tight	84	94	10
SILT	Light olive gray, soft, crumbly	94	116	22
CLAY	Including silt, as above, interbedded	116	141	25
SAND	Very fine to very coarse, thinly interbedded with silt and clay layers, highly lenticular	141	164	23
GRAVEL	Sandy, poorly sorted and lenticular	164	177	13
SHALE	Silty to slightly sandy, medium gray to dark bluish gray with green and brown, thinly interbedded, chunky and slightly crumbly to hard fissile and brittle, tight carbonaceous, Fox Hills Formation	177	184	7
SANDSTONE	Very fine and clayey to loose and fine to medium, more clayey sandy chunky friable and light greenish gray, loose, dark green with black biotite flakes interspersed, semi-consolidated, thin concretions or sandstone layers	184	200	16

Figure B.12.3.1. Shields aquifer lithology.

Location	13308328DCD	Date Drilled	11/13/1971
County	Grant	Land Surface	1872
Aquifer	Shields	Total Depth	240
Purpose	Observation Well	Bedrock Depth	196

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Fine sandy loam, dark brown	0	2	2
CLAY	Dark brown, soft, moderately cohesive, slightly plastic, sticky, organic rich	2	8	6
CLAY	Silty, light olive gray, smooth, moderately soft, cohesive, stiff	8	18	10
SILT	Clayey, dusky yellow, soft, cohesive, slightly plastic, oxidized	18	23	5
CLAY	Silty, yellowish gray, moderately soft, smooth, cohesive, stiff, slippery	23	32	9
SILT	As above, dusky yellow, soft	32	36	4
CLAY	Silty, light olive gray, moderately soft, cohesive, smooth, moderately soft, cohesive, smooth, moderately stiff, tight	36	45	9
SAND	Very fine and fine, light olive gray, loose, sorted, subrounded	45	51	6
CLAY	Light olive to olive gray, very silty, soft, moderately cohesive	51	57	6
SAND	Very fine to very coarse with a large amount of detrital lignite, loose, used water	57	86	29
CLAY	Silty, light olive and olive gray, soft, smooth, cohesive and plastic to moderately soft and stiff, thinly interbedded with silt and very fine to fine sand	86	157	71
SAND	Fine and medium, light olive gray, well sorted and uniform, subangular and subrounded, used water	157	180	23
CLAY	Dark gray, moderately soft to slightly hard, cohesive, smooth, very tight	180	190	10
SAND	Fine with medium, dark green, loose, subangular, well sorted and uniform, bedrock	190	196	6

Figure B.13.1.1. Lithology of Beaver Creek aquifer.

Location	13007302CCC	Date Drilled	08/10/1976
County	Mcintosh	Land Surface	2030
Aquifer	No Obs Well Installed	Total Depth	140
Purpose	Test Hole	Bedrock Depth	117

Unit	Description	Begin Int	End Int	Thickness
SAND	Gravel (25% gravel); very fine sand to medium pebble; predominantly coarse sand; 50% quartz, 40% limestone, 10% shale; moderately sorted	1	19	18
CLAY	Slightly silty, slightly sandy, pebbly; olive-gray	19	65	46
CLAY	Brownish gray	65	85	20
SILT	Clayey, slightly sandy (very fine); brownish gray	85	109	24
GRAVEL	Sandy (60% gravel); medium sand to medium pebble; predominantly very fine pebble; 50% limestone, 40% quartz, 10% shale; poorly sorted	109	117	8
CLAY	Brittle; grayish black (Pierre Formation)	117	140	23

Figure B.13.1.2. Lithology of Beaver Creek aquifer.

Location	13007327AAA	Date Drilled	08/06/1976
County	McIntosh	Land Surface	2007
Aquifer	Undefined	Total Depth	160
Purpose	Observation Well - Pluggec	Bedrock Depth	132

Unit	Description	Begin Int	End Int	Thickness
CLAY	Silty, sandy, slightly pebbly; dark yellowish brown	1	45	44
CLAY	Slightly silty, slightly sandy, pebbly; grayish brown	45	53	8
CLAY	Slightly silty, slightly sandy; pebbly; olive-gray	53	98	45
CLAY	Sandy; very fine to fine	98	109	11
SAND	Gravelly (15% gravel); very fine sand to medium pebble; predominantly coarse sand, 80% quartz, 15% limestone, 5% shale; well-sorted; predominantly subrounded	109	132	23
CLAY	Sandy (very fine to fine); dusky yellow (Fox Hills Formation?)	132	136	4
CLAY	Sandy (very fine to fine); greenish gray (Fox Hills Formation?)	136	142	6
CLAY	Silty; brittle; grayish black (Pierre Formation)	142	154	12
CLAY	Brittle; grayish black (Pierre Formation)	154	160	6

Figure B.13.3.1. Hillsburg aquifer lithology.

Location	13406903DDD1	Date Drilled	07/16/1979
County	Logan	Land Surface	1900
Aquifer	Hillsburg	Total Depth	212
Purpose	Observation Well	Bedrock Depth	173

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Black	0	1	1
CLAY	(Till), silty, sandy, pebbly, yellowish brown	1	10	9
CLAY	(Till), silty, sandy, pebbly, olive-gray	10	15	5
GRAVEL	Fine to medium, predominantly fine, sandy, angular to well-rounded	15	19	4
CLAY	(Till), very silty, very sandy, pebbly, olive-gray	19	46	27
SAND	Very fine to very coarse, predominantly very fine to fine, gravelly; 80 percent quartz, 10 percent shale, and 10 percent carbonate grains	46	61	15
CLAY	(Till), very sandy, very silty, pebbly, olive-gray	61	158	97
SAND	Very fine to very coarse, predominantly medium to coarse, gravelly, angular to well-rounded; composed largely of quartz and carbonate grains	158	169	11
CLAY	(Till), silty, sandy, pebbly, olive-gray	169	180	11
SHALE	Slightly silty and sandy, black, brittle (Pierre Shale)	180	212	32

Figure B.13.3.2. Hillsburg aquifer lithology.

Location	13406934CCC1	Date Drilled	05/30/1979
County	Logan	Land Surface	1961
Aquifer	No Obs Well Installed	Total Depth	242
Purpose	Test Hole	Bedrock Depth	185

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Black	0	1	1
CLAY	(Till), silty, sandy, pebbly, yellowish brown	1	17	16
CLAY	(Till), silty, sandy, pebbly, olive-gray	17	33	16
GRAVEL	Very fine to medium, predominantly fine, sandy	33	46	13
CLAY	(Till), very sandy, pebbly, olive-gray; few sand lenses	46	72	26
GRAVEL	Fine, well-rounded; composed largely of carbonate pebbles; clay lens from 82 to 86 ft.	72	100	28
CLAY	(Till), very sandy, pebbly, olive-gray	100	151	51
CLAY	(Till), sandy, black; abundant shale pebbles	151	184	33
SHALE	Black, hard; bentonitic streaks [Pierre Shale(?)]	184	242	58

Figure B.13.4.1. McIntosh aquifer lithology.

Location	13206802DDD2	Date Drilled	09/08/1976
County	McIntosh	Land Surface	2102
Aquifer	McIntosh	Total Depth	40
Purpose	Observation Well - Pluggec	Bedrock Depth	0

Unit	Description	Begin Int	End Int	Thickness
CLAY	Silty, sandy, pebbly; moderate yellowish brown	1	13	12
CLAY	Silty, sandy; moderate yellowish brown	13	16	3
CLAY	Silty; olive-gray	16	19	3
SAND	Gravelly (20% gravel), very fine sand to fine pebble, predominantly medium sand, 70% quartz, 5% igneous rock fragments, 15% limestone, 10% shale, moderately sorted	19	35	16
CLAY	Sandy (predominantly very fine to fine); olive-gray	35	40	5

Figure B.13.4.2. McIntosh aquifer lithology.

Location	13206901BBB	Date Drilled	09/21/1977
County	McIntosh	Land Surface	2086
Aquifer	McIntosh	Total Depth	182
Purpose	Observation Well	Bedrock Depth	154

Unit	Description	Begin Int	End Int	Thickness
CLAY	Sandy, silty, pebbly (very gravelly top few feet), moderate yellowish brown, moderate tight to tight, cohesive, very slightly plastic, oxidized (till)	0	30	30
CLAY	As that above, medium dark gray to olive-gray, tight (till)	30	85	55
SAND AND GRAVEL	Sand (65%), gravel (35%); sand, fine to very coarse, predominantly coarse, subangular to rounded, predominantly quartz and carbonate; gravel, fine to medium, angular to subrounded, 50% carbonate, 40% shale, 10% quartz and granitics, moderately well-sorted	85	109	24
CLAY	Sandy, silty, pebbly, moderate yellowish brown, very tight, brittle, oxidized (till)	109	154	45
CLAY	Shale, black to grayish black, tight, hard, brittle, non-calcareous (Pierre Formation)	154	182	28

Figure B.13.5.1. Napoleon aquifer lithology.

Location	13507216BBB	Date Drilled	11/14/1978
County	Logan	Land Surface	1990
Aquifer	Napoleon	Total Depth	0
Purpose	Observation Well - Destroy	Bedrock Depth	0

Unit	Description	Begin Int	End Int	Thickness
SAND	Fine to very coarse, predominantly medium, oxidized; 90 percent quartz, 5 percent limestone, and 5 percent igneous and shale grains	0	24	24
SILT	Clayey, olive-gray	24	33	9
SAND	Fine to medium, predominantly medium, gravelly; 90 percent quartz, 5 percent limestone, and 5 percent igneous sand shale grains	33	46	13
SILT	Clayey, olive-gray	46	54	8
SAND	Fine to medium, predominantly medium, gravelly; 90 percent quartz, 5 percent limestone, and 5 percent igneous and shale grains	54	73	19
SILTSTONE	Sandy, yellowish brown; some organic material (Fox Hills Sandstone)	73	78	5
SANDSTONE	Very fine, silty, clayey, medium gray (Fox Hills Sandstone)	78	84	6
CLAYSTONE	Silty, sandy, medium gray; few siltstone interbeds (Fox Hills Sandstone)	84	122	38

Figure B.13.5.2. Napoleon aquifer lithology.

Location	13507309ABB	Date Drilled	11/07/1978
County	Logan	Land Surface	1936.23
Aquifer	Napoleon	Total Depth	142
Purpose	Observation Well	Bedrock Depth	16

Unit	Description	Begin Int	End Int	Thickness
GRAVEL	Fine to coarse, predominantly medium, sandy; 40 percent limestone, 25 percent igneous and quartz, 20 percent shale, 10 percent sandstone, and 5 percent silicate pebbles	0	22	22
SILTSTONE	Sandy (Fox Hills Sandstone)	22	30	8
SANDSTONE	Fine to medium, silty, clayey, grayish blue-green to dusky blue-green, glauconitic, micaceous; cemented zone from 65 to 68 ft.; interbedded with siltstone from 102 to 114 ft. (Fox Hills Sandstone)	30	114	84
CLAYSTONE	Silty, sandy, dark gray, glauconitic (Fox Hills Sandstone)	114	142	28

Figure B.13.5.3. Napoleon aquifer lithology.

Location	13607326CBB1	Date Drilled	06/13/1979
County	Logan	Land Surface	1940.68
Aquifer	Napoleon	Total Depth	197
Purpose	Observation Well	Bedrock Depth	175

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Black	0	1	1
CLAY	(Till), silty, sandy, pebbly, yellowish brown	1	20	19
CLAY	(Till), silty, sandy, pebbly, olive-gray	20	40	20
CLAY	(Lacustrine), olive-gray	40	50	10
CLAY	(Lacustrine), very silty	50	74	24
GRAVEL	Fine, sandy, well-rounded to subangular; composed of 60 percent shale, 20 percent silicate, and 20 percent carbonate pebbles	74	104	30
CLAY	(Till), silty, slightly sandy, olive-gray	104	133	29
CLAY	(Till), silty, sandy, pebbly, olive-gray	133	142	9
GRAVEL	Fine to coarse, predominantly fine to medium, sandy; 65 percent carbonate, 25 percent shale, and 10 percent silicate pebbles	142	175	33
SANDSTONE	Very fine to fine, slightly clayey, dusky blue-green; some glauconite and carbonaceous material (Fox Hills Sandstone)	175	197	22

Figure B.13.5.4. Napoleon aquifer lithology.

Location	13607335DDD1	Date Drilled	11/08/1978
County	Logan	Land Surface	1970
Aquifer	Napoleon	Total Depth	282
Purpose	Observation Well - Pluggec	Bedrock Depth	236

Unit	Description	Begin Int	End Int	Thickness
GRAVEL	Fine to medium, and coarse to very coarse sand; oxidized; composed largely of limestone and quartz	0	8	8
CLAY	Silty, moderately yellowish brown; very fine sand laminae	8	19	11
CLAY	Silty, olive-gray; very fine sand laminae	19	58	39
SILT	(Till), clayey, sandy, olive-gray	58	73	15
SAND	Fine to very coarse; 50 percent limestone, 30 percent shale, and 20 percent igneous and quartz grains	73	130	57
CLAY	(Till), sandy, dark gray to olive-gray; few sand and gravel lenses	130	151	21
SAND	Fine to very coarse, predominantly medium to coarse, gravelly; few clay lenses	151	178	27
SANDSTONE	Fine to medium, silty, grayish blue-green to medium bluish gray, glauconitic; some mica and organic material (Fox Hills Sandstone)	178	195	17
SANDSTONE	Fine to medium, silty, glauconitic; abundant organic material (Fox Hills Sandstone)	195	208	13
CLAYSTONE	Silty, dark gray to grayish black, siliceous (Fox Hills Sandstone)	208	232	24
SHALE	Grayish black, slightly siliceous; trace of glauconite at top (Fox Hills Sandstone)	232	282	50

Figure B.13.6.1. Spring Creek aquifer lithology.

Location	12906809CCB1	Date Drilled	08/25/1977
County	McIntosh	Land Surface	1970
Aquifer	Spring Creek	Total Depth	262
Purpose	Observation Well - Destroy	Bedrock Depth	247

Unit	Description	Begin Int	End Int	Thickness
CLAY	Silty, sandy, (gravelly near surface), moderate yellowish brown, soft, sticky, oxidized (lacustrine)	0	21	21
CLAY	Sandy, silty, pebbly, slightly gravelly, tight, cohesive, very slightly plastic, moderate yellowish brown, oxidized (till)	21	30	9
CLAY	As that above, medium dark gray to olive-gray, tight (till)	30	44	14
SAND	Fine to very coarse, predominantly coarse, subangular to rounded, well-sorted, predominantly quartz and carbonates with abundant shale, some fine gravel	44	70	26
CLAY	Sandy, silty, pebbly, slightly gravelly, medium dark gray to olive-gray, tight, cohesive, very slightly plastic (till)	70	115	45
CLAY	Silty, sandy, medium dark gray, moderately tight, sticky, cohesive, slightly plastic (lacustrine)	115	140	25
CLAY	As that above, pebbly, very tight (till)	140	184	44
SAND	Very fine to medium, rounded, well-sorted, very silty, "dirty", predominantly quartz, with carbonate and shale	184	205	21
CLAY	Sandy, silty, pebbly, dark gray to olive-gray, tight, cohesive, brittle (till)	205	224	19
SAND AND GRAVEL	Sand (70%), gravel (30%); sand, fine to very coarse, predominantly coarse, subangular to rounded, predominantly quartz, carbonate and shale; gravel fine to medium, subangular to subrounded, predominantly carbonate and shale with quartz and granitics	224	247	23
CLAY	Shale, black to grayish black, tight, hard, brittle, non-calcareous (Pierre Formation)	247	262	15

Figure B.13.6.2. Spring Creek aquifer lithology.

Location	12906728BCB1	Date Drilled	06/29/1978
County	McIntosh	Land Surface	1973.5
Aquifer	Spring Creek	Total Depth	0
Purpose	Observation Well - Pluggec	Bedrock Depth	0

Unit	Description	Begin Int	End Int	Thickness
CLAY	Silty, sandy, pebbly; light olive clay, poorly compact and somewhat plastic, oxidized (till)	0	2	2
GRAVEL	Sandy, clayey; fine to medium gravel, fine to coarse sand; 40% fine gravel, 10-20% medium gravel; clay 10-15%; poorly sorted; subrounded to rounded; predominantly carbonate (40%), shale (30%), igneous and metamorphic (25%), oxidized	2	9	7
CLAY	Silty, sandy, pebbly; light olive clay, moderately compact and plastic; moderately sandy and silty; slightly pebbly; oxidized (till)	9	16	7
CLAY	(As above); dark grey, unoxidized, moderately compact and plastic clay; slightly pebbly, gravel lens at 117-118 ft. (till)	16	128	112
GRAVEL	(Sandy, clayey, silty); fine to coarse gravel, very fine to very coarse sand; slightly silty; predominantly (50-60%) fine gravel; 10-20% sand; 10-20% clay/ poorly sorted; predominantly carbonate (30-40%), shale (30%), igneous and metamorphic (20%); subrounded to rounded; intermittent or interbedded clay lenses	128	160	32
CLAY	Dark grey, very compact clay; very cohesive; not plastic but nearly brittle (Pierre Formation)	160	180	20

Figure B.13.6.3. Spring Creek aquifer lithology.

Location	13006909DAD	Date Drilled	09/23/1976
County	McIntosh	Land Surface	2012
Aquifer	Spring Creek	Total Depth	260
Purpose	Observation Well - Pluggec	Bedrock Depth	249

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Black; silty	0	1	1
SAND	Fine to very coarse and, gravelly, clay lenses	1	5	4
SAND	Fine to very coarse: gravelly (40%)	5	7	2
CLAY	Silt lenses; yellowish brown to medium gray	7	10	3
CLAY	Sandy: bluish gray	10	20	10
CLAY	Silty; medium gray	20	42	22
CLAY	Sandy; medium gray	42	53	11
SAND	Fine	53	59	6
CLAY	Slightly silty; olive-gray	59	64	5
SAND	Gravelly (15% gravel); very fine sand to fine pebble, predominantly medium sand	64	83	19
CLAY	Silty, slightly sandy, slightly pebbly, dusky brown	83	103	20
CLAY	Silty; olive-gray	103	120	17
CLAY	Silty, sandy, pebbly; olive-gray	120	181	61
GRAVEL	Sandy (60% gravel), medium sand to medium pebble; predominantly very fine pebbly; 35% limestone, 30% igneous rock fragments and metamorphic rock fragments, 15% shale, 20% quartz; poorly sorted	181	222	41
CLAY	Sandy; olive-gray	222	249	27
CLAY	Brittle; grayish black (Pierre Formation)	249	260	11

Figure B.13.6.4. Spring Creek aquifer lithology.

Location	13006930DDD	Date Drilled	07/28/1976
County	McIntosh	Land Surface	2014
Aquifer	Spring Creek	Total Depth	220
Purpose	Observation Well - Pluggec	Bedrock Depth	199

Unit	Description	Begin Int	End Int	Thickness
SAND	Very fine to coarse; predominantly fine sand	1	7	6
CLAY	Slightly silty; moderate yellow brown	7	32	25
CLAY	Slightly silty; olive-gray	32	35	3
CLAY	Slightly silty; moderate yellowish brown	35	46	11
CLAY	Slightly silty; olive-gray	46	50	4
CLAY	Slightly silty, slightly sandy, slightly pebbly; olive-gray to grayish brown (boulder at 61 ft.)	50	132	82
GRAVEL	Coarse sand to coarse pebble; predominantly fine pebble	132	136	4
CLAY	Slightly silty, slightly sandy, pebbly; dusky brown	136	177	41
GRAVEL	Sandy (50% gravel); fine sand to medium pebble; predominantly very fine pebble, 30% limestone, 30% quartz, 20% igneous rock fragments, 20% shale, poorly sorted	177	199	22
CLAY	Grayish black; fissile; brittle (Pierre Formation)	199	220	21

Figure B.13.7.1. Wishek aquifer lithology.

Location	13207017CCC2	Date Drilled	08/26/1976
County	McIntosh	Land Surface	2069.38
Aquifer	Wishek	Total Depth	80
Purpose	Observation Well	Bedrock Depth	0

Unit	Description	Begin Int	End Int	Thickness
CLAY	Slightly silty, slightly sandy, pebbly; moderate yellowish brown	1	12	11
CLAY	Slightly silty, slightly sandy, pebbly; olive-gray	12	26	14
GRAVEL	Sandy (35% gravel), very fine sand to coarse pebble, predominantly very coarse sand, 25% shale, 40% quartz, 25% limestone, 10% igneous rock fragments, poorly sorted, contains layers of clay 30-37 ft., 40-44 ft.	26	67	41
CLAY	Silty; brownish gray	67	75	8
GRAVEL	Sandy	75	78	3
CLAY	Silty; brownish gray	78	80	2

Figure B.13.7.2. Wishek aquifer lithology.

Location	13207114BBC1	Date Drilled	08/12/1976
County	McIntosh	Land Surface	2040.71
Aquifer	Wishek	Total Depth	120
Purpose	Observation Well - Pluggec	Bedrock Depth	108

Unit	Description	Begin Int	End Int	Thickness
GRAVEL	Sandy (55% gravel), fine sand to coarse pebble, predominantly very fine pebble, 40% quartz, 30% limestone, 20% shale, 10% igneous rock fragments, poorly sorted	1	37	36
CLAY	Plastic; brownish gray	37	56	19
CLAY	Slightly sandy (very fine to fine); grayish brown	56	63	7
CLAY	Dense; grayish brown	63	91	28
GRAVEL	Sandy (45% gravel), fine sand to coarse pebble, predominantly very coarse sand, 30% shale, 30% limestone, 20% quartz, 10% igneous rock fragments, poorly sorted	91	108	17
CLAY	Brittle; dark brownish gray (Pierre Formation)	108	120	12

Figure B.13.8.1. Zeeland aquifer lithology.

Location	12907234DAA	Date Drilled	08/18/1977
County	McIntosh	Land Surface	1997
Aquifer	Zeeland	Total Depth	122
Purpose	Observation Well	Bedrock Depth	98

Unit	Description	Begin Int	End Int	Thickness
CLAY	Sandy, silty, pebbly, slightly gravelly, moderate yellowish brown, moderately tight to tight, cohesive, very slightly plastic, oxidized (till)	0	42	42
CLAY	As that above, olive-gray, tight (till)	42	51	9
SAND	Very fine to very coarse, predominantly medium, subrounded, fairly well-sorted, predominantly quartz, with some carbonate and shale, looked somewhat oxidized	51	98	47
CLAY	Siltstone, shale, dark gray to grayish black, tight, hard, brittle (Pierre Formation)	98	122	24

Figure B.13.8.2. Zeeland aquifer lithology.

Location	12907230BBA	Date Drilled	08/18/1976
County	McIntosh	Land Surface	1965
Aquifer	Zeeland	Total Depth	140
Purpose	Observation Well - Pluggec	Bedrock Depth	122

Unit	Description	Begin Int	End Int	Thickness
GRAVEL	Sandy, clayey	1	3	2
CLAY	Slightly silty, slightly sandy, pebbly; moderate yellowish brown (till)	3	13	10
CLAY	Slightly silty, slightly sandy, pebbly; dark yellowish brown (till)	13	22	9
CLAY	Slightly silty, slightly sandy, pebbly; olive-gray (till)	22	63	41
GRAVEL	Sandy, predominantly shale	63	64	1
CLAY	Slightly silty, slightly sandy, pebbly; olive-gray (till)	64	87	23
GRAVEL	Sandy	87	88	1
CLAY	Slightly silty, slightly sandy, pebbly; olive-gray (till)	88	106	18
GRAVEL	Sandy; fine sand to medium pebble	106	110	4
GRAVEL	With layers of clay	110	118	8
GRAVEL	Sandy	118	122	4
CLAY	Brittle, grayish black (Pierre Formation)	122	140	18

Figure B.13.8.3. Zeeland aquifer lithology.

Location	12907301CCC	Date Drilled	08/23/1976
County	McIntosh	Land Surface	2043
Aquifer	Zeeland	Total Depth	140
Purpose	Observation Well - Pluggec	Bedrock Depth	115

Unit	Description	Begin Int	End Int	Thickness
GRAVEL	Sandy	1	2	1
CLAY	Slightly silty, slightly sandy, pebbly; moderate yellowish brown	2	4	2
GRAVEL	Sandy	4	6	2
CLAY	Slightly silty, slightly sandy, pebbly, moderate yellowish brown	6	15	9
CLAY	Slightly silty, slightly sandy, pebbly; dusky yellowish brown	15	27	12
CLAY	Slightly silty, slightly sandy, pebbly; olive-gray	27	70	43
SAND	Gravelly (15% gravel), very fine sand to medium pebble; predominantly coarse sand; 80% quartz, 10% limestone, 5% igneous rock fragments, 5% shale; well-sorted; predominantly subrounded; contains clay layers 78-80, 84-86, 95-96	70	115	45
CLAY	Brittle, grayish black (Pierre Formation)	115	140	25

Figure B.14.1.1. Lithology of the Ellendale aquifer.

Location	13106129BBB	Date Drilled	09/30/1975
County	Dickey	Land Surface	1405
Aquifer	Ellendale	Total Depth	300
Purpose	Test Hole	Bedrock Depth	278

Unit	Description	Begin Int	End Int	Thickness
CLAY	Sandy, silty, pebbly, moderately yellowish brown, cohesive, very slightly plastic, tight, oxidized (till)	0	14	14
CLAY	As above, medium dark gray to olive-gray (till); sand layer 57-60 ft., fine to very coarse sand, mostly quartz, some carbonates and igneous	14	71	57
SAND AND GRAVEL	Sand (70%), gravel (30%); sand, fine to very coarse, predominantly medium to coarse, angular to subrounded, 70% quartz, 20% carbonates, 10% shale with a little igneous; gravel, fine to medium, angular to subrounded, 50% carbonates, 30% shale, 20% igneous with a little igneous, moderate to poor sorting, clean	71	104	33
CLAY	Sandy, silty, pebbly, slightly gravelly, cohesive, very slightly plastic, very tight, medium dark gray to olive-gray (till), small interbedded gravel lenses	104	278	174
SHALE	Clay, brownish black to grayish black, siliceous, hard, tight, brittle, non-calcareous (Pierre Formation--may have hit Niobrara at 294 ft.	278	300	22

Figure B.14.1.2. Lithology of the Ellendale aquifer.

Location	13406130DDC	Date Drilled	09/03/1982
County	LaMoure	Land Surface	1423.96
Aquifer	Ellendale	Total Depth	302
Purpose	Observation Well	Bedrock Depth	287

Unit	Description	Begin Int	End Int	Thickness
TILL	Yellowish brown, oxidized, silty, clayey, slightly pebbly, slightly cohesive, plastic	3	18	15
TILL	Olive-gray, silty, slightly pebbly, slightly cohesive, slightly plastic	18	27	9
SAND AND GRAVEL	Very coarse sand to medium gravel, predominantly fine gravel, subangular, carbonates	27	31	4
TILL	Yellowish brown, oxidized, silty, pebbly, cohesive, slightly plastic	31	33	2
TILL	Olive-gray to dark olive-gray, silty, pebbly, moderately to very cohesive, cobble at 55 ft.	33	67	34
CLAY	Sandy and silty, interbedded with coarse sand lenses (poor sample)	67	85	18
SAND AND GRAVEL	Drilling consistently appears to be coarse sand to medium gravel, predominantly very coarse sand and ! fine gravel, predominantly subrounded shale and carbonates, possibly some interbedded till below 98 ft., ! boulder at 108 ft.	85	109	24
CLAY	Silty, medium gray, cohesive, brittle, slightly sandy (fluvial?)	109	120	11
TILL?	Medium gray, very silty, slightly pebbly, slightly cohesive, possibly fluvially reworked--below 40 ft.,! more plastic and cohesive; cobble at 184 ft. and 213 ft.; at 261-263 ft., sand; boulder at 163 ft.	120	287	167
CLAYSTONE	Brownish gray, poorly indurated, calcareous	287	302	15

Figure 14.2.1. Lithology of the Spiritwood aquifer.

Location	13806217AAA	Date Drilled	07/21/1970
County	Stutsman	Land Surface	1478.9
Aquifer	Spiritwood	Total Depth	240
Purpose	Observation Well	Bedrock Depth	0

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Sandy, siltyk pebbly, brownish-black	0	1	1
CLAY	Moderately sandy to sandy, silty, pebbly, a few cobbles, moderately yellowish-brown, moderately cohesive, plastic, oxidized (till)	1	22	21
CLAY	Silty, moderately sandy to sandy, pebbly, an occasional, thin, gravelly sand lense or layer, olive gray, moderately cohesive, plastic, calcareous (till)	22	130	108
CLAY	Silty, moderately sandy, pebbly, numerous cobbles and boulders, medium dark gray to olive gray, moderately cohesive, plastic, calcareous (till) (possibly older till?)	130	148	18
SAND	Slightly gravelly, clayey (lenses and layers and some matrix material), very fine to very coarse grained (mostly subangular), angular to rounded, moderately well sorted, about 20% shale and lignite 20% feldspar, carbonates and miscellaneous siliceous rock grains and 60% quartz, taking small amount of water, not caving in - lignite content increases with depth	148	200	52
GRAVEL	Sandy, fine to coarse (some cobble-sized material), angular to rounded, fair sorting, about 40% carbonates (limestone and dolostone), 30% shale, 30% granitics, metamorphics and miscellaneous siliceous rocks, taking water rapidly, caving in, mixed 4 bags bentonite - rough drilling	200	228	28
SHALE	Siliceous, grayish-black, indurated, non-calcareous, occasional small yellowish-gray limestone concretions (Pierre Formation)	228	240	12

Figure 14.2.2. Lithology of the Spiritwood aquifer.

Location	13706219BBB1	Date Drilled	06/09/1982
County	Stutsman	Land Surface	1457.84
Aquifer	Spiritwood	Total Depth	263
Purpose	Observation Well	Bedrock Depth	248

Unit	Description	Begin Int	End Int	Thickness
TILL	Yellow brown oxidized silty, pebbly, moderately cohesive and plastic, interbedded sand and gravel around 4', below 20' interbedded silt	0	30	30
TILL	Dark olive gray, clayey, pebbly, interbedded sand and silt lenses, moderately cohesive and plastic, cobbles at 85'	30	86	56
TILL	Olive gray, clayey, very pebbly (shale) cobbly, very tight, slightly brittle, many shale fragments, cobbles around 104'	86	105	19
TILL	Greenish gray, soft, silty, sandy, many carbonate and coal pebbles	105	110	5
SILT	Greenish gray, slightly clayey, organic streaks, slightly sandy	110	122	12
SAND	Very coarse to fine gravel - predominantly very coarse, angular to rounded, predominantly subrounded and rounded from 122'-135' interbedded with clayey very fine sand to clayey coarse sand, below 135' is clean, contains detrital coal	122	153	31
SILT	Very clayey, interbedded with clayey fine sand	153	163	10
GRAVEL	Very coarse sand to coarse gravel (1" diameter) predominantly fine gravel, subrounded and rounded, many silicates	163	174	11
CLAY	Greenish gray, black organic zones, very tight and plastic, interbedded brittle silty zones, (lacustrine) below 180' becomes very silty interbedded with gravel below 208', also clay becomes sandy, coarse gravel and cobbles at 239' and 245'	174	248	74
SHALE	Dark gray to black, poorly indurated, tight, a few silty zones	248	263	15

APPENDIX B - LITHOLOGY

Figure 15.1.1. Lithology of the Brightwood aquifer.

Location	13005028BBB	Date Drilled	08/20/1992
County	Richland	Land Surface	1122.79
Aquifer	Brightwood	Total Depth	220
Purpose	Observation Well	Bedrock Depth	198

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Topsoil, black.	0	2	2
TILL	Clay, silty, sandy, pebbly, light olive-brown, soft, oxidized (Till).	2	13	11
CLAY	Clay, slightly silty, light olive-brown, soft, slightly sticky, plastic, oxidized.	13	16	3
TILL	Clay, silty, sandy, pebbly, light olive-brown, soft, oxodized (Till).	16	25	9
TILL	Clay, silty, sandy, pebbly, olive-gray, soft, unoxodized (Till).	25	27	2
SAND & GRAVEL	Sand, pebbly, fine, oxodized.	27	31	4
TILL	Clay, silty, sandy, pebbly, light olive-brown, soft, oxidized (Till).	31	34	3
CLAY	Clay, silty, very sandy, pebbly, olive-gray.	34	41	7
SAND	Sand, fine to coarse, predominantly medium and coarse, pebbly, granular and fine, angular to sub-rounded, medium sorted, igneous, carbonate, shale; interbedded silt, clayey, medium dark gray from 73 to 92 feet, most beds less than 1 foot in thickness.	41	92	51
TILL	Clay, silty, very sandy, pebbly, olive-gray, slightly firm (Till).	92	96	4
SAND	Sand, fine to coarse, pebbly, granular and fine; interbedded silt.	96	104	8
CLAY	Clay, very sandy, pebbly, olive-gray, soft.	104	111	7
SILT	Silt, very sandy, very fine sand, olive-gray, very soft; interbedded clay, silt, sand; more sandy from 140 to 152 feet; lignite return from 140 feet.	111	152	41
TILL	Clay, silty, sandy, pebbly, olive-gray, slightly firm; cobbles from 168 to 169 feet; very sandy, pebbly at bottom of section; medium shale, fine igneous and carbonate pebbles (Till)..	152	196	44

Figure 15.1.2. Lithology of the Brightwood aquifer.

Location	12905003BBB	Date Drilled	08/19/1992
County	Richland	Land Surface	1131.89
Aquifer	Brightwood	Total Depth	240
Purpose	Observation Well	Bedrock Depth	221

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Topsoil, black.	0	1	1
TILL	Clay, silty, sandy, pebbly, light olive-brown, oxidized (Till).	1	12	11
CLAY	Clay, silty, light olive-brown, oxidized.	12	16	4
GRAVEL	Gravel, oxidized.	16	18	2
CLAY	Clay, silty, olive-gray, unoxidized.	18	20	2
GRAVEL	Gravel, coarse, sandy, oxodized.	20	36	16
SAND	Sand, coarse, unoxodized.	36	42	6
SILT	Silt, clayey, olive-gray, soft.	42	55	13
TILL	Clay, silty, sandy, pebbly, olive-gray, soft; cobbles from 58 to 59 feet (Till).	55	59	4
SAND	Sand, fine to coarse, predominantly coarse, pebbly, granular and fine, angular to sub-rounded, medium sorted, shale, carbonate, igneous.	59	82	23
SILT	Silt, clayey, sandy, olive-gray.	82	111	29
SAND	Sand, fine to coarse, pebbly, granular and fine, shale, igneous, carbonate; lignite return from 120 to 140 feet.	111	149	38
TILL	Clay, silty, sandy, very pebbly, olive-gray, firm; very firm by 172 feet; coarse pebbles from 182 to 203 feet (Till).	149	203	54
SILT	Silt, clayey, slightly sandy, very fine, olive-gray, soft.	203	208	5
TILL	Clay, silty, sandy, pebbly, olive-gray, firm; very firm by 213 feet (Till).	208	221	13
SHALE	Shale, dark gray at top, olive-black with depth, firm; streaks of white, very fine crystalline material.	221	240	19

Figure 15.1.3. Lithology of the Brightwood aquifer.

Location	13005122CBC	Date Drilled	08/16/2005
County	Richland	Land Surface	1165.06
Aquifer	Brightwood	Total Depth	220
Purpose	Observation Well	Bedrock Depth	208

Unit	Description	Begin Int	End Int	Thickness
CLAY	Clay, silty, yellow, oxidized	0	7	7
CLAY	Clay, silty, sandy, pebbly, yellow, oxidized	7	27	20
CLAY	Clay, silty, sandy, yellow, oxidized	27	34	7
SAND	Sand, fine to coarse, oxidized	34	38	4
CLAY	Clay, silty, sandy, gray, reduced	38	43	5
SAND & GRAVEL	Sand, fine to coarse, gravelly, fine and medium; detrital coal	43	58	15
CLAY	Clay, silty, sandy, gray	58	76	18
SAND & GRAVEL	Sand, fine to coarse, gravelly, fine and medium; layers predominantly shale, detrital coal	76	87	11
SAND & GRAVEL	Sand, fine to coarse, gravelly	87	120	33
CLAY	Clay, silty, very sandy, black	120	142	22
SAND & GRAVEL	Sand, fine to coarse, gravelly; detrital coal	142	188	46
CLAY	Clay, silty, sandy, pebbly, gray	188	190	2
COBBLES	Cobbles	190	191	1
CLAY	Clay, silty, sandy, pebbly, gray	191	208	17
CLAYSTONE	Clay, black (bedrock)	208	220	12

Figure 15.1.4. Lithology of the Brightwood aquifer.

Location	13005028CCC	Date Drilled	10/20/1964
County	Richland	Land Surface	1181
Aquifer	Brightwood	Total Depth	92
Purpose	Observation Well - Destroy	Bedrock Depth	0

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Sandy loam, black.	0	1	1
TILL	Silt, clayey to pebbly, moderate olive-brown, soft, calcareous, oxidized (till).	1	7	6
SAND & GRAVEL	Sand, fine to very coarse, with fine to coarse gravel; contains cobbles; cross bedding; iron stained.	7	79	72
TILL	Clay, very silty to pebbly, olive-gray, soft, plastic, cohesive, calcareous (till).	79	92	13

APPENDIX B - LITHOLOGY

Figure 15.2.1. Lithology of the Colfax aquifer.

Location	13504915BBB	Date Drilled	08/26/1993
County	Richland	Land Surface	935
Aquifer	Colfax	Total Depth	320
Purpose	Observation Well - Pluggec	Bedrock Depth	292

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	clay loam, black	0	2	2
CLAY	light olive-brown (5Y 5/6), soft, sticky, plastic, calcareous, oxidized (lacustrine)	2	37	35
CLAY	olive-gray (5Y 3/2), soft, sticky, plastic, calcareous, reduced (lacustrine)	37	55	18
TILL	clay, silty, sandy, very pebbly, olive-gray, soft, calcareous; rocks at 61, 68, and 81 feet; sand and gravel at 65 to 66 feet; interbedded sand and gravel (<1 ft beds) from 72 to 76 feet; less sand and pebbles, slightly firm, slightly darker below 72 feet; occasional cobble, firm below 108 feet; sand, fine to coarse from 143 to 145 feet	55	178	123
SAND & GRAVEL	fine to coarse, pebbly, fine and medium, angular to subrounded, mixed mineralogy, pebbles predominantly shale; occasional interbedded clay and silt; less pebbles, predominantly shale sand by 200 feet; pebbly with cobbles from 273 to 274 feet	178	274	96
CLAY	silty, very sandy, pebbly, light olive-gray (5Y 2/1), calcareous; occasional cobbles; rock at 282 feet	274	292	18
SHALE	clay, slightly silty, olive-black (5Y 2/1), firm, noncalcareous; slightly lighter color below 303 feet; silt and sand, very fine lamination below 307 feet (bedrock)	292	320	28

Figure 15.2.2. Lithology of the Colfax aquifer.

Location	13304933CDD	Date Drilled	09/02/1993
County	Richland	Land Surface	967
Aquifer	Colfax	Total Depth	280
Purpose	Observation Well - Pluggec	Bedrock Depth	260

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	silty loam, black	0	2	2
CLAY	very silty, light olive-brown (5Y 5/6), soft, slightly sticky, slightly plastic, calcareous, oxidized; clay, slightly firm, sticky, plastic by 20 feet (lacustrine)	2	28	26
CLAY	olive-gray (5Y 3/2), slightly firm, sticky, plastic, reduced (lacustrine)	28	73	45
TILL	clay, silty, slightly sandy, slightly pebbly, olive-gray, soft, sticky, slightly plastic, calcareous	73	103	30
SILT	clayey, olive-gray, soft, slightly sticky, nonplastic, calcareous	103	113	10
TILL	clay, silty, sandy, pebbly, olive-gray	113	121	8
SILT	clayey, olive-gray, soft, sticky, nonplastic	121	136	15
TILL	clay, very silty, sandy, pebbly, olive-gray, soft	136	153	17
SAND & GRAVEL	medium and coarse, granular, pebbly, fine, subangular to rounded, mixed mineralogy; pebbles predominantly rounded shale	153	162	9
TILL	clay, silty, sandy, pebbly, olive-gray, soft; numerous cobbles from 162 to 171 feet; sand from 171 to 175 feet; interbedded sand (<1 ft beds) from 180 to 197 feet; rock at 197 feet; very sandy, sligtly firm, nonsticky, slightly plastic from 198 to 223 feet	162	223	61
SAND & GRAVEL	medium and coarse, granular, pebbly, fine subangular to rounded, mixed mineralogy; interbedded clay (<1 ft beds) from 244 to 247 feet	223	247	24
CLAY	silty, olive-gray, slightly firm	247	252	5
TILL	clay, silty, sandy, pebbly, olive-gray, slightly firm	252	260	8
SHALE	clay, slightly silty, olive-black (5Y 2/1), slightly firm to firm, slightly sticky, plastic, noncalcareous; waxy appearance; brown and white return near bottom of section; brown rounded granules at bottom of section (bedrock)	260	280	20

Figure 15.3.1. Lithology of the Sheyenne Delta aquifer

Location	13305412BBB2	Date Drilled	09/15/1977
County	Ransom	Land Surface	1073.87
Aquifer	Sheyenne Delta	Total Depth	40
Purpose	Observation Well	Bedrock Depth	0

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Topsoil.	0	1	1
SAND	Sand, fine and medium, yellowish-brown, oxidized.	1	7	6
SAND	Sand, medium, light brown.	7	35	28
TILL	Clay, sandy, gray (Till).	35	40	5

Figure 15.3.2. Lithology of the Sheyenne Delta aquifer

Location	13405303CCC2	Date Drilled	12/17/1974
County	Ransom	Land Surface	1075
Aquifer	Sheyenne Delta	Total Depth	80
Purpose	Observation Well - Destroy	Bedrock Depth	0

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Silty, black.	0	1	1
SAND	Sand, fine and medium.	1	3	2
CLAY	Clay, silty, yellowish-brown.	3	6	3
SAND	Sand, fine to coarse, pebbly; detrital lignite.	6	55	49
CLAY	Clay, silty, sandy, olive-gray.	55	80	25

Figure 15.3.3. Lithology of the Sheyenne Delta aquifer

Location	13505204AAA	Date Drilled	05/15/1972
County	Richland	Land Surface	975
Aquifer	Sheyenne Delta	Total Depth	80
Purpose	Observation Well - Destroy	Bedrock Depth	0

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Very silty, clayey, grayish-black	0	1	1
SILT	Clayey, sandy, dark yellowish-brown, slightly cohesive, plastic, oxidized	1	10	9
SAND	Slightly silty, very fine to coarse grained, mostly medium subangular to rounded, moderately well sorted, numerous snail shells, some shale, lignitic, taking some water	10	24	14
CLAY	Very silty, olive gray with medium light gray laminae, slightly cohesive, plastic, highly calcareous	24	30	6
SAND	A few thin silty clay layers, very fine to coarse grained, subangular to subrounded, well sorted, snail shells, shaley	30	40	10
SAND	Slightly gravelly (about 20% fine gravel), subangular to rounded, moderately well sorted, gravel fraction mostly shale, numerous white snail shells, taking some water	40	51	11
CLAY	Very silty, olive gray, cohesive, highly plastic, highly calcareous	51	80	29

APPENDIX B - LITHOLOGY

Figure 15.3.4. Lithology of the Sheyenne Delta aquifer

Location	13605110BBB	Date Drilled	09/12/1972
County	Richland	Land Surface	1022
Aquifer	Sheyenne Delta	Total Depth	120
Purpose	Observation Well - Destroy	Bedrock Depth	0

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Sandy loam, black.	0	0.5	0.5
SAND	Sand, very fine and fine, clayey, silty, subangular to rounded, well sorted, slightly oxidized; lignitic.	0.5	12	11.5
SILT	Silt, clayey, sandy, medium gray, slightly cohesive, slightly plastic, calcareous; light olive-gray laminae.	12	20	8
SAND	Sand, very fine and fine, clayey, silty, subrounded, moderately well sorted.	20	33	13
SILT	Silt, clayey, medium gray, slightly cohesive, slightly plastic, calcareous; light olive-gray laminae.	33	50	17
SAND	Sand, very fine and fine, clayey, silty, subrounded, moderately well sorted; lignitic.	50	53	3
SILT	Silt, clayey, medium gray, slightly cohesive, slightly plastic, calcareous; light olive-gray laminae.	53	62	9
SAND	Sand, very fine, clayey, slightly silty, subangular to rounded; lignitic	62	64	2
SILT	Silt, slightly sandy, medium gray, slightly cohesive, highly calcareous; some light olive-gray laminae.	64	83	19
SAND	Sand, very fine, very clayey, subrounded; lignitic; poor return.	83	86	3
SILT	Silt, very clayey, olive-gray, moderately cohesive, moderately plastic; some thin light gray laminae.	86	94	8
CLAY	Clay, silty, olive-gray, very cohesive, sticky, plastic, highly calcareous.	94	120	26

APPENDIX B - LITHOLOGY

Figure 15.3.5. Lithology of the Sheyenne Delta aquifer

Location	13605314BBB	Date Drilled	12/07/2006
County	Ransom	Land Surface	1062.3
Aquifer	Sheyenne Delta	Total Depth	136
Purpose	Observation Well	Bedrock Depth	0

Unit	Description	Begin Int	End Int	Thickness
SAND	Sand, very fine, silty, light olive brown (5Y 5/6), oxidized (upper delta)	0	8	8
SAND	Sand, fine, silty, light olive gray (5Y 5/2), reduced (upper delta)	8	56	48
SAND	Sand, very fine, silty, olive gray (5Y 3/2), reduced (upper delta)	56	83	27
SILT	Silt, sandy, very fine, olive gray (upper delta)	83	87	4
SAND	Sand, very fine, silty, olive gray (upper delta)	87	90	3
SILT	Silt, sandy, very fine, olive gray (lower delta)	90	96	6
CLAY	Clay, very silty, olive gray (lower delta)	96	101	5
SILT	Silt, clayey, slightly sandy, very fine, olive gray (lower delta)	101	106	5
SILT	Silt, very clayey, olive gray (lower delta)	106	121	15
CLAY	Clay, firm, olive gray (lacustrine)	121	136	15

APPENDIX B - LITHOLOGY

Figure 15.4.1. Lithology of the Spiritwood aquifer - Richland and Sargent Counties.

Location	12905425AAA	Date Drilled	01/01/1970
County	SD-Marshall	Land Surface	1262.33
Aquifer	Spiritwood	Total Depth	230
Purpose	Observation Well	Bedrock Depth	213

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Topsoil.	0	3	3
CLAY	Yellowish-brown.	3	33	30
CLAY	Gray, 7" gravel stringers at 87'.	33	120	87
GRAVEL	Gravel.	120	160	40
SILT	Gravel stringer at 173 feet, rock at 213.	160	213	53
SHALE	Pierre shale.	213	230	17

Figure 15.4.2. Lithology of the Spiritwood aquifer - Richland and Sargent Counties.

Location	13005435CCC2S	Date Drilled	08/10/2006
County	Sargent	Land Surface	1180.07
Aquifer	Spiritwood	Total Depth	200
Purpose	Observation Well	Bedrock Depth	0

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	No description	0	1	1
TILL	Oxidize yellowish	1	37	36
TILL	Gray	37	121	84
SAND & GRAVEL	Coarse	121	127	6
TILL	Gray clay	127	142	15
TILL	Gray	142	176	34
SAND	Fine to coarse sand and layers of clay	176	186	10
SAND & GRAVEL	Coarse sand and medium gravel	186	195	9
SAND	Sand and gray clay	195	197	2
ROCK	Rocks and gravel	197	200	3

Figure 15.4.3. Lithology of the Spiritwood aquifer - Richland and Sargent Counties.

Location	13005525AAA	Date Drilled	12/09/1974
County	Sargent	Land Surface	1223.84
Aquifer	Spiritwood	Total Depth	280
Purpose	Observation Well - Pluggec	Bedrock Depth	260

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	Silty loam, dark yellow-brown	0	1	1
CLAY	Silty, sandy, pebbly, dark gray, firm, plastic, gravelly (till)	1	32	31
CLAY	Silty, sandy, pebbly, dark gray, firm, plastic, gravelly (till)	32	100	68
CLAY	Silty, sandy, pebbly, dark olive gray, firm, tight, plastic, gravelly (till)	100	152	52
SAND	Approximately 10% gravel, medium to very coarse, dark gray, angular to subrounded, approximately 40% shale, 30% carbonates, 20% quartz, 10% igneous, till lenses	152	160	8
SAND AND GRAVEL	Sand (70)-gravel (30); sand, medium to very coarse, angular to subrounded, approximately 60% quartz, 30% carbonates, 5% igneous and brown siliceous rocks, 5% shale, trace detrital lignite; gravel, fine to medium, angular to subrounded, approximately 50% carbonates, 30% igneous and brown siliceous rocks, 10% shale, 10% quartz, clean, (Spiritwood?), moderate lignite fragments	160	221	61
CLAY	Silty, sandy, pebbly, dark gray, plastic, sand lenses (till)	221	230	9
CLAY	Silty, sandy, pebbly, olive gray, tight, very tough, slightly plastic, silt lenses, sand lenses (till)	230	251	21
SAND	As above	251	260	9
CLAY	Grayish black, soft, plastic, white specks, non-calcareous (Pierre or Carlile?)	260	280	20

Figure 15.4.4. Lithology of the Spiritwood aquifer - Richland and Sargent Counties.

Location	13005506ABB2	Date Drilled	08/08/2006
County	Sargent	Land Surface	1253.54
Aquifer	Spiritwood	Total Depth	180
Purpose	Observation Well	Bedrock Depth	0

Unit	Description	Begin Int	End Int	Thickness
TOPSOIL	No description	0	1	1
TILL	Oxidize yellowish	1	22	21
TILL	Gray	22	148	126
SAND & GRAVEL	Including layers of clay	148	170	22
TILL	Gray	170	180	10

Figure 15.4.5. Lithology of the Spiritwood aquifer - Richland and Sargent Counties.

Location	13105326DCB	Date Drilled	09/07/1977
County	Sargent	Land Surface	1117.63
Aquifer	Undefined	Total Depth	200
Purpose	Observation Well - Pluggec	Bedrock Depth	175

Unit	Description	Begin Int	End Int	Thickness
CLAY	Silty, slightly sandy, pebbly, moderately yellow-brown (till)--6-7, gravelly till; 15-15.5, gravelly till	1	28	27
CLAY	Silty, slightly sandy, pebbly, olive gray, (till)--32.5-33, coarse gravel	28	40	12
CLAY	Silty, very sandy to silty, clayey	40	62	22
SAND	Slight gravel, very fine sand to very fine pebble, predominantly medium sand, predominantly quartz, trace lignite, predominantly subrounded, containing some silty zones	62	126	64
SILT	Clayey, sandy (very fine to fine) to clayey silts	126	175	49
CLAY	Black, reacts HCl (Greenhorn)	175	200	25

Figure 15.4.6. Lithology of the Spiritwood aquifer - Richland and Sargent Counties.

Location	13105330CCC	Date Drilled	08/24/1995
County	Sargent	Land Surface	1141.26
Aquifer	Undefined	Total Depth	170
Purpose	Observation Well	Bedrock Depth	156

Unit	Description	Begin Int	End Int	Thickness
CLAY	Silty, occasional sand, gravel, grain not large, pebbles, cobbles, soft, pale yellow-gray (till?)	0	12	12
CLAY	Silty, sandy, pebbly, cobbles, soft, yellow-gray, with red-yellow stringers, oxidized (till)	12	30	18
CLAY	Silty, sandy, pebbly, cobbles, soft, olive gray (till)	30	63	33
SAND	Very fine to coarse, predominantly fine, lots of quartz, carbonates, shale, some shield silicates, minor detrital lignite fragments, subangular to well rounded	63	92	29
SAND	Very fine to very coarse, predominantly coarse, as above, 1-2% very fine gravel	92	112	20
CLAY	Very silty, very sandy, hard, slightly brittle, more silty, sandy, brittle than above till, olive gray (till)	112	156	44
CLAY	Greasy, black, does not effervesce in dilute HCl (Carlile Shale)	156	170	14

APPENDIX C

WATER DEPOTS – PERMITS AND APPLICATIONS

(Summary Statistics and List: 7/8/10, From Alan Wanek)

APPENDIX C – WATER DEPOT STATISTICS

WATER DEPOTS – PERMITS AND APPLICATIONS

To serve the oil industry in Northwest North Dakota

NDSWC/Office of the State Engineer – July 8, 2010

Water permits issued (depots): **38** **34 groundwater, 4 surface**

Issued before 2007: 10
Issued 2007 or later: 28 (2007-4; 2008-8; 2009-7; 2010-9)

Annual quantity of groundwater permitted: 2,634.0 acre-feet (858M gal)
Annual quantity of surface water permitted: 2,429 acre-feet (791M gal)

4 permits are for supplemental water at existing depots
Water from 3 of the depots is used primarily for brine dilution
NDSWC-SW Pipeline permit (& app.) included – Dodge depot
Additional water is being sold under municipal permits (apps. pending)

Permits with a portion held in abeyance: **10** **All groundwater: 1,959.4 ac-ft/yr (638M gal)**

Permit applications denied: **6** **5 groundwater, 1 surface water**

Permit applications to be reviewed: **52** **37 groundwater, 15 surface water**

Annual quantity of groundwater applied for: 10,902.7 acre-feet (3,553M gal)
Annual quantity of surface water applied for: 55,091.5 ac-ft (17,952M gal)
2 groundwater applications for 1,588 acre-feet are from the Dakota aquifer

Priority date in 2006: 1
Priority date in 2007: 2
Priority date in 2008: 10
Priority date in 2009: 11
Priority date in 2010 28

Including 12 surface water applications from the Missouri River/Lake Sakakawea for 48,900 acre-feet/year (16 billion gallons per year)
8 applications (6 groundwater, 2 surface) are for supplemental water at existing depots

Oil well drilling rigs 7/8/10: **131**

Mountrail 38; Williams 22; Dunn 26; McKenzie 25; Divide 9; Burke 2; Bottineau 3; Bowman 3; Billings 2; Golden Valley 1; Stark 2; McLean 1 (source: NDIC - Oil & Gas Division website – 7/8/10)

Recent Grants:Pennington 6065 & Simonson 6106. Recent apps. Sheldon 6176/6177

APPENDIX C - WATER DEPOT LIST (7/8/2010)

Appendix C. List of Water Permits and Status for Water Depots used in Oil-Field Service as of July 9, 2010. Source Field: GW = ground water, Sur = surface water.
Status Field: Abey= in abeyance, Appy = new application, Cond = conditional, Perf = peerfected.

No.	Holder	Source	Ac-ft	Near to - mi.	Aquifer	Location	Priority	Issued	Gpm	County	Hydrologist	Grant Status	Status
3218	Leo Fisher	GW	27	Killdeer 3NW	Sentinel Butte/Killdeer	145-95-4C	12/20/79	2/29/80	350	Dunn		Granted	Perf
3689	Larry Signalness	GW	120	Keene 6S	Glacial valley fill	150-96-4E	2/10/84	4/11/84	150	McKenzie	Wanek	Granted	Perf
3701	William Pavlenko	GW	80	Killdeer 2W	Killdeer	145-95-29A	4/3/84	5/8/84	300	Dunn	Wanek	Granted	Perf
3792	Landtech	GW	60	Alexander 2S	Fox Hills	150-101-17A	5/17/85	7/23/85	100	McKenzie	Wanek	Granted	Perf
3882	Alice Simonson	GW	19.4	Watford 2W	Tobacco Garden Cr	150-99-22A	6/3/86	9/11/86	420	McKenzie	Wanek	Granted	Perf
3889	S & J Anderson	GW	20	Cwright 8 NE	Fox Hills	152-103-27B	6/26/86	10/15/86	75	McKenzie	Wanek	Granted	Perf
4063	Clarence Schollmeyer	GW	20	Killdeer 12N	Sentinel Butte (lignite)	147-95-30BB	3/7/89	4/20/89	12	Dunn	Wanek	Granted	Perf
5723	Mike Ames	GW	20	Wildrose 2W	West Wildrose	160-97-32D	10/7/04	4/21/05	450	Divide	Nygren	Granted	Cond
5754	*State Water Comm.*	*Sur*	*1130*	*Renner Bay*	*Lake Sakakawea*	*146-88-14D*	*4/1/05*	*3/31/06*	*700*	*Mercer*	*Farrell*	*Granted*	*Cond*
5761	Terry Ortloff	GW	20	Ross 4W	Tongue River	156-93-21A	5/10/05	2/8/06	20	Mountrail	Pusc	Granted	Cond
5761P	Terry Ortloff	GW	20	Ross 4W	Sentinel Butte	156-98-21A	5/10/05		80	Mountrail	Wanek	Not granted	Abey
5814	Alan Svangstu	GW	30	Crosby 3E	Crosby	163-97-36W	2/24/06	10/17/07	250	Divide	Nygren	Granted	Cond
5828A	Mike Ames	GW	20	Nesson Valley	Hofflund	154-96-17B	5/10/06	1/10/07	300	Williams	Nygren	Granted	Cond
5831	Rick Aalund	GW	20	Crosby .5W	Surficial gravel	163-97-29BC	8/17/06		250	Divide	Wanek	Not granted	Apply
5843	Mike Sheehan	GW	40	Watford City	Tobacco Garden Cr	150-99-24D	11/15/06	2/22/08	200	McKenzie	Wanek	Granted	Cond
5859	*LeMoine Hartel*	*Sur*	*129*	*Watford 3E*	*Sentinel Butte (lignite)*	*150-98-23C*	*10/31/06*	*4/23/07*	*80*	*McKenzie*	*Farrell*	*Granted*	*Cond*
5915	Manley Truchan	GW	20	Killdeer 2W	Killdeer	145-95-28B	3/21/07	10/17/07	300	Dunn	Wanek	Granted	Cond
5934	Linda Monson	GW	50	Alex. 10SW	Fox Hills	150-102-33B	7/17/07		75	McKenzie	Wanek	Denied	Deny
5939	Peter/Jo Westgard	GW	725	Parshall 6N	Shell Creek	153-89-28B	8/14/07		500	Mountrail	Nygren	Denied	Deny
5949	City of New Town	GW	200	New Town	New Town	152-92-17C	9/25/07	4/3/09	125	Mountrail	Nygren	Granted	Cond
5952	Olson Farms	GW	100	Dunn C. 5S	Tributary to Killdeer	144-94-21C	10/4/07	12/11/08	650	Dunn	Honeyman	Granted	Cond
5958A	*City of Parshall*	*Sur*	*370*	*Lake Sak*	*Lake Sakakawea*	*151-91-10B*	*10/23/07*	*3/8/10*	*375*	*Mountrail*	*Farrell*	*Granted*	*Cond*
5960	Jerry & Rich Wurtz	GW	40	Parshall 6W	Shell Creek	152-91-24D	10/26/07	7/14/08	850	Mountrail	Nygren	Granted	Cond
5963	Lyle Bratcher	GW	250	Alexander 7S	Fox Hills	149-101-17B	11/5/07		300	McKenzie	Wanek	Denied	Deny
5966	Energy Equity	GW	20	Parshall 8E	Fox Hills	152-88-13BC	11/16/07		50	Mountrail	Fischer	Not granted	Apply
5967	Energy Equity	GW	20	Stanley 5NE	Fox Hills	156-91-12DD	11/19/07		50	Mountrail	Fischer	Not granted	Apply
5968	James Edward	GW	120	Parshall 14N	Shell Creek	154-89-15D	11/19/07	7/3/08	350	Mountrail	Nygren	Granted	Cond
5973	Mike Ames	GW	30	Nesson Valley	Hofflund	154-96-17B	3/5/08	4/21/09	300	Williams	Nygren	Granted	Cond
5974	Mike Ames	GW	20	Wildrose 2W	West Wildrose	160-97-32D	3/5/08	3/8/10	350	Divide	Nygren	Granted	Cond
5975	Jerry Wurtz/M Ames	GW	50	Parshall5NW	Sand/gravel lens	152-90-15C	12/5/07	5/7/08	425	Mountrail	Nygren	Granted	Cond
5978	*Scott Fladeland*	*Sur*	*58*	*NewTwn 10N*	*Spring-Little Knife R.*	*154-92-31D*	*12/12/07*		*125*	*Mountrail*	*Farrell*	*Denied*	*Deny*
5988	James Dennis	GW	120	Stanley 1N	Tongue River	156-91-16D	1/8/08	5/7/08	250	Mountrail	Nygren	Granted	Cond
5988P	James Dennis	GW	240	Stanley 1N	Tongue River	156-91-16D	1/8/08		0	Mountrail	Nygren	Not granted	Abey
5989	Manley Truchan	GW	130	Killdeer 2W	Killdeer	145-95-28B	1/10/08	5/1/09	360	Dunn	Nygren	Granted	Cond
5989P	Manley Truchan	GW	220	Killdeer 2W	Killdeer	145-95-28B	1/10/08		0	Dunn	Nygren	Not granted	Abey
6003	*Robert Ferebee*	*Sur*	*50*	*Halliday1NW*	*Spring Creek*	*145-92-23W*	*2/15/08*		*300*	*Dunn*	*Farrell*	*Not granted*	*Apply*
6005	Dunn Co. Golf Course	GW	75	Killdeer	Killdeer	145-95-14D	2/21/08	6/17/09	400	Dunn	Nygren	Granted	Cond
6005P	Dunn Co. Golf Course	GW	225	Killdeer	Killdeer	145-95-14D	2/21/08		0	Dunn	Nygren	Not granted	Abey
6006	City of Killdeer	GW	75	Killdeer	Killdeer	145-95-23B	2/21/08	6/17/09	350	Dunn	Nygren	Granted	Cond
6006P	City of Killdeer	GW	290	Killdeer	Killdeer	145-95-23B	2/21/08		0	Dunn	Nygren	Not granted	Abey
6007	Greg Nordsven	GW	80	Werner 4S	Horse Nose Butte	144-93-16W	2/26/08	7/15/08	400	Dunn	Nygren	Granted	Cond
6007P	Greg Nordsven	GW	320	Werner 4S	Horse Nose Butte	144-93-16W	2/26/08		0	Dunn	Nygren	Not granted	Abey
6011	Pauper Industries	GW	134	Killdeer 1W	Killdeer	145-95-21D	3/12/08		250	Dunn	Nygren	Not granted	Apply
6018	City of Dunn Center	GW	325	Dunn Center	Fox Hills	145-94-26CA	4/2/08		200	Dunn	Fischer	Not granted	Apply
6023	City of Stanley	GW	92	Stanley	Sentinel Butte	156-91-28B	4/15/08	3/9/10	200	Mountrail	Nygren	Granted	Cond
6024	Clark and Jane Rismon	GW	100	Powers L 7S	Shell Creek-White Lake	157-92-6A	4/15/08	3/8/10	350	Mountrail	Nygren	Granted	Cond
6024P	Clark and Jane Rismon	GW	250	Powers L 7S	Shell Creek - White Lal	157-92-6A	4/15/08		0	Mountrail	Nygren	Not granted	Abey
6027	R & T Water Supply	GW	200	Ray 1E	Ray	150-97-15B	4/25/08	12/12/08	500	Williams	Nygren	Granted	Cond
6027P	R & T Water Supply	GW	200	Ray 1E	Ray	150-97-15B	4/25/08		500	Williams	Nygren	Not granted	Abey
6031	Harvey Johnson	GW	80.7	Stan 11 NE	Surficial gravel	157-89-7D	5/16/08		50	Mountrail	Nygren	Not granted	Apply
6032	Jim Schaper	GW	125	Halliday 7N	Goodman Creek	146-91-20A	5/12/08	1/21/09	500	Dunn	Nygren	Granted	Cond
6032P	Jim Schaper	GW	125	Halliday 7N	Goodman Creek	146-91-20A	5/12/08		0	Dunn	Nygren	Not granted	Abey
6033	Rodney Barstad	GW	30	Stanley 4N	Shell Creek - White Lal	156-91-4W	5/27/08	4/27/10	400	Mountrail	Nygern	Granted	Cond
6036	Thoral & Patrica Sax	GW	50	Watford 5NE	Cherry Creek	151-98-27	6/3/08	5/3/10	400	McKenzie	Nygren	Granted	Cond
6038	Dwyght Lindberg	GW	90	Parshall 14N	Shell Creek	154-89-22A	6/5/08		400	Mountrail	Nygren	Not granted	Apply
6043	Bill Pavlenko	GW	350	Killdeer 2W	Killdeer	145-95-29A	6/25/08		350	Dunn	Nygren	Not granted	Apply

APPENDIX C - WATER DEPOT LIST (7/8/2010)

Appendix C. List of Water Permits and Status for Water Depots used in Oil-Field Service as of July 9, 2010. Source Field: GW = ground water, Sur = surface water.
Status Field: Abey= in abeyance, Appy = new application, Cond = conditional, Perf = peerfected.

No.	Holder	Source	Ac-ft	Near to - mi.	Aquifer	Location	Priority	Issued	Gpm	County	Hydrologist	Grant Status	Status
6049	Earl Jensen	GW	120	Stanley 7NE	Surficial gravel	157-90-35D	8/12/08	6/7/10	250	Mountrail	Nygren	Granted	Cond
6052	City of Halliday	GW	310	Halliday	Fox Hills	145-92-24BC & 25AB	9/15/08		300	Dunn	Fischer	Not granted	Apply
6053	David Veeder	GW	50	Keene 7S	Glacial valley fill	150-96-10/11	9/15/08		400	McKenzie	Wanek	Not granted	Apply
6061	Jack Sjol	GW	184	Stanley 5E	Shell Creek - White Lal	156-90-21B	10/21/08		400	Mountrail	Nygren	Not granted	Apply
6064	Homer Nesson	GW	50	Minot 18SW	Douglas	152-85-10-14	4/13/09		450	Ward	Pusc	Not granted	Apply
6065	*D,S, & J Pennington*	*Sur*	*800*	*Lake Sak*	*Lake Sakakawea -VH a*	*151-92-3/10*	*12/5/08*	*6/15/10*	*1000*	*Mountrail*	*Farrell*	*Granted*	*Cond*
6068	Jim Footh	GW	483	Power L 6SE	Glacial valley fill	158-92-15D	12/22/08		300	Mountrail	Wanek	Not granted	Apply
6081	Arnold Moll	GW	250	Parshall 15S	White Shield	149-089-11B	4/23/09	8/2/09	400	Mclean	Pusc	Granted	Cond
6086	Watford City	GW	250	Watford City	Tbacco Garden Cr	150-99-19/24	3/19/09		450	McKenzie	Wanek	Not granted	Apply
6102	Powers Lake	GW	300	Powers Lake	Shell Creek - White Lal	159-93-36B	7/24/09		350	Mountrail	Wanek	Not granted	Apply
6104	Missouri Basin WS	GW	180	Stanley 3E	Shell Creek - White Lal	156-90-18D	8/7/09		400	Mountrail	Nygren	Not granted	Apply
6106	Alice Simonson	GW	130.6	Watford 2W	Tobacco Garden Cr	150-99-22A	8/11/09	6/28/10	1000	McKenzie	Nygren	Granted	Cond
6106	Alice Simonson	GW	69.4	Watford 2W	Tobacco Garden Cr	150-99-22A	8/11/09			McKenzie	Nygren	Not granted	Abey
6111	Dakota Disp & Fresh W	GW	20	Johnson 3W	Sentinel Butte	150-96-17CC	8/24/09		100	McKenzie	Wanek	Not granted	Apply
6115	*Steve Mortenson*	*Sur*	*5000*	*Williston18 SW*	*Missouri River*	*152-104-14B*	*1/7/10*		*3600*	*Williams*	*Farrell*	*Not granted*	*Apply*
6116	*Steve Mortenson*	*Sur*	*141.5*	*Williston 7W*	*Painted Woods trib*	*154-102-16A*	*1/4/10*		*1200*	*Williams*	*Farrell*	*Not granted*	*Apply*
6117	*Steve Mortenson*	*Sur*	*5000*	*Trenton*	*Lake Trenton*	*153-102-17CD*	*1/7/10*		*3600*	*Williams*	*Farrell*	*Not granted*	*Apply*
6121	*Hexom Earth Construct*	*Sur*	*2000*	*Red Mike 4E*	*Lake Sakakawea*	*154-96-13D*	*11/16/09*		*1400*	*Williams*	*Farrell*	*Not granted*	*Apply*
6123	Myron Sylte	GW	600	13 MC 1W	Till	156-101-10D	12/21/09		800	Williams	Nygren	Not granted	Apply
6124M	*International Western*	*Sur*	*6000*	*New Town 6NW*	*Lake Sakakawea*	*153-93-26D*	*12/15/09*	*7/x/2010*	*4200*	*Mountrail*	*Farrell*	*Granted*	*Cond*
6124N	*International Western*	*Sur*	*6000*	*Charlson 5NE*	*Lake Sakakawea*	*154-94-31A*	*12/15/09*	*7/x/2010*	*4200*	*Mountrail*	*Farrell*	*Granted*	*Cond*
6124S	*International Western*	*Sur*	*6000*	*NewTown 11SW*	*Lake Sakakawea*	*151-93-31B*	*12/15/09*	*7/x/2010*	*4200*	*Mountrail*	*Farrell*	*Granted*	*Cond*
6125	Loren Sackman	GW	80	Dickinson 2N	Tongue River	140-96-15CB	12/22/09		80	Stark	Wanek	Not granted	Apply
6129	Michels and Watterud	GW	320	Columbus NW	Columbus	163-93-30D	1/4/10		250	Burke	Wanek	Not granted	Apply
6134	Hess Corporation	GW	1342	Tioga 8SW	Dakota	155-096-3A	2/3/10		832	Williams	Nygren	Not granted	Apply
6135	Hess Corporation	GW	1246	Tioga 6SW	Dakota	156-096-23C	2/3/10		773	Williams	Nygren	Not granted	Apply
6136	Willard & Irene Kovalof	GW	724	Killdeer 3S	Killdeer	144-095-06A	2/17/10		450	Dunn	Nygren	Not granted	Apply
6138	Don Reistad, Mike Ame	GW	100	Fortuna 6W	Skjermo Lake	163-102-28D/34C	2/19/10		900	Divide	Wanek	Not granted	Apply
6139	*International Western*	*Sur*	*6000*	*Dodge 18N*	*Lake Sakakawea*	*147-090-09C*	*2/24/10*		*4200*	*Mercer*	*Farrell*	*Not granted*	*Apply*
6141	D/R Gunlikson, M Ame	GW	200	29 Mile Corner	Little Muddy	158-100-28C	3/15/10		1000	Williams	Nygren	Denied	Deny
6142	Westhope	GW	150	Westhope 2W	Souris River	163-079-30C	3/15/10		320	Bottineau	Wanek	Not granted	Apply
6143	Terry Smith	GW	724	13 Mile Cor 3SE	Yellowstone Valley	156-100-29B	3/18/10		500	Williams	Nygren	Not granted	Apply
6144	Daryn/Dorothy Smith	GW	200	29 Mile Cor 1S		159-100-32N	3/19/10		1000	Williams	Nygren	Denied	Deny
6145	*State Water Comm.*	*Sur*	*8000*	*Renner Bay*	*Lake Sakakawea*	*146-88-14D*	*4/1/10*		*4970*	*Mercer*	*Farrell*	*Not granted*	*Apply*
6147	*Parshall*	*Sur*	*1000*	*Parshall 13SW*	*Lake Sakakawea*	*150-090-31B*	*4/1/10*		*600*	*Mclean*	*Farrell*	*Not granted*	*Apply*
6149	Beulah	GW	1000	Beulah	Knife River	144-088-25C	4/8/10		900	Mercer	Schultz	Not granted	Apply
6151	*Kodiak Oil & Gas*	*Sur*	*3000*	*Halliday 20N*	*Lake Sakakawea*	*148-091-17D*	*4/9/10*		*2000*	*Dunn*	*Farrell*	*Not granted*	*Apply*
6155	*Bernard Pease*	*Sur*	*1000*	*Garrison 13SW*	*Lake Sakakawea*	*147-086-07D*	4/23/10			*McLean*	*Farrell*	*Not granted*	*Apply*
6156	J Mike Ames	GW	200	Red Mike Hil W	Hofflund	154-96-17/18	4/23/10			Williams	Nygren	Not granted	Apply
6157	Roger Baker	GW	50	Red Mike Hill	Hofflund	155-0960-31D	4/28/10			Williams	Nygren	Not granted	Apply
6158	Olson Farms	GW	100	Dunn Center 5S	Killdeer tributary	144-094-21C	4/30/10			Dunn	Wanek	Not Granted	Apply
6159	City of Grenora	GW	150	Grenora .5S	Grenora	159-103-12CA	4/23/10		150	Williams	Nygren	Not Granted	Apply
6161	J Mike Ames	GW	100	Wildrose 2 W	W. Wildrose	160-097-32S	5/7/10		600	Divide	Nygren	Not Granted	Apply
6168	Don Negaard	GW	200	Columbus 1E	Columbus	163-093-21E	6/1/10		200	Burke	Wanek	Not granted	Apply
6169	*Sakakawea Pipeline*	*Sur*	*4900*	*Red Mike 2E*	*Lake Sakakawea*	*154-097-24B*	*5/26/10*		*3000*	*Williams*	*Farrell*	*Not granted*	*Apply*
6170	Roger Baker	GW	50	SE Nesson Val	Hofflund	154-096-10C	6/17/10		850	Williams	Nygren	Not granted	Apply
6172	Coteau Cattle/N. Biwer	GW	400	Stanley 8NE	Surficial gravel	157-090-9/10	6/4/10		800	Mountrail	Wanek	Not granted	Apply
6173	Russell Gafkjen	GW	200	Williston 20 N	Little Muddy	157-100-5E/158-100-32S	6/9/10		1200	Williams	Nygren	Not granted	Apply
6176	*Willian Sheldon*	*Sur*	*1000*	*Red Mike 1W*	*Lake Sakakawea*	*154-096-18S/19E*	*6/23/10*		*2000*	*Williams*	*Farrell*	*Not granted*	*Apply*
6177	William Sheldon	GW	300	Red Mike 1W	Hofflund	154-096-18S19E	6/23/10		1800	Williams	Nygren	Not granted	Apply

APPENDIX D

AGENDA OF THE MEETING TITLED: WESTERN NORTH DAKOTA WATER RESOURCE OPPORTUNITIES

(Bismarck Ramada Inn, Governor's Room, 12/10/2009)

APPENDIX D – AGENDA OF OIL-FIELD WATER MEETING: 12/10/2009

State of North Dakota
Office of the Governor
John Hoeven
Governor

Western North Dakota
Water Resource Opportunities

12:30 pm – 2:00 pm CST
Thursday, December 10, 2009
Governor's Room, Ramkota Hotel
Bismarck, ND

Welcome and Opening Remarks	Governor's Office ND Petroleum Council
Oil Development Likely Water Needs	Lynn Helms, ND Oil & Gas Division
Fracturing Water Quality	Mike Eberhard, Halliburton
Bakken Water Study	Beth Kurz, EERC
Water Access	Bob Shaver, State Water Commission Phillip H. Brown, Corps of Engineers Marvin Danks, Three Affiliated Tribes
Water Resource Management/ Opportunities/Considerations	Mary Massad, Southwest Water Authority Jeret Wirtz, McKenzie County Water Resource District Jerry Ranum, RT Water Users
Project Financing Considerations	Dale Frink, State Water Commission Tim Porter, ND Public Finance Authority
Next Steps?	
Discussion/Questions	

APPENDIX E

REQUIREMENTS FOR A CORPS OF ENGINEERS REAL ESTATE PERMIT

(As of January, 2010 – #6 Was A New Requirement)

U.S. ARMY CORPS OF ENGINEERS
OPERATIONS DIVISION PROCESS
FOR REAL ESTATE ACTIONS

***Prior to submittal of the application packet, consultation with staff mentioned below is strongly encouraged.**

Applicant package must include:

1) Formal letter stating the purpose/need for the request

2) Submit Tribal/County/City/etc. resolution (if applicable)

3) Submit detailed plans and specifications indicating any effects on Corps managed lands,
    a. Site Plan (show planned development drawn to scale on topographic or aerial photo map). Provide map(s) of the requested area showing Corps boundary line
    b. Schedule of phased development (if applicable)
    c. Operation and maintenance plan (# out years)
    d. State number of acres requested for easement
    e. Identify quantity and duration of water needs (if applicable)

4) Submit Regulatory Permit Application(i.e. Section 10/404 of Clean Water Act)

5) Provide approval/permit from appropriate regulatory agency (state/local), water supply contract, authorizing document, or decision document based on statute, for authorizing a water supply intake (if applicable).

6) Industrial Water Intakes - The applicant will be required to provide information pertaining to current status of water depots / municipal supplies within the region of industrial supply need. The applicant needs to provide documentation regarding the capacity or feasibility constraints with those existing sources for supporting justification towards developing new/additional industrial water intakes.

APPENDIX F

SUMMARY OF WATER PERMITS CURRENTLY HELD OR IN PROGRESS FOR AQUIFERS MAPPED AS HAVING "GOOD" OR " CONDITIONAL" POTENTIAL FOR FURTHER DEVELOPMENT

(May 2010 – Prepared by Michael Hove)

APPENDIX F: Total Permit Count for All Ground Water Permits in "Good Aquifers"

(MHove-May 23, 2010)

Count of Hdr-App_Ac		Status					
Study Area	Rod Aquifers	App. In Process	Cond. Approved	Held In Abey.	Perfected	Empty	Grand Total
Map Area01	Crosby		1			1	2
	Grenora		3			2	5
	Little Muddy		2			5	7
	Ray		2			7	9
	Smoky Butte		1		1		2
	Unnamed	1	1			2	4
	Wildrose					1	1
	Wildrose Buried Channel		2			1	3
	Yellowstone Buried Channel	1				1	2
	Yellowstone River Channel	7	9		2	28	46
Map Area01 Total		9	21		3	48	81
Map Area02	Columbus	1	1			2	4
	Tongue River					1	1
Map Area02 Total		1	1			3	5
Map Area03	Dakota Group					1	1
Map Area03 Total						1	1
Map Area04	Rolla					1	1
	Spiritwood		3		1	3	7
Map Area04 Total			3		1	4	8
Map Area05	Icelandic		1		1		2
Map Area05 Total			1		1		2
Map Area06	Bennie Peer					1	1
	Charbonneau		2			1	3
	Fox Hills					2	2
	Missouri River - Lake Sakakawea					5	5
	Sentinel Butte-Tongue River					2	2
	Tobacco Garden	1				2	3
	Tobacco Garden Creek		1				1
	Tongue River					1	1
	Trenton		2			4	6
	Yellowstone		3		1	6	10
	Yellowstone River Channel		1			3	4
	Yellowstone-Missouri		1				1
Map Area06 Total		1	10		1	27	39
Map Area07	Bismarck	1	1			10	12
	Burnt Creek		2			7	9
	Fort Mandan					1	1
	Fox Hills					1	1
	Glenview					2	2
	Heart River					3	3
	Lost Lake					1	1
	Missouri River		7			8	15
	Missouri River - Lake Sakakawea					1	1
	New Town		1			2	3
	Painted Woods Lake					4	4
	Wagonsport					1	1
	White Shield		1				1
Map Area07 Total		1	12			41	54
Map Area08	Horseshoe Valley					1	1
	Lake Nettie	1	1			3	5
	Martin					2	2
	North Burleigh					1	1
	Strawberry Lake					2	2
	Weller Slough					1	1
Map Area08 Total		1	1			10	12
Map Area09	Cherry Lake					2	2
	Eastman		1			1	2
	New Rockford		3			12	15
	Pipestem Creek		1			1	2
	Rusland					2	2
	Spiritwood-Devils Lake					2	2
	Tokio					2	2
	Unnamed					3	3
	Warwick Aquifer					15	15
Map Area09 Total			5			40	45
Map Area10	Grand Forks					1	1
	McVille					2	2
Map Area10 Total						3	3
Map Area11	Central Dakota	2	1			1	4
Map Area11 Total		2	1			1	4
Map Area12	Elm Creek					3	3
	Killdeer		1			1	2
	Tongue River					2	2
Map Area12 Total			1			6	7
Map Area13	Napolean		2			3	5
	Spring Creek					2	2
	Zeeland					1	1
Map Area13 Total			2			6	8
Map Area14	Ellendale	1				2	3
Map Area14 Total		1				2	3
Map Area15	Brightwood	1					1
	Sheyenne Delta	4	14			64	82
	Spiritwood					3	3
Map Area15 Total		5	14			67	86
(blank)	(blank)						
(blank) Total							
Grand Total		21	72		6	259	358

APPENDIX F: Total Acre-Feet for All Ground Water Permits in "Good Aquifers"

(MHove-May23. 2010)

Sum of AcFt Approv. & Request		Status					
Study Area	Rod Aquifer Map	Abey-InActive	Active Abeyance	App. In Process	Cond. Approv.	Perfected	Grand Total
Map Area01	Crosby				30	403	433
	Grenora				239.9	152.6	392.5
	Little Muddy				818	880.3	1698.3
	Ray				496.2	1240.9	1737.1
	Smoky Butte	207.5	207.5		205.2		620.2
	Unnamed			20	20	12	52
	Wildrose					120	120
	Wildrose Buried Channel				10	4	14
	Yellowstone Buried Channel			350		2	352
	Yellowstone River Channel	408	312	1601	2020.86	6147	10488.86
Map Area01 Total		615.5	519.5	1971	3840.16	8961.8	15907.96
Map Area02	Columbus			320	160	229.8	709.8
	Tongue River					162	162
Map Area02 Total				320	160	391.8	871.8
Map Area03	Dakota Group					38	38
Map Area03 Total						38	38
Map Area04	Rolla					560	560
	Spiritwood	406	284		977	511	2178
Map Area04 Total		406	284		977	1071	2738
Map Area05	Icelandic	195	90		240		525
Map Area05 Total		195	90		240		525
Map Area06	Bennie Peer					16	16
	Charbonneau				1007	223	1230
	Fox Hills					45	45
	Missouri River - Lake Sakakawea					22.2	22.2
	Sentinel Butte-Tongue River					5	5
	Tobacco Garden			200		67.9	267.9
	Tobacco Garden Creek				204		204
	Tongue River					1.3	1.3
	Trenton				1132	251.6	1383.6
	Yellowstone	111	66		772	2815	3764
	Yellowstone River Channel				130	103	233
	Yellowstone-Missouri				10		10
Map Area06 Total		111	66	200	3255	3550	7182
Map Area07	Bismarck			400	155	973.4	1528.4
	Burnt Creek				80.5	2170.1	2250.6
	Fort Mandan					20	20
	Fox Hills					60	60
	Glenview					286	286
	Heart River					461	461
	Lost Lake					200	200
	Missouri River				7089.5	1561.3	8650.8
	Missouri River - Lake Sakakawea					1	1
	New Town				200	600	800
	Painted Woods Lake					1007	1007
	Wagonsport					44.8	44.8
	White Shield				250		250
Map Area07 Total				400	7775	7384.6	15559.6
Map Area08	Horseshoe Valley					717	717
	Lake Nettie			175	170	758.9	1103.9
	Martin					150	150
	North Burleigh					106.5	106.5
	Strawberry Lake					258	258
	Weller Slough					400	400
Map Area08 Total				175	170	2390.4	2735.4
Map Area09	Cherry Lake					0.8	0.8
	Eastman				405	202.5	607.5
	New Rockford				918	3944.4	4862.4
	Pipestem Creek				575	39	614
	Rusland					450	450
	Spiritwood-Devils Lake					301	301
	Tokio					712	712
	Unnamed					354.4	354.4
	Warwick Aquifer					9647.5	9647.5
Map Area09 Total					1898	15651.6	17549.6
Map Area10	Grand Forks					400	400
	McVille					518	518
Map Area10 Total						918	918
Map Area11	Central Dakota			374.1	188.4	195	757.5
Map Area11 Total				374.1	188.4	195	757.5
Map Area12	Elm Creek					683.4	683.4
	Killdeer				8	180	188
	Tongue River					450	450
Map Area12 Total					8	1313.4	1321.4
Map Area13	Napolean				390	573.5	963.5
	Spring Creek					480.4	480.4
	Zeeland					54	54
Map Area13 Total					390	1107.9	1497.9
Map Area14	Ellendale			1120		402	1522
Map Area14 Total				1120		402	1522
Map Area15	Brightwood			200			200
	Sheyenne Delta			3316.5	4074.6	15870.4	23261.5
	Spiritwood					584.5	584.5
Map Area15 Total				3516.5	4074.6	16454.9	24046
Grand Total		**1,327.5**	**959.5**	**8,076.6**	**22,976.2**	**59,830.4**	**93,170.2**

APPENDIX F: Total Permit Count for All Ground Water Permits in "Conditional Aquifers"

(MHove-May24, 2010)

Count of AcFt Approv. & Proc.		Status					
Study Area	Rod Aquifer	App. In Process	Cond. Approved	Held In Abeyance	Perfected	(blank)	Grand Total
Map Area02	Columbus					1	1
	Gravel Sediments	1					1
	Shell Creek-White Lake	2				1	3
Map Area02 Total		3				2	5
Map Area03	Denbigh Buried Channel		1			1	2
	Denbigh-Lake Souris		1			4	5
	Lake Souris	3	5			11	19
Map Area03 Total		3	7			16	26
Map Area04	Wolford					1	1
Map Area04 Total						1	1
Map Area05	Icelandic		1				1
	Pembina Delta					1	1
	Pembina River					1	1
Map Area05 Total			1			2	3
Map Area07	Ryder					1	1
Map Area07 Total						1	1
Map Area09	James River					1	1
	Juanita Lake					2	2
	Kilgore Channel		1				1
	Maddock					1	1
	Spiritwood					1	1
	Spiritwood-Griggs	3	3	4		29	39
	Spiritwood-Sheyenne River		1				1
	Spiritwood-Warwick	3	7	1		10	21
	Unnamed					1	1
Map Area09 Total		6	12	5		45	68
Map Area10	Belmont					1	1
	McVille		2			4	6
	Tower City					1	1
Map Area10 Total			2			6	8
Map Area11	Central Dakota	1				1	2
	Long Lake		1			4	5
Map Area11 Total		1	1			5	7
Map Area12	Strasburg		2			5	7
Map Area12 Total			2			5	7
Map Area13	Unnamed					1	1
	Wishek		1			2	3
Map Area13 Total			1			3	4
Map Area14	Seven Mile Coulee					2	2
	Spiritwood					2	2
	Spiritwood-LaMoure SE	6	2			10	18
	Spritwood-Stutsman		1			5	6
Map Area14 Total		6	3			19	28
Map Area15	Colfax					1	1
Map Area15 Total						1	1
(blank)	(blank)						
(blank) Total							
Grand Total		19	29	5	106		159

APPENDIX F: Total Acre-Feet for All Ground Water Permits in "Conditional Aquifers"

(MHove-May 24, 2010)

Sum of AcFt Approv. & Proc.		Status					
Study Area	Rod Aquifer	Active Abeyance	App. In Process	Cond. Approved	In-Active Abey	Perfected	Grand Total
Map Area02	Columbus					448.0	448.0
	Gravel Sediments		120.0				120.0
	Shell Creek-White Lake		783.0			219.8	1,002.8
Map Area02 Total			903.0			667.8	1,570.8
Map Area03	Denbigh Buried Channel			325.0		350.0	675.0
	Denbigh-Lake Souris			485.0		674.0	1,159.0
	Lake Souris		1,112.3	1,530.9		2,738.5	5,381.7
Map Area03 Total			1,112.3	2,340.9		3,762.5	7,215.7
Map Area04	Wolford					160.0	160.0
Map Area04 Total						160.0	160.0
Map Area05	Icelandic			900.0			900.0
	Pembina Delta					400.0	400.0
	Pembina River					161.0	161.0
Map Area05 Total				900.0		561.0	1,461.0
Map Area07	Ryder					73.9	73.9
Map Area07 Total						73.9	73.9
Map Area09	James River					24.0	24.0
	Juanita Lake					1,002.0	1,002.0
	Kilgore Channel			718.8			718.8
	Maddock					399.0	399.0
	Spiritwood					30.0	30.0
	Spiritwood-Griggs	1,848.1	1,366.6	1,242.0	703.6	6,666.7	11,827.0
	Spiritwood-Sheyenne River			202.2			202.2
	Spiritwood-Warwick	2,000.0	484.0	2,297.5	800.0	2,878.0	8,459.5
	Unnamed					152.0	152.0
Map Area09 Total		3,848.1	1,850.6	4,460.5	1,503.6	11,151.7	22,814.5
Map Area10	Belmont					15.0	15.0
	McVille			641.0		493.8	1,134.8
	Tower City					67.0	67.0
Map Area10 Total				641.0		575.8	1,216.8
Map Area11	Central Dakota		10.0			48.0	58.0
	Long Lake			501.6		1,250.0	1,751.6
Map Area11 Total			10.0	501.6		1,298.0	1,809.6
Map Area12	Strasburg			878.3		1,904.5	2,782.8
Map Area12 Total				878.3		1,904.5	2,782.8
Map Area13	Unnamed					60.0	60.0
	Wishek			198.0		668.5	866.5
Map Area13 Total				198.0		728.5	926.5
Map Area14	Seven Mile Coulee					540.0	540.0
	Spiritwood					351.0	351.0
	Spiritwood-LaMoure SE		8,919.0	257.2		2,231.9	11,408.1
	Spritwood-Stutsman			326.0		1,278.0	1,604.0
Map Area14 Total			8,919.0	583.2		4,400.9	13,903.1
Map Area15	Colfax					122.0	122.0
Map Area15 Total						122.0	122.0
Grand Total		**3,848.1**	**12,794.9**	**10,503.5**	**1,503.6**	**25,406.6**	**54,056.7**