

UNITED STATES DEPARTMENT OF THE INTERIOR  
GEOLOGICAL SURVEY

Preliminary Study of Geotechnical  
Properties of the Fort Union Formation  
near Recluse, Wyoming

By E. E. McGregor and J. K. Odum

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This report is preliminary and has not  
been edited or reviewed for conformity  
with U.S. Geological Survey standards  
or nomenclature.

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Introduction

This report contains the results of selected physical-properties tests of rocks from the Fort Union Formation near Recluse, Wyo. The rocks were obtained from drill holes cored by a contractor for the U.S. Geological Survey (see figs. 1, 2, and appendix for locations and legal descriptions). Testing was done at the drill hole sites by E. E. McGregor and J. Sebesta and in the laboratory by J. K. Odum and J. Sebesta of the U.S. Geological Survey, Golden, Colo. The purpose of this study is to gather data on the physical properties of the Fort Union Formation that relate to coal mining operations in this area and to make these data public; this study is part of an engineering geologic research program on rock properties in the Powder River Basin, and is part of the Energy Lands Program.

Testing of the rock samples has followed ASTM (Am. Soc. Testing and Materials, 1964) procedures wherever possible. The ASTM test designations are discussed in section called "Explanatory Notes." The other tests that are not ASTM standards are included in this report as research and experimental information.

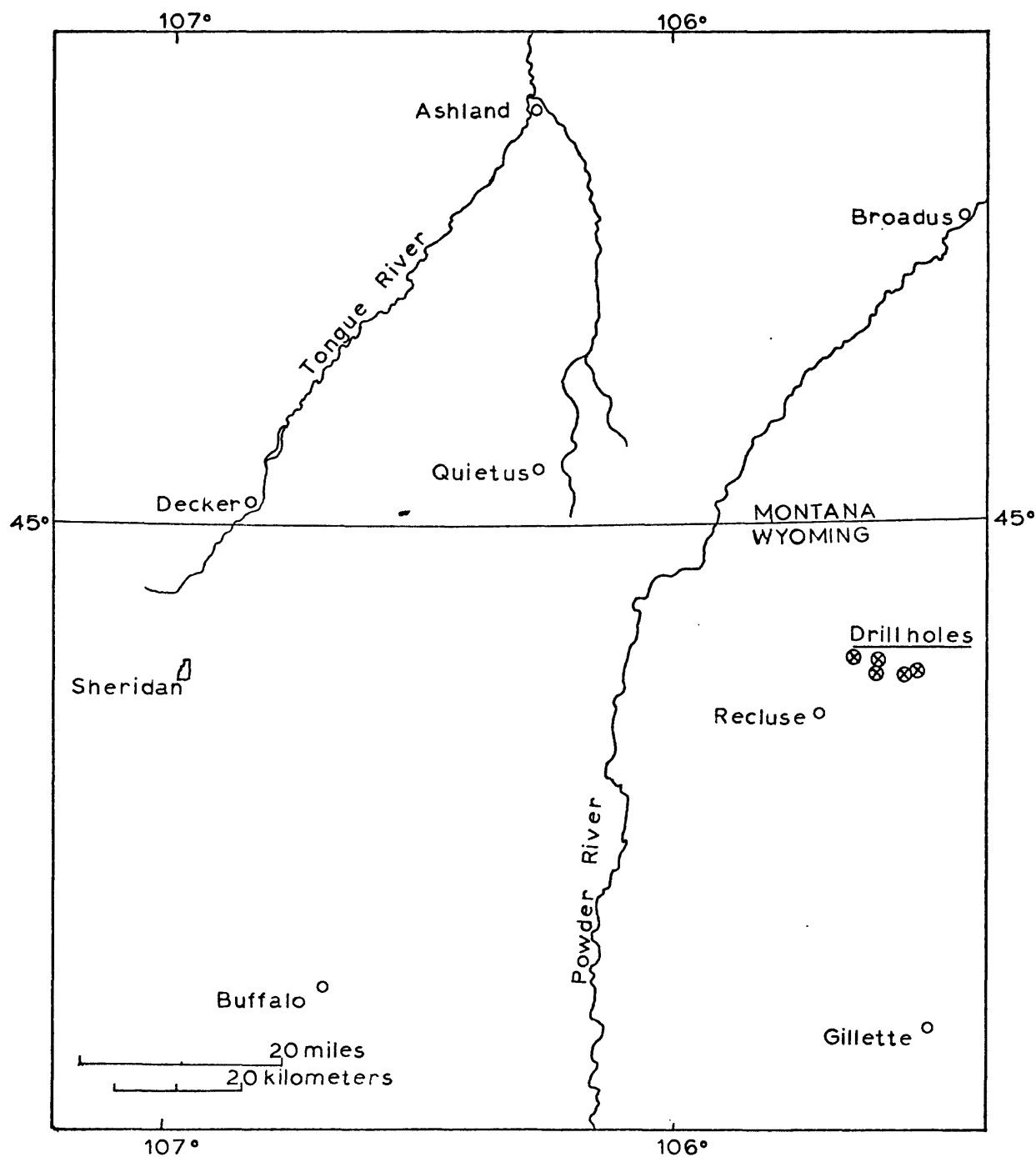


Figure 1. Index map of Northern Powder River Basin, showing locations of drill holes from which cores were tested. Drillhole numbers shown on figure 2.

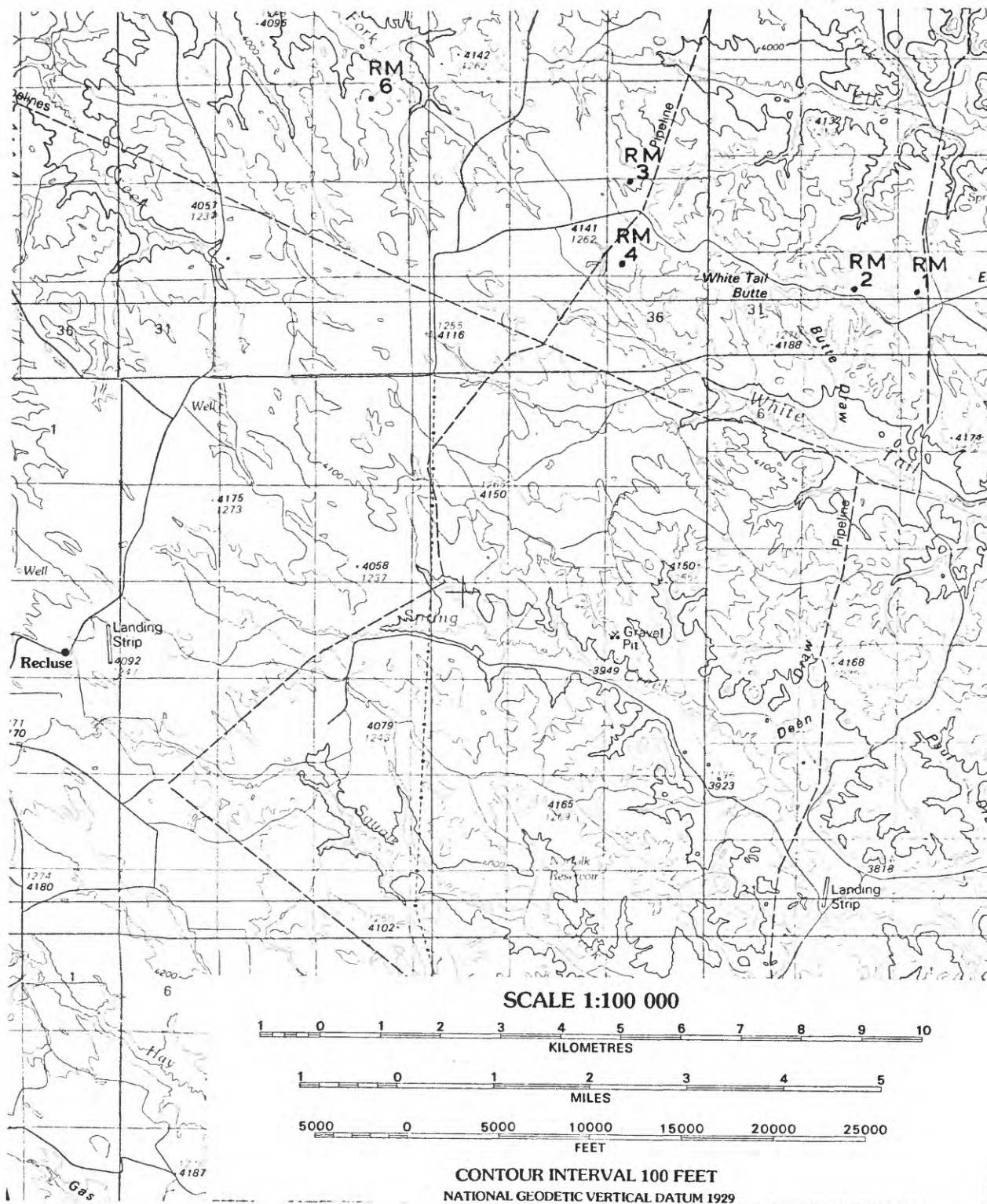


Figure 2. Map of Recluse-White Tail Butte area, showing locations of drill holes included in this report. Legal descriptions are in Appendix.

## Engineering Geology

Approximately 250 tests were performed on 72 samples of core, 82.6 mm in diameter, to determine geotechnical properties. An average of 14 rock samples was taken from each drill hole for testing, both in the field and in the laboratory. The results of these tests indicate weak rocks that can pose engineering geologic problems associated with the in-place material and the disturbed material.

With only a few exceptions, compressive- and tensile-index tests performed on the rock samples have low values similar to those test results obtained on rock samples from drill holes at Ashland, Mont. (McGregor, 1975). These data and the physical-properties data, Atterberg limits, and gradation (grain-size distribution) suggest the need for careful design in slopes, open mine faces, and open-pit floors. Some of the rocks were so weak that they could not be tested as rocks and had to be considered as soils for geotechnical testing.

Testing of rocks from other areas in the Powder River Basin, near Quietus, Mont., Sheridan, Buffalo, and Monarch, Wyo., is in progress at this writing. It is hoped that results from this testing, along with those in this report, will give more definitive answers to some of the engineering geologic problems of the rocks in the Fort Union Formation.

### Explanatory Notes

The Unified Soil Classification, gradation, and Atterberg limits are from the "Earth manual--A water resources technical publication" (U.S. Bureau of Reclamation, 1974):

1. Unified Soil Classification System.
2. Gradation (grain-size distribution): ASTM designation D-422-63. Material finer than a No. 200 sieve is subdivided as follows--silt, 0.074-0.004 mm; clay-size is less than 0.004 mm, according the Wentworth classification (1922).
3. Atterberg limits: ASTM designation D-423-66, liquid limit of soils. ASTM designation D-424-54T, plastic and plasticity index of soils.

The following field index tests are described in Aufmuth (1974):

1. The Schmidt rebound hammer is essentially a nondestructive, portable, and inexpensive test device that expends a definite amount of energy stored in a spring (approximately 0.54 ft/lb) in impelling a steel hammer of uniform weight and cross-sectional area against the material's surface. The amount of rebound of the hammer after striking the surface is indicated on a graduated scale. This number has been designated as "R," and has been correlated with the compressive strength of concrete and rock. Values shown in the column are in "R's".
2. The slake durability test is a measurement of the resistance of a rock to weakening and (or) disintegration resulting from cyclic wetting and drying. Values shown in the column are the percentages of material larger than 2 mm remaining after the test. Ten rock specimens, each weighing 40-60 g and oven-dried at 43°C to constant weight, are placed in a 2-mm standard mesh cylinder. The cylinder is placed in a water tank containing distilled water as the slaking fluid and is rotated at 20 r/min  $\pm$  1 r/min by a motor assembly for 10 minutes. Then the mesh drum is removed from the slaking fluid tank, and the remaining material is removed from the drum, dried to constant weight, and weighed. The slake durability index is calculated as the percentage ratio of the final to initial dry-sample weight. Data for one cycle are shown in this report.

3. The point-load strength test is intended to measure the strength of rock samples in the form of specimens of regular geometry. Testing was done on natural core in the field and as received in the laboratory. Data obtained consist of failure load in psi (pounds per square inch) at time of failure, and the core diameter and (or) cross-sectional area at initial loading. From this, the point-load tensile strength of the rock may be calculated. Values shown in the column by the triangles are the tensile strengths parallel to bedding, and, by the circles, normal to bedding. These values are expressed in  $\text{MN/m}^2$  (meganewtons per square meter). The test procedure was described in detail by Broch and Franklin (1972).

# Geologic and Geotechnical Log of Drill Hole RM-1

Powder River Basin  
Recluse area  
Hole RM-1  
Collar elevation: 4204'

Depth feet	Description of lithology taken from Hobbs and others, 1977)	Fracture spacing (cm)	Unified Soil Classification <sup>3</sup>	Grain size distribution (percentage of dry soil weight)	As-received water content & Atterberg limits (percentage of dry soil weight)	Slake durability index (pct. of dry soil weight retained)	Schmidt hammer index <sup>6</sup>	Point-to-point penetration index <sup>7</sup> MN m <sup>2</sup>	Vane shear strength <sup>8</sup> lb/ft <sup>2</sup> $\frac{\Delta}{\sigma}$
24	Mudstone, gray to dark gray, slightly silty, some mottling		CH	25 75	(+)				1.2
25									
30	Mudstone, as above		CH	51 49	(-)	88			1.4
31	Shale, brown, numerous silty streaks, highly carbonaceous, coal streaks and stringers								
32	Coal, dark brown, highly fractured								
36	Mudstone, dark brown to black, highly carbonaceous		CH	32 68	(T)				0.9
37	less carbonaceous, silty streaks, becomes more grayish in color								
39	massive and hard								
41	Shale, dark brown to black, some silty streaks		CH	41 59	(T)	95			1.0
42	slightly laminated								
43	becomes browner in color with depth								
44	carbonaceous streaks								
45	Coal, dull, woody, shaly streaks		MH	1 46 53	(T)				0.18
46									
47	Mudstone, brown grading to gray, silty Sandstone, gray, very fine to fine grained, some bedding								
48	thin carbonaceous zones								
220									
221									
222									
223									
224									
225									
226									
227									
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300									

Explanatory notes:

See Graphic Lithology Key in Appendix

Asterisk, \*, shows sample depth

<sup>3</sup>Symbols from Unified Soil Classification Chart (from U.S. Bureau of Reclamation, 1974).

<sup>4</sup>PL = plastic limit  
LL = liquid limit  
○ = natural water content

<sup>5</sup>+, positive  
-, negative  
T, trace

<sup>6</sup>Black-faced Rocks

<sup>7</sup>Δ = value recorded parallel to bedding

○ = value recorded perpendicular to bedding

# Geologic and Geotechnical Log of Drill Hole RM-2

Powder River Basin Recluse area Hole RM-2 Collar elevation: 4238'		(Description of lithology taken from Hobbs and others, 1977)	Fracture spacing (cm)	Unified Soil Classification	Grain size distribution (percentage of dry soil weight)	Sand	Silt	Clay	As-received water content & Atterberg limits (percentage of dry soil weight)	5 <sub>CaCO<sub>3</sub></sub>	Slake durability index (pct. of dry soil weight retained)	Schmidt hammer Index <sup>6</sup>	Point-load strength <sup>7</sup> (MPa)	Angle of internal friction <sup>8</sup> (°)
Depth (m)	Depth (ft)	Lithologic description	5	15	25				PL <sup>4</sup>	LL <sup>4</sup>		30	0.3	0.6
1	3	Mudstone, brown to gray												
2	6	scattered sandstone laminae and beds												
3	9													
4	12													
5	15													
6	18	Sandstone, brown to buff, silty, scattered carbonaceous flakes and fragments				CL	53	47			(+)			
7	21	friable				CL	51	49			(+)			
8	24													
9	27					CL	42	58			(+)			
10	30	Mudstone, yellowish brown, oxidized coloration changing to gray and brown												
11	33					CH	38	62			(T)			
12	36					CH	7	93			(-)			
13	39	silty												
14	42													
15	45	dark gray, slightly carbonaceous fractures common				CH	29	71			(+)			
16	48	scattered siltstone zones				CH	38	62			(+)			
17	51	Shale, dark brown, highly carbonaceous to coaly												
18	54	Mudstone, gray to light gray, carbonaceous streaks				CH	38	62			(+)			
19	57	Sandstone, medium to light gray, very fine to fine grained, subangular				ML	40	28	32		(T)			

EXPLANATORY notes:  
1 See Graphic Lithology Key in Appendix  
2 Asterisk, \*, shows sample depth

<sup>3</sup>Symbols from Unified Soil  
Classification Chart (from  
U.S. Bureau of Reclamation,  
1974).

<sup>4</sup>PL = plastic limit  
LL = liquid limit  
O = natural water  
content

<sup>5</sup>+, positive  
-, negative  
T, trace

<sup>6</sup>Dimensionless R number

<sup>7</sup>Δ = value recorded parallel  
to bedding  
O = value recorded perpendicular  
to bedding

9

Explanatory notes:

<sup>1</sup>See Graphic Lithology Key in Appendix

<sup>2</sup>Asterisk, \*, shows sample depth

<sup>3</sup>Symbols from Unified Soil  
Classification Chart (from  
U.S. Bureau of Reclamation,  
1974).

<sup>4</sup>PL = plastic limit  
LL = liquid limit  
O = natural water  
content

<sup>5</sup>Dimensionless R<sub>value</sub>  
<sup>6</sup>Δ = value recorded parallel  
to bedding  
O = value recorded perpendicular  
to bedding



# Geologic and Geotechnical Log of Drill Hole RM-2--Continued

Used in River Basin  
Reclamation  
Hole RM-2  
Cottrell reference 4238'

Depth (feet)	Lithologic description (Description of lithology taken from Hobbs and others, 1977)	Fracture spacing (cm)	Unified Soil Classification <sup>1</sup>	Grain size distribution (percentage of dry soil weight) Sand Silt Clay	As-received water content & Atterberg limits (percentage of dry soil weight) PL LL <sup>2</sup>	s <sub>u</sub> (psf)	Slab durability (% index of dry soil retained)	Shield hammer index <sup>3</sup>	MW	Δ
-41	Siltstone, light gray to brown		CH	31 69		(+)				
-42	Mudstone, gray									
-43	Mudstone, gray, very silty, numerous light gray brown calcareous sandy streaks		CR	30 70		(+)				
-44	scattered shell fragments									
-45										
-46	shaly, scattered carbonaceous flakes		CH	35 67		(+)				
-47										
-48										
-49	Siltstone, gray, shaly with some sandy streaks		CH	27 73		(-)				
-50										
-51	Mudstone, gray to dark gray brown, sandy, carbonaceous									
-52	Shale, dark brown to black, grades to coal		CL	5 47 48		(-)				
-53	Mudstone, as above									
-54										
-55	carbonaceous streaks and sandy		MR	51 49		(-)				
-56										
-57										
-58	Shale, dark grayish brown, carbona- ceous, silty to sandy zones									
-59										

Plastic limit  
LL = Liquid limit

Plastic limit  
LL = Liquid limit

Symbols from Unified Soil  
Classification Chart (from  
U.S. Bureau of Reclamation,  
1974).

See Appendix Key in Appendix  
A for new sample depth

Explained

Geologic and Geotechnical Log of Drill Hole RM-2--Continued

Powder River Basin  
Be. 205-000  
Hole RM-2  
Cohesion 4238'

Depth ft	Lithologic description (Description of lithology taken from Hobbs and others, 1977)	Fracture spacing (cm)	Unified Soil Classification <sup>1</sup>	Grain size distribution (percentage of dry soil weight)	As-received water content & atterberg limits (percentage of dry soil weight)	Shrinkage value index (per cent of weight retained)	Schmidt hammer index <sup>2</sup>	Soil strength index <sup>3</sup>	Δ <sup>4</sup>
-200-61	Shale, dark grayish brown, silty carbonaceous and coal stringers	15-20	ME	58 42	PL 30 LL 40	(-)	20		
-62	Coal, bright to dull, semi-banded, fractured and blocky								
-63									
-64	highly pyritic								
-65									
-66									
-67									
-68	highly fractured zones								
-69									
-70	Shale parting, dark gray to black, carbonaceous, grades to claystone								
-71	Claystone, light gray to black, carbonaceous to coaly, grades to shale								
-72	Coal, dark brown to black, silty								
-73	fractured pyritic shale parting as above								
-74									
-75									
-250-76	some banding and occasional woody material								
-77									
-78									
-79									
-80	less fractured								

<sup>1</sup>Symbols from Unified Soil  
Classification Chart (from  
U.S. Bureau of Reclamation,  
1974).

<sup>2</sup>PL = plastic limit  
LL = liquid limit  
O = natural water  
content

<sup>3</sup>Δ = value re bedded portion  
to bedding  
O = value re bedded portion  
to bedding

Posner River Basin  
Recurve area  
Hole  
RM-2  
Elevation: 4238'

# Geologic and Geotechnical Log of Drill Hole RM-2--Continued

Depth (feet)	Lithologic description	Fracture spacing (cm)	Unified Soil Classification	Grain size distribution (percentage of dry soil weight)	As-received water content & Atterberg limits (percentage of dry soil weight)				Slake durability index (% of dry soil weight retained)	Schmidt hammer index	Pore water pressure (psf)	Δ
					PL	LL	PI	LI				
81	Coal, dull to shiny		CL	8 58 34	10	30	20	20				
82	Mudstone, light gray, coaly streaks											
83	Sandstone, gray fine grained		CL	9 57 34								
84	Siltstone, gray, shaly and coaly											
85	Sandstone, as above											
86												
87												
88												
89												
90												
91	Sandstone, as above		CL	2 51 47								
92												
93												
94	Sandstone, petrolierous											
95	Shale, dark gray to brown, carbonaceous		CL	3 50 47								
96	Coal, dark brown, clayey											
97	pyritic fractures											
98	low grade - poor quality											
99												

Symbols from Unified Soil Classification Chart (from U.S. Bureau of Reclamation, 1974).  
 PL = plastic limit  
 LL = liquid limit  
 PI = plasticity index  
 LI = liquid index  
 Δ = value recorded  
 O = value recorded perpendicular to bedding  
 to bedding

Geologic and Geotechnical Log of Drill Hole RM-2--Continued

Cooper River Basin Re-use area CRM-2 Well elevation: 4238'		Depth		Lithologic description (Description of lithology taken from Hobbs and others, 1977)		Fracture spacing (cm)		Unified Soil Classification		Grain size distribution (percentage of dry soil weight)		As-received water content & Atterberg limits (percentage of dry soil weight)		Shrinkage index <sup>a</sup>		Slake durability index (per cent dry soil weight retained)		Shrinkage index <sup>b</sup>		Shrinkage index <sup>c</sup>		Shrinkage index <sup>d</sup>		Shrinkage index <sup>e</sup>		Shrinkage index <sup>f</sup>		Shrinkage index <sup>g</sup>		Shrinkage index <sup>h</sup>		Shrinkage index <sup>i</sup>		Shrinkage index <sup>j</sup>		Shrinkage index <sup>k</sup>		Shrinkage index <sup>l</sup>		Shrinkage index <sup>m</sup>		Shrinkage index <sup>n</sup>		Shrinkage index <sup>o</sup>		Shrinkage index <sup>p</sup>		Shrinkage index <sup>q</sup>		Shrinkage index <sup>r</sup>		Shrinkage index <sup>s</sup>		Shrinkage index <sup>t</sup>		Shrinkage index <sup>u</sup>		Shrinkage index <sup>v</sup>		Shrinkage index <sup>w</sup>		Shrinkage index <sup>x</sup>		Shrinkage index <sup>y</sup>		Shrinkage index <sup>z</sup>		Shrinkage index <sup>aa</sup>		Shrinkage index <sup>ab</sup>		Shrinkage index <sup>ac</sup>		Shrinkage index <sup>ad</sup>		Shrinkage index <sup>ae</sup>		Shrinkage index <sup>af</sup>		Shrinkage index <sup>ag</sup>		Shrinkage index <sup>ah</sup>		Shrinkage index <sup>ai</sup>		Shrinkage index <sup>aj</sup>		Shrinkage index <sup>ak</sup>		Shrinkage index <sup>al</sup>		Shrinkage index <sup>am</sup>		Shrinkage index <sup>an</sup>		Shrinkage index <sup>ao</sup>		Shrinkage index <sup>ap</sup>		Shrinkage index <sup>aq</sup>		Shrinkage index <sup>ar</sup>		Shrinkage index <sup>as</sup>		Shrinkage index <sup>at</sup>		Shrinkage index <sup>au</sup>		Shrinkage index <sup>av</sup>		Shrinkage index <sup>aw</sup>		Shrinkage index <sup>ax</sup>		Shrinkage index <sup>ay</sup>		Shrinkage index <sup>az</sup>		Shrinkage index <sup>ba</sup>		Shrinkage index <sup>bb</sup>		Shrinkage index <sup>bc</sup>		Shrinkage index <sup>bd</sup>		Shrinkage index <sup>be</sup>		Shrinkage index <sup>bf</sup>		Shrinkage index <sup>bg</sup>		Shrinkage index <sup>bh</sup>		Shrinkage index <sup>bi</sup>		Shrinkage index <sup>bj</sup>		Shrinkage index <sup>bk</sup>		Shrinkage index <sup>bl</sup>		Shrinkage index <sup>bm</sup>		Shrinkage index <sup>bn</sup>		Shrinkage index <sup>bo</sup>		Shrinkage index <sup>bp</sup>		Shrinkage index <sup>bq</sup>		Shrinkage index <sup>br</sup>		Shrinkage index <sup>bs</sup>		Shrinkage index <sup>bt</sup>		Shrinkage index <sup>bu</sup>		Shrinkage index <sup>bv</sup>		Shrinkage index <sup>bw</sup>		Shrinkage index <sup>bx</sup>		Shrinkage index <sup>by</sup>		Shrinkage index <sup>bz</sup>		Shrinkage index <sup>ca</sup>		Shrinkage index <sup>cb</sup>		Shrinkage index <sup>cc</sup>		Shrinkage index <sup>cd</sup>		Shrinkage index <sup>ce</sup>		Shrinkage index <sup>cf</sup>		Shrinkage index <sup>cg</sup>		Shrinkage index <sup>ch</sup>		Shrinkage index <sup>ci</sup>		Shrinkage index <sup>cj</sup>		Shrinkage index <sup>ck</sup>		Shrinkage index <sup>cl</sup>		Shrinkage index <sup>cm</sup>		Shrinkage index <sup>cn</sup>		Shrinkage index <sup>co</sup>		Shrinkage index <sup>cp</sup>		Shrinkage index <sup>cq</sup>		Shrinkage index <sup>cr</sup>		Shrinkage index <sup>cs</sup>		Shrinkage index <sup>ct</sup>		Shrinkage index <sup>cu</sup>		Shrinkage index <sup>cv</sup>		Shrinkage index <sup>cw</sup>		Shrinkage index <sup>cx</sup>		Shrinkage index <sup>cy</sup>		Shrinkage index <sup>cz</sup>		Shrinkage index <sup>da</sup>		Shrinkage index <sup>db</sup>		Shrinkage index <sup>dc</sup>		Shrinkage index <sup>dd</sup>		Shrinkage index <sup>de</sup>		Shrinkage index <sup>df</sup>		Shrinkage index <sup>dg</sup>		Shrinkage index <sup>dh</sup>		Shrinkage index <sup>di</sup>		Shrinkage index <sup>dj</sup>		Shrinkage index <sup>dk</sup>		Shrinkage index <sup>dl</sup>		Shrinkage index <sup>dm</sup>		Shrinkage index <sup>dn</sup>		Shrinkage index <sup>do</sup>		Shrinkage index <sup>dp</sup>		Shrinkage index <sup>dq</sup>		Shrinkage index <sup>dr</sup>		Shrinkage index <sup>ds</sup>		Shrinkage index <sup>dt</sup>		Shrinkage index <sup>du</sup>		Shrinkage index <sup>dv</sup>		Shrinkage index <sup>dw</sup>		Shrinkage index <sup>dx</sup>		Shrinkage index <sup>dy</sup>		Shrinkage index <sup>dz</sup>		Shrinkage index <sup>ea</sup>		Shrinkage index <sup>eb</sup>		Shrinkage index <sup>ec</sup>		Shrinkage index <sup>ed</sup>		Shrinkage index <sup>ee</sup>		Shrinkage index <sup>ef</sup>		Shrinkage index <sup>eg</sup>		Shrinkage index <sup>eh</sup>		Shrinkage index <sup>ei</sup>		Shrinkage index <sup>ej</sup>		Shrinkage index <sup>ek</sup>		Shrinkage index <sup>el</sup>		Shrinkage index <sup>em</sup>		Shrinkage index <sup>en</sup>		Shrinkage index <sup>eo</sup>		Shrinkage index <sup>ep</sup>		Shrinkage index <sup>eq</sup>		Shrinkage index <sup>er</sup>		Shrinkage index <sup>es</sup>		Shrinkage index <sup>et</sup>		Shrinkage index <sup>eu</sup>		Shrinkage index <sup>ev</sup>		Shrinkage index <sup>ew</sup>		Shrinkage index <sup>ex</sup>		Shrinkage index <sup>ey</sup>		Shrinkage index <sup>ez</sup>		Shrinkage index <sup>fa</sup>		Shrinkage index <sup>fb</sup>		Shrinkage index <sup>fc</sup>		Shrinkage index <sup>fd</sup>		Shrinkage index <sup>fe</sup>		Shrinkage index <sup>ff</sup>		Shrinkage index <sup>fg</sup>		Shrinkage index <sup>fh</sup>		Shrinkage index <sup>fi</sup>		Shrinkage index <sup>fj</sup>		Shrinkage index <sup>fk</sup>		Shrinkage index <sup>fl</sup>		Shrinkage index <sup>fm</sup>		Shrinkage index <sup>fn</sup>		Shrinkage index <sup>fo</sup>		Shrinkage index <sup>fp</sup>		Shrinkage index <sup>fq</sup>		Shrinkage index <sup>fr</sup>		Shrinkage index <sup>fs</sup>		Shrinkage index <sup>ft</sup>		Shrinkage index <sup>fu</sup>		Shrinkage index <sup>fv</sup>		Shrinkage index <sup>fw</sup>		Shrinkage index <sup>fx</sup>		Shrinkage index <sup>fy</sup>		Shrinkage index <sup>fz</sup>		Shrinkage index <sup>ga</sup>		Shrinkage index <sup>gb</sup>		Shrinkage index <sup>gc</sup>		Shrinkage index <sup>gd</sup>		Shrinkage index <sup>ge</sup>		Shrinkage index <sup>gf</sup>		Shrinkage index <sup>gg</sup>		Shrinkage index <sup>gh</sup>		Shrinkage index <sup>gi</sup>		Shrinkage index <sup>gj</sup>		Shrinkage index <sup>gk</sup>		Shrinkage index <sup>gl</sup>		Shrinkage index <sup>gm</sup>		Shrinkage index <sup>gn</sup>		Shrinkage index <sup>go</sup>		Shrinkage index <sup>gp</sup>		Shrinkage index <sup>gq</sup>		Shrinkage index <sup>gr</sup>		Shrinkage index <sup>gs</sup>		Shrinkage index <sup>gt</sup>		Shrinkage index <sup>gu</sup>		Shrinkage index <sup>gv</sup>		Shrinkage index <sup>gw</sup>		Shrinkage index <sup>gx</sup>		Shrinkage index <sup>gy</sup>		Shrinkage index <sup>gz</sup>		Shrinkage index <sup>ha</sup>		Shrinkage index <sup>hb</sup>		Shrinkage index <sup>hc</sup>		Shrinkage index <sup>hd</sup>		Shrinkage index <sup>he</sup>		Shrinkage index <sup>hf</sup>		Shrinkage index <sup>hg</sup>		Shrinkage index <sup>hh</sup>		Shrinkage index <sup>hi</sup>		Shrinkage index <sup>hj</sup>		Shrinkage index <sup>hk</sup>		Shrinkage index <sup>hl</sup>		Shrinkage index <sup>hm</sup>		Shrinkage index <sup>hn</sup>		Shrinkage index <sup>ho</sup>		Shrinkage index <sup>hp</sup>		Shrinkage index <sup>hq</sup>		Shrinkage index <sup>hr</sup>		Shrinkage index <sup>hs</sup>		Shrinkage index <sup>ht</sup>		Shrinkage index <sup>hu</sup>		Shrinkage index <sup>hv</sup>		Shrinkage index <sup>hw</sup>		Shrinkage index <sup>hx</sup>		Shrinkage index <sup>hy</sup>		Shrinkage index <sup>hz</sup>		Shrinkage index <sup>ia</sup>		Shrinkage index <sup>ib</sup>		Shrinkage index <sup>ic</sup>		Shrinkage index <sup>id</sup>		Shrinkage index <sup>ie</sup>		Shrinkage index <sup>if</sup>		Shrinkage index <sup>ig</sup>		Shrinkage index <sup>ih</sup>		Shrinkage index <sup>ii</sup>		Shrinkage index <sup>ij</sup>		Shrinkage index <sup>ik</sup>		Shrinkage index <sup>il</sup>		Shrinkage index <sup>im</sup>		Shrinkage index <sup>in</sup>		Shrinkage index <sup>io</sup>		Shrinkage index <sup>ip</sup>		Shrinkage index <sup>iq</sup>		Shrinkage index <sup>ir</sup>		Shrinkage index <sup>is</sup>		Shrinkage index <sup>it</sup>		Shrinkage index <sup>iu</sup>		Shrinkage index <sup>iv</sup>		Shrinkage index <sup>iw</sup>		Shrinkage index <sup>ix</sup>		Shrinkage index <sup>iy</sup>		Shrinkage index <sup>iz</sup>		Shrinkage index <sup>ja</sup>		Shrinkage index <sup>jb</sup>		Shrinkage index <sup>jc</sup>		Shrinkage index <sup>jd</sup>		Shrinkage index <sup>je</sup>		Shrinkage index <sup>jf</sup>		Shrinkage index <sup>jg</sup>		Shrinkage index <sup>jh</sup>		Shrinkage index <sup>ji</sup>		Shrinkage index <sup>jj</sup>		Shrinkage index <sup>jk</sup>		Shrinkage index <sup>jl</sup>		Shrinkage index <sup>jm</sup>		Shrinkage index <sup>jn</sup>		Shrinkage index <sup>jo</sup>		Shrinkage index <sup>jp</sup>		Shrinkage index <sup>jq</sup>		Shrinkage index <sup>jr</sup>		Shrinkage index <sup>js</sup>		Shrinkage index <sup>jt</sup>		Shrinkage index <sup>ju</sup>		Shrinkage index <sup>jv</sup>		Shrinkage index <sup>jw</sup>		Shrinkage index <sup>jx</sup>		Shrinkage index <sup>jy</sup>		Shrinkage index <sup>jz</sup>		Shrinkage index <sup>ka</sup>		Shrinkage index <sup>kb</sup>		Shrinkage index <sup>kc</sup>		Shrinkage index <sup>kd</sup>		Shrinkage index <sup>ke</sup>		Shrinkage index <sup>kf</sup>		Shrinkage index <sup>kg</sup>		Shrinkage index <sup>kh</sup>		Shrinkage index <sup>ki</sup>		Shrinkage index <sup>kj</sup>		Shrinkage index <sup>kk</sup>		Shrinkage index <sup>kl</sup>		Shrinkage index <sup>km</sup>		Shrinkage index <sup>kn</sup>		Shrinkage index <sup>ko</sup>		Shrinkage index <sup>kp</sup>		Shrinkage index <sup>kq</sup>		Shrinkage index <sup>kr</sup>		Shrinkage index <sup>ks</sup>		Shrinkage index <sup>kt</sup>		Shrinkage index <sup>ku</sup>		Shrinkage index <sup>kv</sup>		Shrinkage index <sup>kw</sup>		Shrinkage index <sup>kx</sup>		Shrinkage index <sup>ky</sup>		Shrinkage index <sup>kz</sup>		Shrinkage index <sup>la</sup>		Shrinkage index <sup>lb</sup>		Shrinkage index <sup>lc</sup>		Shrinkage index <sup>ld</sup>		Shrinkage index <sup>le</sup>		Shrinkage index <sup>lf</sup>		Shrinkage index <sup>lg</sup>		Shrinkage index <sup>lh</sup>		Shrinkage index <sup>li</sup>		Shrinkage index <sup>lj</sup>		Shrinkage index <sup>lk</sup>		Shrinkage index <sup>ll</sup>		Shrinkage index <sup>lm</sup>		Shrinkage index <sup>ln</sup>		Shrinkage index <sup>lo</sup>		Shrinkage index <sup>lp</sup>		Shrinkage index <sup>lq</sup>		Shrinkage index <sup>lr</sup>		Shrinkage index <sup>ls</sup>		Shrinkage index <sup>lt</sup>		Shrinkage index <sup>lu</sup>		Shrinkage index <sup>lv</sup>		Shrinkage index <sup>lw</sup>		Shrinkage index <sup>lx</sup>		Shrinkage index <sup>ly</sup>		Shrinkage index <sup>lz</sup>		Shrinkage index <sup>ma</sup>		Shrinkage index <sup>mb</sup>		Shrinkage index <sup>mc</sup>		Shrinkage index <sup>md</sup>		Shrinkage index <sup>me</sup>		Shrinkage index <sup>mf</sup>		Shrinkage index <sup>mg</sup>		Shrinkage index <sup>mh</sup>		Shrinkage index <sup>mi</sup>		Shrinkage index <sup>mj</sup>		Shrinkage index <sup>mk</sup>		Shrinkage index <sup>ml</sup>		Shrinkage index <sup>mm</sup>		Shrinkage index <sup>mn</sup>		Shrinkage index <sup>mo</sup>		Shrinkage index <sup>mp</sup>		Shrinkage index <sup>mq</sup>		Shrinkage index <sup>mr</sup>		Shrinkage index <sup>ms</sup>		Shrinkage index <sup>mt</sup>		Shrinkage index <sup>mu</sup>		Shrinkage index <sup>mv</sup>		Shrinkage index <sup>mw</sup>		Shrinkage index <sup>mx</sup>		Shrinkage index <sup>my</sup>		Shrinkage index <sup>mz</sup>		Shrinkage index <sup>na</sup>		Shrinkage index <sup>nb</sup>		Shrinkage index <sup>nc</sup>		Shrinkage index <sup>nd</sup>		Shrinkage index <sup>ne</sup>		Shrinkage index <sup>nf</sup>		Shrinkage index <sup>ng</sup>		Shrinkage index <sup>nh</sup>		Shrinkage index <sup>ni</sup>		Shrinkage index <sup>nj</sup>		Shrinkage index <sup>nk</sup>		Shrinkage index <sup>nl</sup>		Shrinkage index <sup>nm</sup>		Shrinkage index <sup>nn</sup>		Shrinkage index <sup>no</sup>		Shrinkage index <sup>np</sup>		Shrinkage index <sup>nq</sup>		Shrinkage index <sup>nr</sup>		Shrinkage index <sup>ns</sup>		Shrinkage index <sup>nt</sup>		Shrinkage index <sup>nu</sup>		Shrinkage index <sup>nv</sup>		Shrinkage index <sup>nw</sup>		Shrinkage index <sup>nx</sup>		Shrinkage index <sup>ny</sup>		Shrinkage index <sup>nz</sup>		Shrinkage index <sup>oa</sup>		Shrinkage index <sup>ob</sup>		Shrinkage index <sup>oc</sup>		Shrinkage index <sup>od</sup>		Shrinkage index <sup>oe</sup>		Shrinkage index <sup>of</sup>		Shrinkage index <sup>og</sup>		Shrinkage index <sup>oh</sup>		Shrinkage index <sup>oi</sup>		Shrinkage index <sup>oj</sup>		Shrinkage index <sup>ok</sup>		Shrinkage index <sup>ol</sup>		Shrinkage index <sup>om</sup>		Shrinkage index <sup>on</sup>		Shrinkage index <sup>oo</sup>		Shrinkage index <sup>op</sup>		Shrinkage index <sup>oq</sup>		Shrinkage index <sup>or</sup>		Shrinkage index <sup>os</sup>		Shrinkage index <sup>ot</sup>		Shrinkage index <sup>ou</sup>		Shrinkage index <sup>ov</sup>		Shrinkage index <sup>ow</sup>		Shrinkage index <sup>ox</sup>		Shrinkage index <sup>oy</sup>		Shrinkage index <sup>oz</sup>		Shrinkage index <sup>pa</sup>		Shrinkage index <sup>pb</sup>		Shrinkage index <sup>pc</sup>		Shrinkage index <sup>pd</sup>		Shrinkage index <sup>pe</sup>		Shrinkage index <sup>pf</sup>		Shrinkage index <sup>pg</sup>		Shrinkage index <sup>ph</sup>		Shrinkage index <sup>pi</sup>		Shrinkage index <sup>pj</sup>		Shrinkage index <sup>pk</sup>		Shrinkage index <sup>pl</sup>		Shrinkage index <sup>pm</sup>		Shrinkage index <sup>pn</sup>		Shrinkage index <sup>po</sup>		Shrinkage index <sup>pp</sup>		Shrinkage index <sup>pq</sup>		Shrinkage index <sup>pr</sup>		Shrinkage index <sup>ps</sup>		Shrinkage index <sup>pt</sup>		Shrinkage index <sup>pu</sup>		Shrinkage index <sup>pv</sup>		Shrinkage index <sup>pw</sup>		Shrinkage index <sup>px</sup>		Shrinkage index <sup>py</sup>		Shrinkage index <sup>pz</sup>		Shrinkage index <sup>qa</sup>		Shrinkage index <sup>qb</sup>		Shrinkage index <sup>qc</sup>		Shrinkage index <sup>qd</sup>		Shrinkage index <sup>qe</sup>		Shrinkage index <sup>qf</sup>		Shrinkage index <sup>qg</sup>		Shrinkage index <sup>qh</sup>		Shrinkage index <sup>qi</sup>		Shrinkage index <sup>qj</sup>		Shrinkage index <sup>qk</sup>		Shrinkage index <sup>ql</sup>		Shrinkage index <sup>qm</sup>		Shrinkage index <sup>qn</sup>		Shrinkage index <sup>qo</sup>		Shrinkage index <sup>qp</sup>		Shrinkage index <sup>qq</sup>		Shrinkage index <sup>qr</sup>		Shrinkage index <sup>qs</sup>		Shrinkage index <sup>qt</sup>		Shrinkage index <sup>qu</sup>		Shrinkage index <sup>qv</sup>		Shrinkage index <sup>qw</sup>		Shrinkage index <sup>qx</sup>		Shrinkage index <sup>qy</sup>		Shrinkage index <sup>qz</sup>		Shrinkage index <sup>ra</sup>		Shrinkage index <sup>rb</sup>		Shrinkage index <sup>rc</sup>		Shrinkage index <sup>rd</sup>		Shrinkage index <sup>re</sup>		Shrinkage index <sup>rf</sup>		Shrinkage index <sup>rg</sup>		Shrinkage index <sup>rh</sup>		Shrinkage index <sup>ri</sup>		Shrinkage index <sup>rj</sup>		Shrinkage index <sup>rk</sup>		Shrinkage index <sup>rl</sup>		Shrinkage index <sup>rm</sup>		Shrinkage index <sup>rn</sup>		Shrinkage index <sup>ro</sup>		Shrinkage index <sup>rp</sup>		Shrinkage index <sup>rq</sup>		Shrinkage index <sup>rr</sup>		Shrinkage index <sup>rs</sup>		Shrinkage index <sup>rt</sup>		Shrinkage index <sup>ru</sup>		Shrinkage index <sup>rv</sup>		Shrinkage index <sup>rw</sup>		Shrinkage index <sup>rx</sup>		Shrinkage index <sup>ry</sup>		Shrinkage index <sup>rz</sup>		Shrinkage index <sup>sa</sup>		Shrinkage index <sup>sb</sup>		Shrinkage index <sup>sc</sup>		Shrinkage index <sup>sd</sup>		Shrinkage index <sup>se</sup>		Shrinkage index <sup>sf</sup>		Shrinkage index <sup>sg</sup>		Shrinkage index <sup>sh</sup>		Shrinkage index <sup>si</sup>		Shrinkage index <sup>sj</sup>		Shrinkage index <sup>sk</sup>		Shrinkage index <sup>sl</sup>		Shrinkage index <sup>sm</sup>		Shrinkage index <sup>sn</sup>		Shrinkage index <sup>so</sup>		Shrinkage index <sup>sp</sup>		Shrinkage index <sup>sq</sup>		Shrinkage index <sup>sr</sup>		Shrinkage index <sup>ss</sup>		Shrinkage index <sup>st</sup>		Shrinkage index <sup>su</sup>		Shrinkage index <sup>sv</sup>		Shrinkage index <sup>sw</sup>		Shrinkage index <sup>sx</sup>		Shrinkage index <sup>sy</sup>		Shrinkage index <sup>sz</sup>		Shrinkage index <sup>ta</sup>		Shrinkage index <sup>tb</sup>		Shrinkage index <sup>tc</sup>		Shrinkage index <sup>td</sup>		Shrinkage index <sup>te</sup>		Shrinkage index <sup>tf</sup>		Shrinkage index <sup>tg</sup>		Shrinkage index <sup>th</sup>		Shrinkage index <sup>ti</sup>		Shrinkage index <sup>tj</sup>		Shrinkage index <sup>tk</sup>		Shrinkage index <sup>tl</sup>		Shrinkage index <sup>tm</sup>		Shrinkage index <sup>tn</sup>		Shrinkage index <sup>to</sup>		Shrinkage index <sup>tp</sup>		Shrinkage index <sup>tq</sup>		Shrinkage index <sup>tr</sup>		Shrinkage index <sup>ts</sup>		Shrinkage index <sup>tt</sup>		Shrinkage index <sup>tu</sup>		Shrinkage index <sup>tv</sup>		Shrinkage index <sup>tw</sup>		Shrinkage index <sup>tx</sup>		Shrinkage index <sup>ty</sup>		Shrinkage index <sup>tz</sup>		Shrinkage index <sup>ua</sup>		Shrinkage index <sup>ub</sup>		Shrinkage index <sup>uc</sup>		Shrinkage index <sup>ud</sup>		Shrinkage index <sup>ue</sup>		Shrinkage index <sup>uf</sup>		Shrinkage index <sup>ug</sup>		Shrinkage index <sup>uh</sup>		Shrinkage index <sup>ui</sup>		Shrinkage index <sup>uj</sup>		Shrinkage index <sup>uk</sup>		Shrinkage index <sup>ul</sup>		Shrinkage index <sup>um</sup>		Shrinkage index <sup>un</sup>		Shrinkage index <sup>uo</sup>		Shrinkage index <sup>up</sup>		Shrinkage index <sup>uq</sup>		Shrinkage index <sup>ur</sup>		Shrinkage index <sup>us</sup>		Shrinkage index <sup>ut</sup>		Shrinkage index <sup>uu</sup>		Shrinkage index <sup>uv</sup>		Shrinkage index <sup>uw</sup>		Shrinkage index <sup>ux</sup>		Shrinkage index <sup>uy</sup>		Shrinkage index <sup>uz</sup>		Shrinkage index <sup>va</sup>		Shrinkage index <sup>vb</sup>		Shrinkage index <sup>vc</sup>		Shrinkage index <sup>vd</sup>		Shrinkage index <sup>ve</sup>		Shrinkage index <sup>vf</sup>		Shrinkage index <sup>vg</sup>		Shrinkage index <sup>vh</sup>		Shrinkage index <sup>vi</sup>		Shrinkage index <sup>vj</sup>		Shrinkage index <sup>vk</sup>		Shrinkage index <sup>vl</sup>		Shrinkage index <sup>vm</sup>		Shrinkage index <sup>vn</sup>		Shrinkage index <sup>vo</sup>		Shrinkage index <sup>vp</sup>		Shrinkage index <sup>vq</sup>		Shrinkage index <sup>vr</sup>		Shrinkage index <sup>vs</sup>		Shrinkage index <sup>vt</sup>		Shrinkage index <sup>vu</sup>		Shrinkage index <sup>vv</sup>		Shrinkage index <sup>vw</sup>		Shrinkage index <sup>vx</sup>		Shrinkage index <sup>vy</sup>		Shrinkage index <sup>vz</sup>		Shrinkage index <sup>wa</sup>		Shrinkage index <sup>wb</sup>		Shrinkage index <sup>wc</sup>		Shrinkage index <sup>wd</sup>		Shrinkage index <sup>we</sup>		Shrinkage index <sup>wf</sup>		Shrinkage index <sup>wg</sup>		Shrinkage index <sup>wh</sup>		Shrinkage index <sup>wi</sup>		Shrinkage index <sup>wj</sup>		Shrinkage index <sup>wk</sup>		Shrinkage index <sup>wl</sup>		Shrinkage index <sup>wm</sup>		Shrinkage index <sup>wn</sup>		Shrinkage index <sup>wo</sup>		Shrinkage index <sup>wp</sup>		Shrinkage index <sup>wq</sup>		Shrinkage index <sup>wr</sup>		Shrinkage index <sup>ws</sup>		Shrinkage index <sup>wt</sup>		Shrinkage index <sup>wu</sup>		Shrinkage index <sup>wv</sup>		Shrinkage index <sup>ww</sup>		Shrinkage index <sup>wx</sup>		Shrinkage index <sup>wy</sup>		Shrinkage index <sup>wz</sup>		Shrinkage index <sup>xa</sup>		Shrinkage index <sup>xb</sup>		Shrinkage index <sup>xc</sup>	
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Powder River Basin  
Recreation Area

Geologic and Geotechnical Log of Drill Hole RM-4

Powder Plotter Record Re Plotting		(Description of lithology taken from Hobbs and others, 1977)		Fracture spacing (cm)		Unified Soil Classification <sup>3</sup>		Grain size distribution (percentage of dry soil weight)		As-received water content & Atterberg limits (percentage of dry soil weight)		Slake durability index <sup>6</sup> (pct. of dry soil weight retained)		Schmidt hammer index <sup>6</sup>		Point-load strength <sup>7</sup> index <sup>7</sup> (MPa)		Uniform Soil Index <sup>8</sup>	
Depth (m)	Depth (ft)	Lithologic description		5	15	25	Sand	Silt	Clay	PL <sup>4</sup>	LL <sup>4</sup>	CaCO <sub>3</sub>	20	30	40	50	60	70	80
8	30	Mudstone, gray, fractured					CH					(+)							
9	30	Sandstone, light gray, medium grained numerous carbonaceous stringers					CH	42	58			(+)							
10	30	Mudstone, light gray brown					CH					(+)							
11	40	Sandstone, light gray, fine to medium grained, numerous carbona- ceous streaks					CH	58	42			(+)							
12	40	Siltstone, light gray, clayey, fissile					CH	45	55			(+)							
13	60	Mudstone, gray to dark gray, silty and sandy partings, fissile					CH					(+)							
14	60	Siltstone, light gray, very calcar- eous and hard					CH-MH	29	71			(T)							
15	115	Mudstone, black, carbonaceous, shaly					CH	30	70			(+)							
16	180	Mudstone, gray, silty					CL	51	49			(-)							
17	180	carbonaceous streaks																	
18	200	Mudstone, dark brown to black, shaly, carbonaceous					MH	15	7			(T)							
19	200	siltstone laminae and zones					CH-MH	6	10			(-)							
20	200						CL	8	42			(T)							
21	200						CH	24	76			(T)							

Explanatory notes:

<sup>1</sup>See Graphic Lithology Key in Appendix

<sup>2</sup>Asterisk, #, shows sample depth

<sup>3</sup>Symbols from Unified Soil  
Classification Chart (from  
U.S. Bureau of Reclamation,  
1974).

<sup>4</sup>PL = plastic limit  
LL = liquid limit  
Θ = natural water  
content

<sup>5</sup>Dimensionless - R units

<sup>6</sup>Δ = value recorded parallel  
to bedding

O = value recorded perpendicular  
to bedding

# Geologic and Geotechnical Log of Drill Hole RM-4--Continued

Powder River Basin Recluse area Hole RM-4 Gallat elevated foot 4142'		(Description of lithology taken from Hobbs and others, 1977)		Fracture spacing (cm)		Unified Soil Classification <sup>3</sup>		Grain size distribution (percentage of dry soil weight)		As-received water content & Atterberg limits (percentage of dry soil weight)		Slake durability index <sup>4</sup> (pet. of dry soil weight retained)		Schmidt hammer index <sup>5</sup>		Dimensionless R <sub>max</sub> s <sup>6</sup>	
Depth		Lithologic description		1 1.5 2.5		Sand Silt Clay		PL LL <sup>7</sup>		PL LL <sup>7</sup>		5 <sub>cat</sub> <sup>8</sup>		6		7	
-64		Mudstone, dark gray, carbonaceous															
-65		Mudstone, ss above															
-66		Siltstone, gray, sandy															
-67		Mudstone, as above															
-68		silty															
-69		Sandstone, medium gray, fine grained															
-70		Mudstone, dark gray, silty, carbonaceous															
-71		coaly stringers															
-72																	
-73		Siltstone, gray, very hard															
-74		Mudstone, medium to dark gray, carbonaceous															
-75																	
-76																	
-77																	
-78																	
-79		cosly streaks															
-80																	
-81																	
-82																	

Explanatory notes:

<sup>1</sup> See Graphic Lithology Key in Appendix

<sup>2</sup> Asterisk, \*, shows sample depth

<sup>3</sup> Symbols from Unified Soil Classification Chart (from U.S. Bureau of Reclamation, 1974).

<sup>4</sup> PL = plastic limit  
LL = liquid limit  
O = natural water content

<sup>5</sup> +, positive  
-, negative  
T, trace

<sup>6</sup> Dimensionless R<sub>max</sub>s

<sup>7</sup> Δ = value recorded parallel to bedding

O = value recorded perpendicular to bedding

# Geologic and Geotechnical Log of Drill Hole RM-4--Continued

<p>                     (Description of lithology taken from Hobbs and others, 1977)                      Lithology description                 </p>		<p>Fracture spacing (cm)</p>	<p>Unified Soil Classification</p>	<p>Grain size distribution (percentage of dry soil weight)</p> <p>Sand Silt Clay</p>	<p>Atterberg limits (percentage of dry soil weight)</p> <p>PL LL</p>	<p>Shake density index (ppt. of light retained)</p>	<p>Schmidt hammer index</p>	<p>Moisture content (%)</p>	<p>Δ</p>
<p>Mudstone, dark gray, carbonaceous</p>	84		CH	29 71		(T)			
	85								
	86								
<p>Coal, black, cleat fractures</p>	87		CH	13 87		(T)			
	88								
	89								
	90		CL-ML	29 71		(T)			
	91								
	92								

Explanatory notes:

See Graphic Lithology Key in Appendix

\* Asterisk, \*, shows sample depth

Symbols from Unified Soil Classification Chart (from U.S. Bureau of Reclamation, 1974).

PL = plastic limit  
LL = liquid limit  
Θ = natural water content

+, positive  
-, negative  
L, trace

Dimensions, P units

Δ = value recorded parallel to bedding

Q = value recorded perpendicular to bedding



Geologic and Geotechnical Log of Drill Hole RH-6--Continued

Depth (feet)	Description of lithology taken from Hobbs and others, 1977)	Fracture spacing (cm)	Unified Soil Classifi- cation	Grain size distribution (percentage of dry soil weight)			As-received water content & Atterberg limits (percentage of dry soil weight)			Slake durability index (pct. of dry soil weight retained)	Schmidt hammer index 6	Point-load strength index 7 (MPa)	Unconfined compressive strength (MPa)
				Sand	Silt	Clay	PL	LL	SH				
48	Sandstone, light gray, very fine to fine grained, silty, scattered coaly streaks and pyritic nodules	5	CL	1	20	79	10	30	50	90	20	50	0.1
49													
50	Sandstone, as above		ML-CL	1	65	34	10	30	50	90			
51													
52	Siltstone, light gray, irregular bedding, pyritic, scattered plant fragments and calcareous fossils		ML-CL		33	67	10	30	50	90			
53													
54													
55													

Explanatory notes:

1. See Graphic Lithology Key in Appendix

2. Asterisk, \*, shows sample depth

<sup>3</sup>Symbols from Unified Soil  
Classification Chart (from  
U.S. Bureau of Reclamation,  
1974).

<sup>4</sup>PL = plastic limit  
LL = liquid limit  
SH = natural water  
content

<sup>5</sup>+, positive  
-, negative  
T, trace

<sup>6</sup>Dimensionless R units

<sup>7</sup>Δ = value recorded parallel  
to bedding

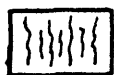
O = value recorded perpendicular  
to bedding

## References

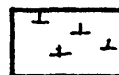
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## Appendix

# LITHOLOGIC SYMBOLS



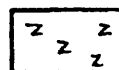
Soil horizons  
and root zones



Calcareous



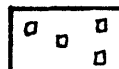
Shale



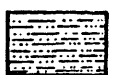
Plant fragments



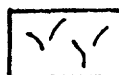
Sandstone



Pyritic



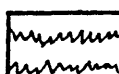
Siltstone



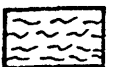
Slickensides



Claystone



Washed-out zones,  
core loss



Mudstone



Coal

### Legal Descriptions of Drill Holes

RM-1	SE1/4 SW1/4 NW1/4 sec. 33, T. 56 N., R. 72 W.
RM-2	SW1/4 SW1/4 NE1/4 sec. 32, T. 56 N., R. 72 W.
RM-3	NE1/4 NW1/4 NW1/4 sec. 25, T. 56 N., R. 73 W.
RM-4	NE1/4 SW1/4 SW1/4 sec. 25, T. 56 N., R. 73 W.
RM-6	NE1/4 NW1/4 NE1/4 sec. 21, T. 56 N., R. 73 W.