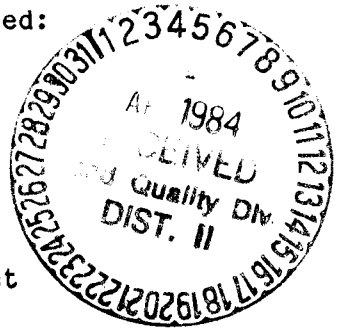
D-5. Geology and Overburden Assessment

The proposed amendment areas are located on the Frontier, Mowry, and Thermopolis shale geological formations. The Red Hole area contains pits 98T, phases 2 through 4, and pit 73T, phase 2, on the Mowry formation, pit 104T, phases 1 and 5 through 7, on the Frontier formation, and Pit 75T, phase 2, on the Thermopolis Shale formation. The Wind area contains pit 108T, phases 1 through 17, on the Frontier formation. The Coal area contains pit 102T, phases 1 through 3, on the Thermopolis Shale formation.

METHODOLGY

Laboratory procedures for determining overburden chemistry included:



1. pH - measured on saturated paste
2. Cond., mmhos/cm - measured on saturated extract @ 25° C
3. Texture - U.S.D.A. textural class
4. Soluble Ca, Mg, and Na - meq/l - measured on saturated extract
5. SAR - Sodium Absorption Ratio

Samples were obtained by augering with a truck-mounted drill. Samples were put in clean paper bags and taken to the Wyo-Ben Lab in Billings, Montana, for testing. Representative portions of each sample were taken to Energy, Inc., in Billings for boron and selenium testing.

Suitability of overburden for potential root zone was determined with Land Quality Division Guideline No. 1, Table I-4 (January, 1981): Criteria to Establish Overburden Suitabilty (Table D-5.1, page 20).

Figure D-5.1, page 22, illustrates the surficial geology of the Red Hole area and Figure D-5.2, page 23, presents a stratigraphic cross-section at B-B, Figure D-5.1, of the area through pit 98T, phases 2 through 4. The lithology of the Red Hole area is described in Geology of Red Spring Anticline, Hot Springs County, Wyoming by Ray Jones Shlemon (1959). The Shlemon study used the bentonite member below the Peay sandstone as the basal member of the Frontier formation. Rioux (1958) used the siliceous shales below the basal Frontier (Peay) sandstone as the basal member of the Frontier formation. We generally recognize Peay sandstone as being the basal member of the Frontier formation, for all practical purposes, when determining the placement of bentonite members (beds) within the Frontier and Mowry formations.

Shlemon describes the lithologic character of the strata overlying the bentonite member under the Peay sandstone as:

> "Sandstone and argillaceous sandstone, medium-to fine-grained, gray to tan, weathering light gray to buff. Basal third highly argillaceous with stringers of black, organic, sandy shale. Contact with Unit 3 gradational.

TABLE D-5.1

LAND QUALITY DIVISION GUIDELINE NO. 1

TABLE I-4: CRITERIA TO ESTABLISH OVERBURDEN SUITABIITY

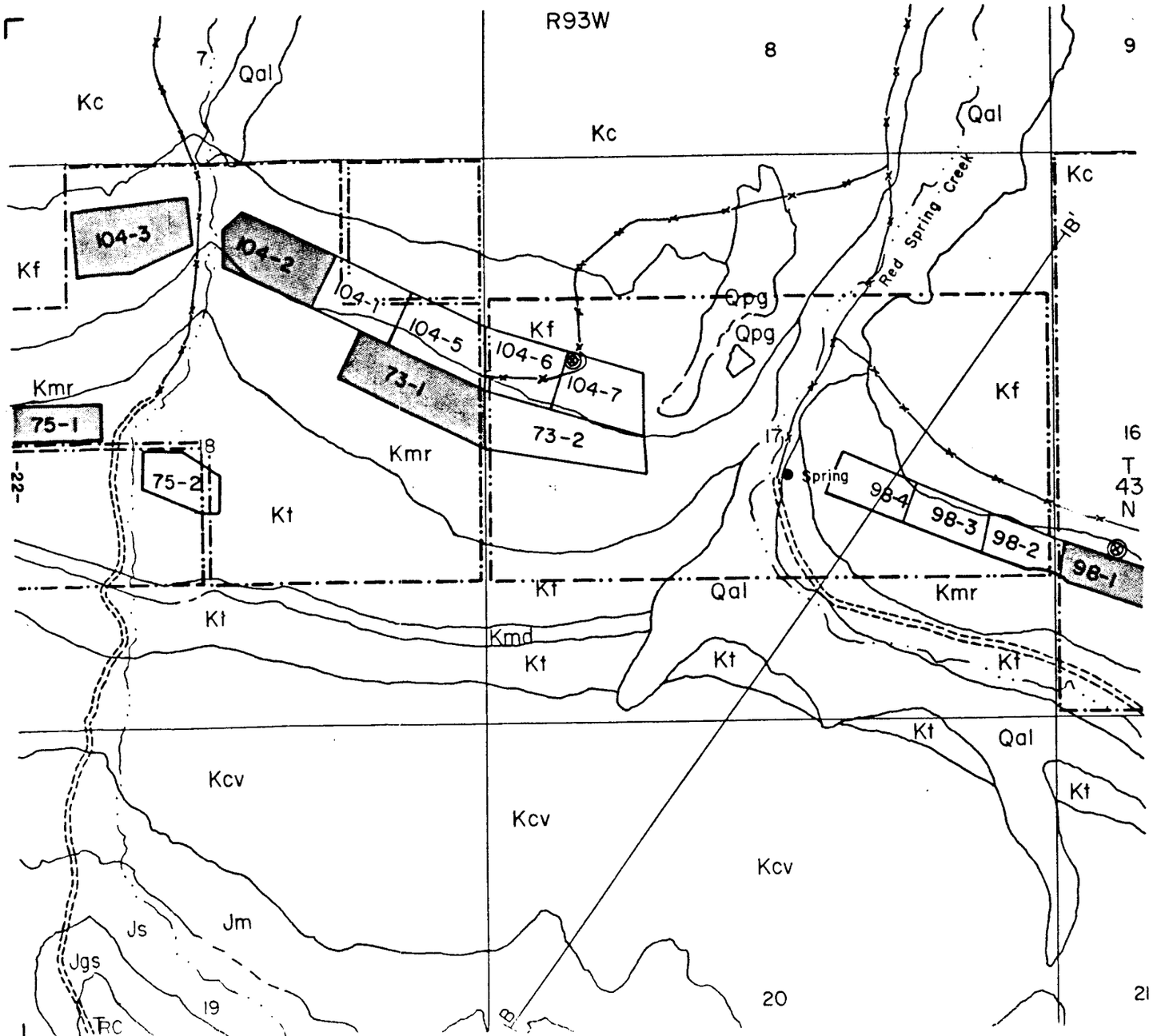
Parameter	Surface (potential root zone) Suitable	Surface (potential root zone) Unsuitable	Aquifer Restoration Suitable	Aquifer Restoration Unsuitable
pH	5.0-9.0	<5.0 >9.0	5.0-9.0	<5.0 >9.0
EC (Conductivity) mmhos/cm	≤ 8.0 1/	>8.0		Depends on premining water quality and overburden quality
Saturation Percentage	25-80	>80 <25		
Texture	≤50% clay ≤85% sand	>50% clay >85% sand		
SAR	≤10	>10 1/		Depends on premining water quality and overburden quality
Selenium	≤2.0 ppm	>2.0 ppm		Depends on premining water quality and overburden quality
Boron	≤5.0 ppm	>5.0 ppm		Depends on premining water quality and overburden quality
Nitrate/ Nitrogen			<50 ppm	>50 ppm
Molybdenum	≤1.0 ppm	>1.0 ppm		
Copper 2/				
Lime	<30%	>30%		
Acid-base Pot. 3/	-5 tons $CaCO_3$ equivalent/1000 tons	-5 tons $CaCO_3$ equivalent/1000 tons		-5 tons $CaCO_3$ equivalent/1000 tons

Lead	≤10 ppm	>10 ppm	Depends on pre-mining water quality and over-burden quality
Arsenic	≤2.0 ppm	>2.0 ppm	Depends on pre-mining water quality and over-burden quality

1/ Overburden material placed directly under respread topsoil should be of similar suitability as the topsoil. The upward migration of soluble salts must be considered.

2/ An excessive consumption of molybdenum through ingestion of vegetation may be toxic to animals. The concern is directly related to the Cu:Mo ratio in the plant tissue.

3/ Record as Acid pot. in meq H^+/100 g, Neutralization pot., acid-base potential in ± tons $CaCO_3$ equivalent/1000 tons.



Qal	ALLUVIUM
Qpg	PEDIMENT GRAVEL
Kc	CODY SHALE
Kf	FRONTIER FORMATION
Kmr	MOWRY SHALE
Kt	THERMOPOLIS SHALE
Kmd	MUDDY SANDSTONE
Kcv	CLOVER FORMATION
Jm	MORRISON FORMATION
Js	SUNDANCE FORMATION
Jgs	GYPSUM SPRING FORMATION
TRc	CHUGWATER FORMATION

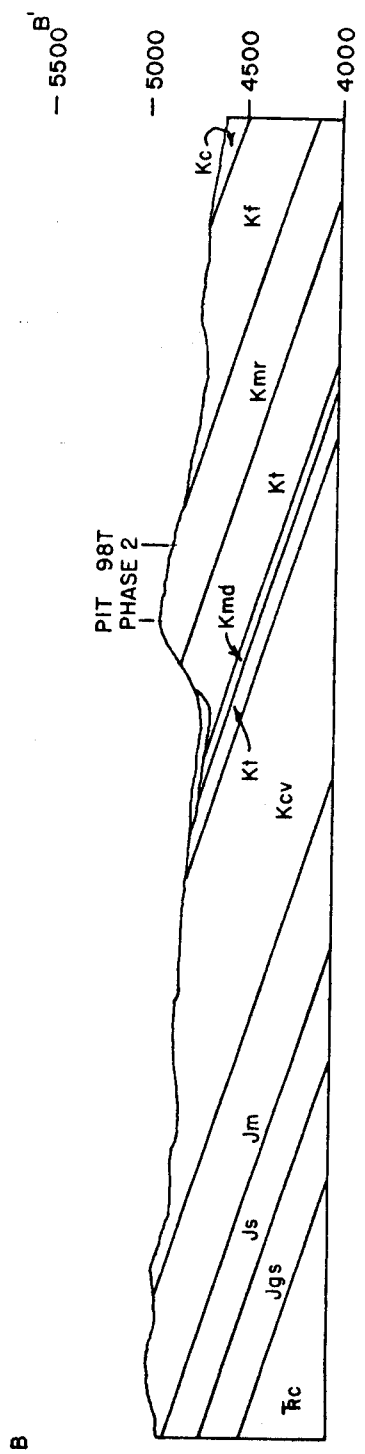
B-B' CROSS SECTION LOCATION
PERMIT 321C BOUNDARY
HAUL ROAD 321C
PROPOSED PIT LOCATION AND NUMBER (WITH PHASE)
ACTIVE AND RECLAIMED PIT LOCATION AND NUMBER (WITH PHASES)
OVERBURDEN SAMPLING LOCATION
PROPOSED AMENDMENT BOUNDARY

N

SCALE
1" = 1320'
AFTER SHLEMON 1959 MODIFIED BY R. BROWN 1983

FIGURE D-5.1

FIGURE D-5.2



CROSS SECTION SCALE
VERTICAL: 1 IN. = 1000 FT.
HORIZONTAL: 1 IN. = 1320 FT.

SEE FIGURE 5.1 FOR LEGEND

AFTER SHLEMON 1959
MODIFIED BY R. BROWN 1983

Shale and sandy shale, siliceous, fissile, black to dark gray, weathering into "silver-chips." Upper third of unit contains scattered stringers of fine grained argillaceous sandstone. Contact with Unit 2 sharp.

Bentonite.

Shale, dark gray to black, siliceous, hard."

Figure D-5.3, page 25, details the description of overburden sampled on July 13, 1981 at the location adjacent to pit 98T, phase 1, as shown on Figure D-5.1. As described in Appendix D-7 of this application, topsoil quantity is sufficient to reclaim the disturbance area and no selective handling of overburden will be used during mining of pit 98T, phases 2 through 4, and pit 73T, phase 2. Table D-5.2, page 26, presents the laboratory results of overburden described in Figure D-5.3. Table D-5.3, page 27, details the overburden suitability analysis based on potential use as plant growth medium. Criteria for evaluating overburden is presented in Table D-5.1, page 20.

Figure D-5.4, page 28, details the stratigraphic section of the overburden at pit 104, phase 5, sampled in February 1983. As described in Appendix D-7 of the application, topsoil quantity is sufficient to reclaim the disturbance area and no selective handling of overburden will be used during mining of pit 104 phases 1 or 5 through 7. Table D-5.4, page 29, presents the laboratory results of overburden described in Figure D-5.4. Table D-5.5, page 30, details the overburden suitability analysis based on potential use as plant growth medium.

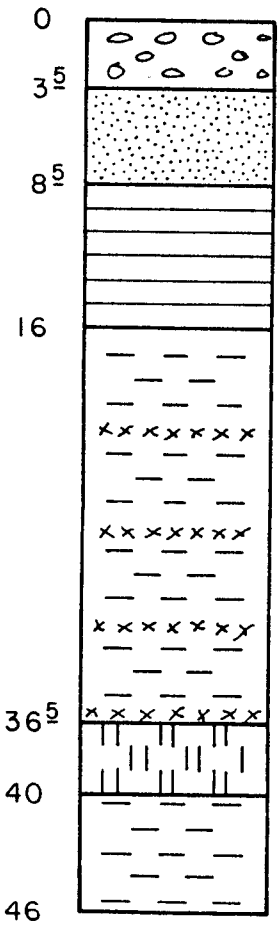
Figure D-5.5, page 31, details the surficial geology of the Pit 108T portion of the Wind area. Pit 108T, phases 1 through 17, are located on the Frontier formation. Figure D-5.6, page 32, shows the stratigraphic cross-section A-A' (Figure D-5.5). The surficial geology is rendered after Weitz and Love, (1952). The lithologic character is described in Figure D-5.7, page 33. and is based on an auger hole drilled on August 1, 1981 at the location shown on Figure D-5.5. As described in Appendix D-7 of this application, topsoil quantity is satisfactory to reclim the area of disturbance. Table D-5.6, page 34, details the results of analysis of overburden while Table D-5.7, page 35, presents the suitablity determination.

Figure D-5.8, page 36, illustrates the surficial geology of the Coal area. Pit 102T, phases 1 through 3, is located on the Thermopolis Shale formation. Figure D-5.9, page 37, details the stratigraphic cross-section A-A' (Figure D-5.8) for pit 102T. The surficial geology is rendered after Weitz and Love (1952). The lithologic character is described in Figure D-5.10, page 38, and is based on an auger hole drilled on February 28, 1983, at the location shown on Figure D-5.8. Photographs of the area shown in Appendix D-8, Vegetation (Figures D-8.14 and 8.15, pages 179 and 180) illustrate the poor existing vegetation growth and the barren character of the ground. The suitability of the overburden for plant growth medium is detailed in Table D-5.9, page 40, while Table D-5.8, page 39, details the results of the laboratory analysis.

To summarize, the overburden material will not be used as a surficial plant growth medium in the Red Hole area, because of the presence of adequate topsoil; in the Wind area the better quality overburden will be placed immediately beneath the subsoil, if present, or topsoil; and in the Coal area, the overburden is unsuitable as a surficial plant growth medium.

FIGURE D-5.3

STRATIGRAPHIC SECTION TO MOWRY "A" BED



SOIL MATERIAL

FINE GRAINED SANDSTONE. OLIVE GREEN. HARD.

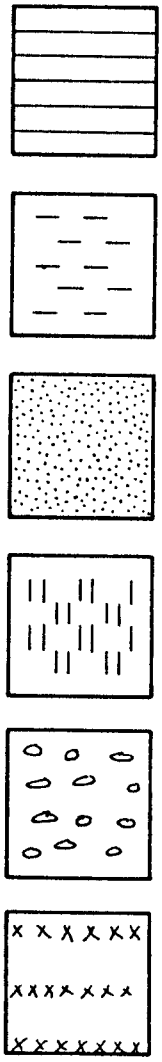
DARK GRAY SILICEOUS SHALE, WEATHERS TO LIGHT GRAY. HARD BUT SOFTER THAN UNDERLYING BEDS.

DARK GRAY SHALE. SOME INTERBEDDED MICA. SIGNS OF OXIDATION.

BENTONITE

VERY HARD BLACK SHALE

LEGEND



SILICEOUS SHALE

SHALE

SANDSTONE

BENTONITE

PEBBLES

MICA

VERTICAL SCALE
1" = 10'

FIELD OBSERVATION: OVERBURDEN PRIMARILY OF DRY HARD GRAY TO BLACK SHALE. VERY CHARACTERISTIC. NO MAJOR CHANGES. MOISTURE CONTENT IS VERY LOW.

SECTION GENERATED FROM DRILL HOLE DATA GATHERED AT LOCATION SHOWN ON FIGURE D-5.1

TABLE D-5.2

LABORATORY ANALYSIS OF OVERBURDEN CHEMISTRY

MOWRY A BED (RED HOLE AREA)

Depth Interval (ft.)	pH	Cond. mmhos/cm	Saturation %	% Sand	% Silt	% Clay	Textural Class	Ca meq/l	Mg meq/l	Na meq/l	SAR	Se ppm	Boron ppm
3.5-8.5	7.3	5.62	40.1	52	27	21	SCL	23.2	13.8	30.7	7.14	<0.02	0.2
8.5-16.0	6.7	6.21	50.1	56	21	23	SCL	21.6	18.0	38.5	8.65	<0.02	<0.1
16.0-36.5	6.6	5.18	56.4	64	17	19	SL	23.6	10.6	31.6	7.64	<0.02	<0.1
36.5-40.0	Bentonite												
40.0-46.0	8.2	3.13	69.3	54	35	11	SL	4.57	2.52	23.2	12.3	0.03	0.1

TABLE D-5.3

EVALUATION OF OVERBURDEN SUITABILITY[1]/ BY DEPTH INTERVAL

MOWRY A BED (RED HOLE AREA)

Depth Intervals (Feet)	pH	Cond. mmhos/cm	Saturation Percent	Texture	SAR	Se ppm	Boron ppm	Overall Rating	Restrictive Features
3.5-8.5	s	s	s	s	s	s	s	Suitable	-----
8.5-16.0	s	s	s	s	s	s	s	Suitable	-----
16.0-36.5	s	s	s	s	s	s	s	Suitable	-----
36.5-40.0	Bentonite								
40.0-46.0	s	s	s	s	u	s	s	Unsuitable	Sodic

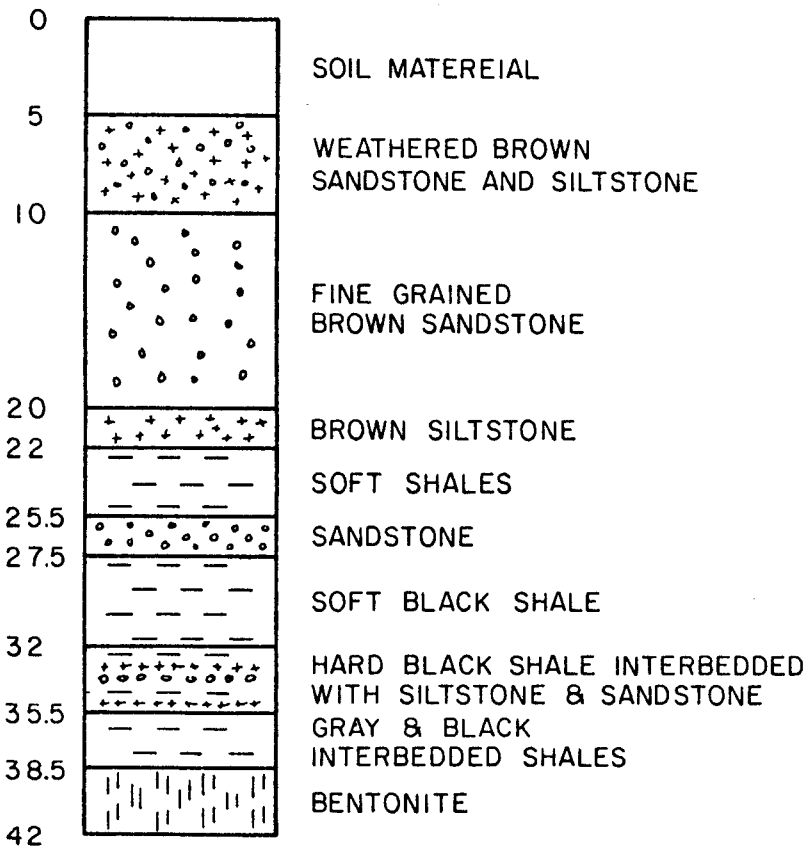
s = suitable

u = unsuitable

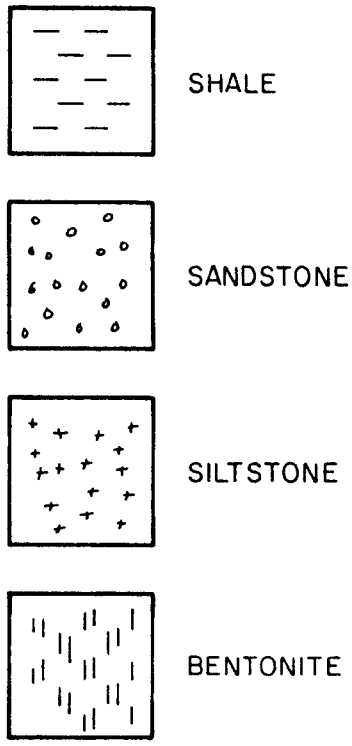
1/ Land Quality Division, Guideline No. 1 (January, 1981)

FIGURE D-5.4

STRATIGRAPHIC SECTION TO FRONTIER NO. 3 BED



LEGEND:



VERTICAL SCALE 1" = 10'

FIELD OBSERVATION: OVERBURDEN PRIMARILY SILTSTONE AND FINE-GRAINED SANDSTONE OVER SOFT BLACK SHALES TYPICAL FOR THE FORMATION.

SECTION GENERATED FROM DRILL HOLE DATA GATHERED AT LOCATION SHOWN ON FIGURE D-5.1

TABLE D-5.4

LABORATORY ANALYSIS OF OVERBURDEN CHEMISTRY

FRONTIER #3 BED (Red Hole Area)

Depth Interval (ft.)	pH	Cond. mmhos/cm	Saturation %	%* Sand	% Silt	% Clay	Textural Class	Ca meq/l	Mg meq/l	Na meq/l	SAR	Se ppm	Boron ppm
5-10	7.9	5.6	31	26-20	48	6	SL	13.7	29.0	41.0	8.9	0.05	0.8
10-20	7.8	5.4	32	42-16	38	4	SL	13.5	19.7	36.8	9.0	0.09	0.7
20-22	7.8	5.6	36	44-12	26	18	SL	14.4	20.2	41.0	9.9	0.20	0.6
22-25.5	7.6	5.4	39	53-15	14	18	SL	14.3	17.0	40.4	10.2	0.10	0.6
25.5-27.5	7.8	5.6	36	45-15	22	18	SL	14.7	17.9	40.6	10.0	0.14	0.6
27.5-32	6.7	5.2	32	58-10	14	18	SL	15.0	14.3	38.8	10.1	0.03	0.6
32-35.5	6.7	3.9	41	58-14	12	16	SL	9.0	7.5	35.2	12.3	0.06	0.5
35.5-38.5	6.9	4.4	30	68-10	10	12	SL	9.9	7.7	41.5	14.0	0.02	0.6

* Second number listed is percent very fine sand.

TABLE D-5.5

EVALUATION OF OVERBURDEN SUITABILITY[1] BY DEPTH INTERVAL

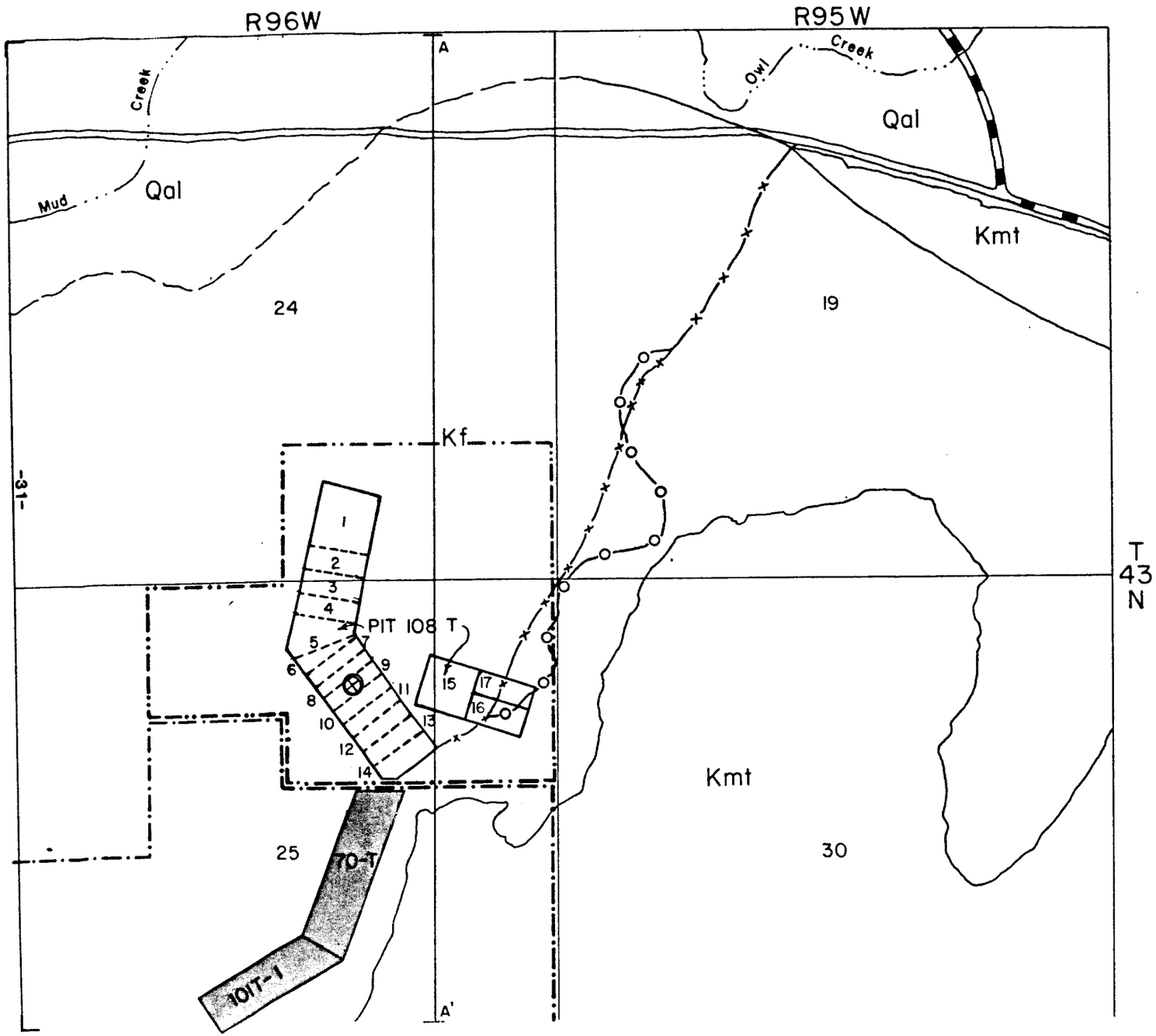
FRONTIER #3 BED (RED HOLE AREA)

Depth Intervals (Feet)	pH	Cond. mmhos/cm	Saturation Percent	Texture	SAR	Se ppm	Boron ppm	Overall Rating	Restrictive Features
5-10	s	s	s	s	s	s	s	Suitable	-----
10-20	s	s	s	s	s	s	s	Suitable	-----
20-22	s	s	s	s	s	s	s	Suitable	-----
22-25.5	s	s	s	s	u	s	s	Unsuitable	Sodic
25.5-27.5	s	s	s	s	u	s	s	Unsuitable	Sodic
27.5-32	s	s	s	s	u	s	s	Unsuitable	Sodic
32-35.5	s	s	s	s	u	s	s	Unsuitable	Sodic
35.5-38.5	s	s	s	s	u	s	s	Unsuitable	Sodic

s = suitable

u = unsuitable

1 Land Quality Division, Guideline No. 1 (January, 1981)



LEGEND:

Qal	ALLUVIUM
Kf	FRONTIER FORMATION
Kmt	MOWRY AND THERMOPOLIS SHALES
A-A'	CROSS SECTION LOCATION
—·—	PERMIT 321C BOUNDARY
—x—	HAUL ROAD 321C
	PROPOSED PIT LOCATION AND NUMBER (WITH PHASES)
	ACTIVE AND RECLAIMED PIT LOCATION AND NUMBER (WITH PHASES)
—o—	RECLAIMED HAUL ROAD 321C
⊗	OVERBURDEN SAMPLING LOCATION
— — —	PROPOSED AMENDMENT BOUNDARY

N

SCALE
1" = 1320'
AFTER WEITZ AND LOVE 1952

FIGURE D-5.5

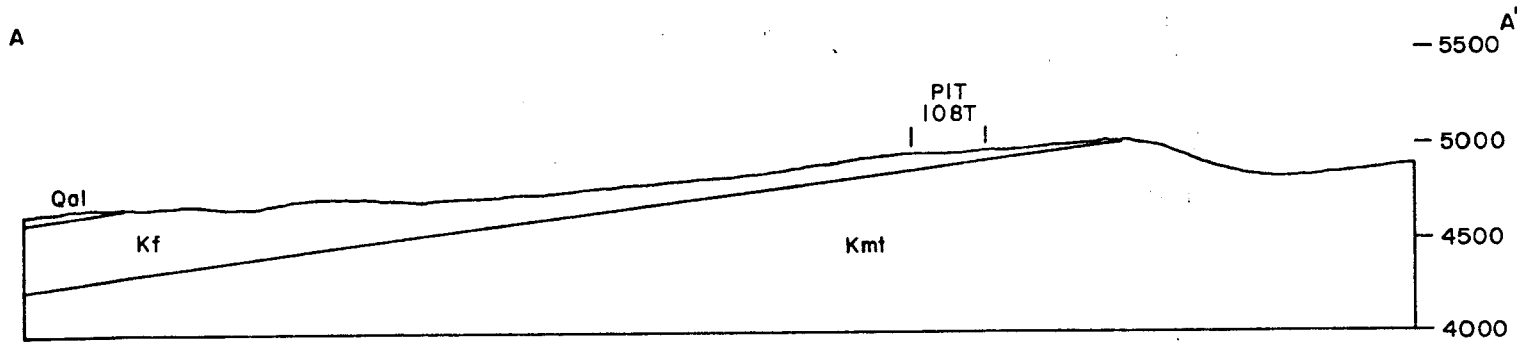


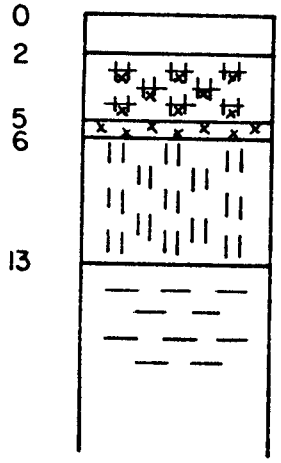
FIGURE D-5.6

CROSS SECTION SCALE
VERTICAL: 1 IN = 1000 FT.
HORIZONTAL: 1 IN. = 1320 FT.

SEE FIGURE D-5.4 FOR LEGEND

FIGURE D-5.7

STRATIGRAPHIC SECTION TO FRONTIER NO. 3 BED



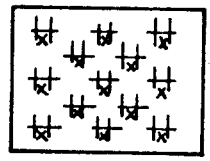
SOIL

SOFT GRAY–BROWN ASHY–SHALE

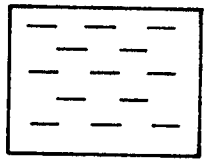
ASH

BENTONITE

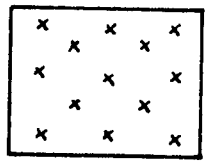
VERY HARD BLACK SHALE



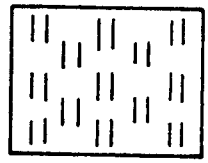
ASHY–SHALE



SHALE



ASH



BENTONITE

VERTICAL SCALE
1"=10'

FIELD OBSERVATION: OVERBURDEN CONSISTS PRIMARILY OF SOFT GRAY–BROWN ASHY–SHALE WITH A THIN ASH LAYER ABOVE BENTONITE.

SECTION GENERATED FROM DRILL HOLE DATA GATHERED AT LOCATION SHOWN ON FIGURE D-5.5

TABLE D-5.6

LABORATORY ANALYSIS OF OVERBURDEN CHEMISTRY

FRONTIER #3 BED (Wind Area)

Depth Interval (ft.)	pH	Cond. mmhos/cm	Saturation %	%* Sand	% Silt	% Clay	Textural Class	Ca meq/l	Mg meq/l	Na meq/l	SAR	Se ppm	Boron ppm
2.0 - 5.5	7.5	5.60	22.2	56-6	35	3	SL	10.1	13.7	60.8	17.60	<0.02	0.8
5.5 - 6.5	7.5	6.60	62.9	55-3	12	30	L	10.7	13.6	63.5	18.20	0.02	1.9

*Second number listed is percent very fine sand.

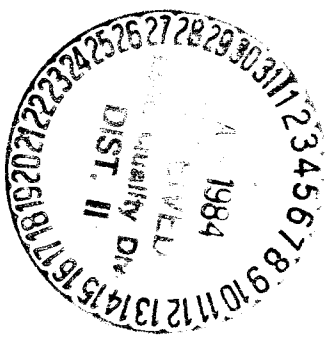


TABLE D-5.7

EVALUATION OF OVERBURDEN SUITABILITY[1] DEPTH INTERVALS

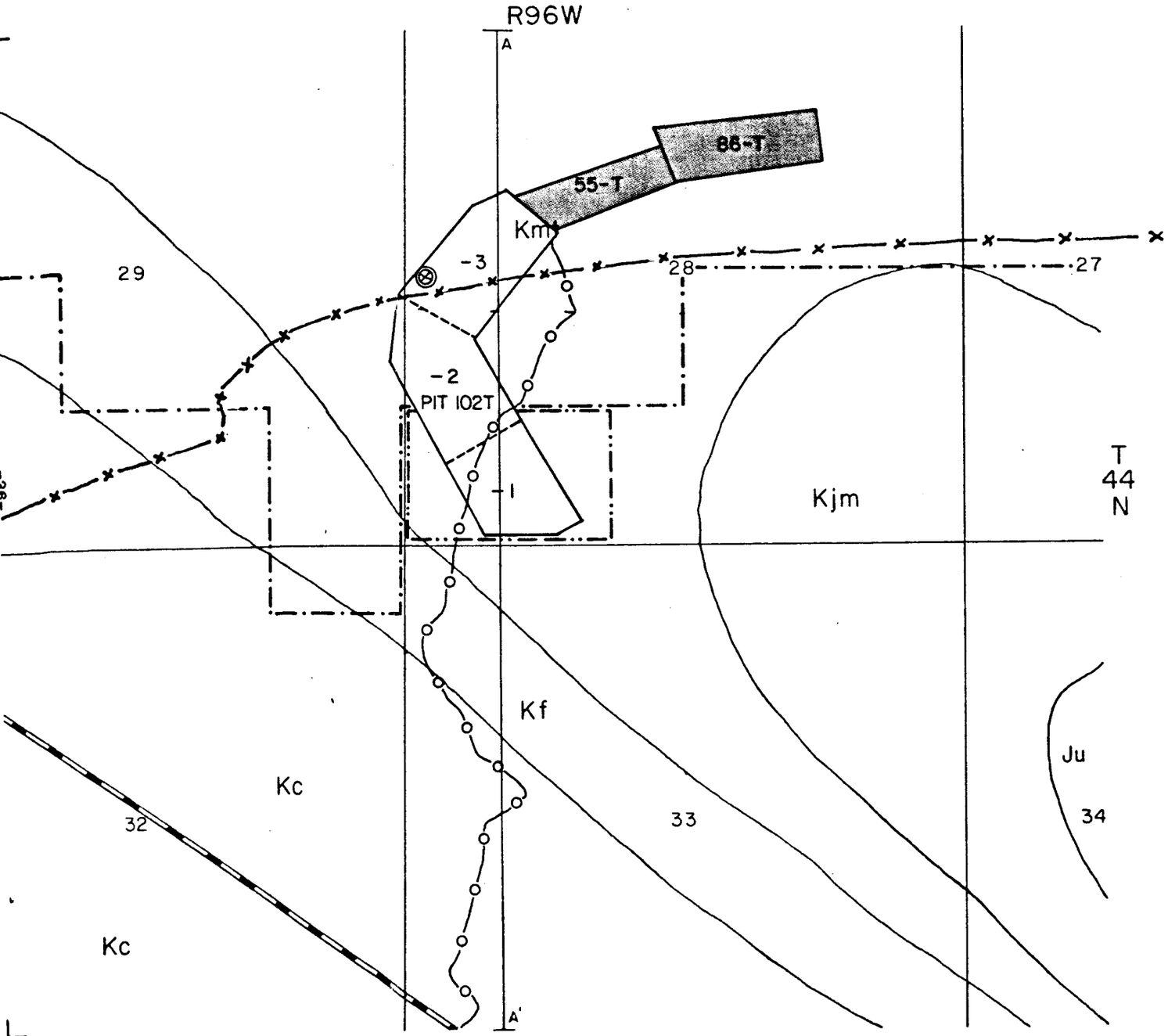
FRONTIER #3 BED (Wind Area)

Depth Intervals (Feet)	pH	Cond. mmhos/cm	Saturation Percent	Texture	SAR	Se ppm	Boron ppm	Overall Rating	Restrictive Features
2.0 - 5.5	s	s	u	s	u	s	s	unsuitable	Low sat.%, sodic
5.5 - 6.5	s	s	s	s	u	s	s	unsuitable	Sodic

s = suitable

u = unsuitable

1 Land Quality Division, Guideline No. 1 (January, 1981)



LEGEND:

Kc	CODY SHALE
Kf	FRONTIER FORMATION
Kmt	MOWRY AND THERMOPOLIS SHALES
Kjm	CLOVERLY AND MORRISON FORMATIONS
Ju	JURASSIC ROCKS, UNDIVIDED

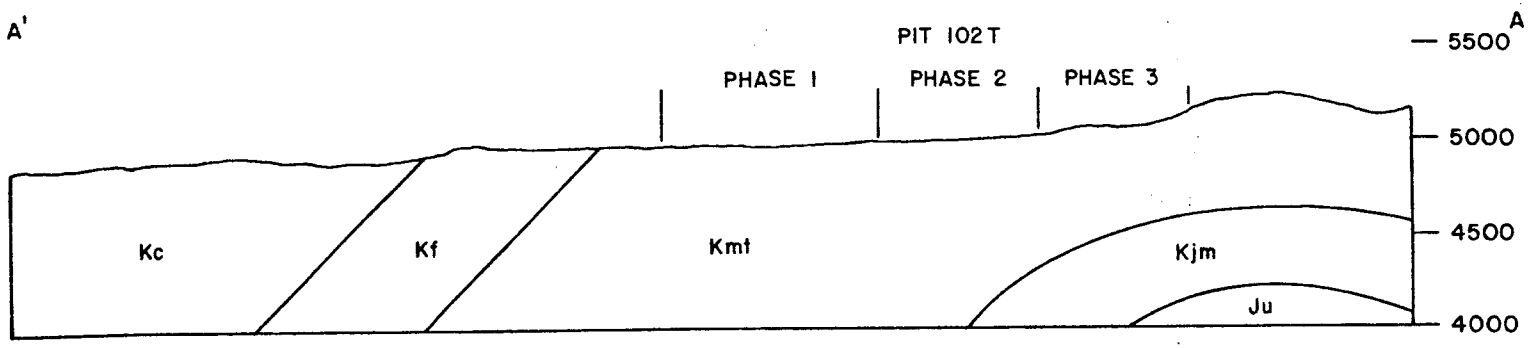
- A-A' CROSS SECTION LOCATION
- PERMIT 321C BOUNDARY
- HAUL ROAD 321C
- PROPOSED PIT LOCATION AND NUMBER (WITH PHASES)
- ACTIVE AND RECLAIMED PIT LOCATION AND NUMBER (WITH PHASES)
- RECLAIMED HAUL ROAD 321C
- OVERBURDEN SAMPLING LOCATION
- PROPOSED AMENDMENT BOUNDARY

N

SCALE
1" = 1320

AFTER WEITZ AND LOVE 1952

FIGURE D-5.8



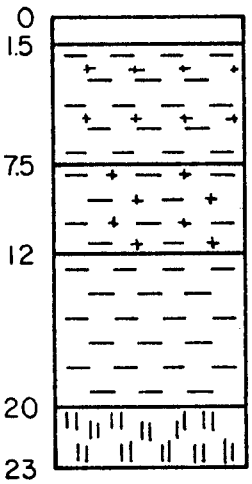
CROSS SECTION SCALE
VERTICAL: 1 IN. = 1000 FT.
HORIZONTAL: 1 IN. = 1320 FT.

SEE FIGURE D-5.7 FOR LEGEND

FIGURE D-5.9

FIGURE D-5.10

STRATIGRAPHIC SECTION TO THERMOPOLIS SHALE NO. 2 BED



SOIL MATERIAL

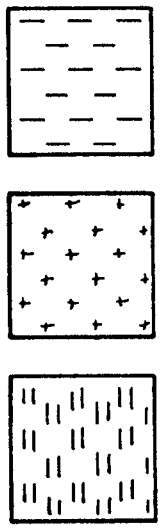
INTERBEDDED BLACK AND BROWN SHALES, AND SILTSTONES

MIXED BLACK SHALES AND SILTSTONE (HARD BLACK SHALES)

BLACK SHALE

BENTONITE

LEGEND:



SHALE

SILTSTONE

BENTONITE

VERTICAL SCALE 1" = 10'

FIELD OBSERVATION: OVERBURDEN PRIMARILY BLACK SHALE WITH SOME INTERBEDDED SILTSTONE. THE SHALES ARE DECREPITATING.

SECTION GENERATED FROM DRILL HOLE DATA GATHERED AT LOCATION SHOWN ON FIGURE D-5.7

TABLE D-5.8

LABORATORY ANALYSIS OF OVERBURDEN CHEMISTRY

THERMOPOLIS SHALE #2 BED (COAL AREA)

Depth Interval (ft.)	pH	Cond. mmhos/cm	Saturation %	%* Sand	% Silt	% Clay	Textural Class	Ca meq/l	Mg meq/l	Na meq/l	SAR	Se ppm	Boron ppm
1.5-7.5	4.4	7.40	46.6	26-6	38	30	SiL	10.9	5.0	87.6	31.10	<0.02	1.8
7.5-12.0	5.9	5.80	52.6	24-4	34	38	SiL	5.8	2.5	62.7	30.80	0.02	2.4
12.0-20.0	9.5	1.90	65.2	22-2	38	38	SiCL	0.2	0.2	21.6	56.90	0.07	2.5
20.0-	Bentonite												

*Second number listed is percent very fine sand.

TABLE D-5.9

EVALUATION OF OVERBURDEN SUITABILITY[1] BY DEPTH INTERVAL

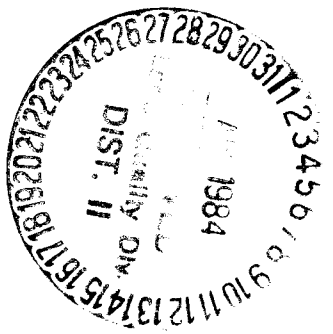
THERMOPOLIS SHALE #2 BED (COAL AREA)

Depth Intervals (Feet)	pH	Cond. mmhos/cm	Saturation Percent	Texture	SAR	Se ppm	Boron ppm	Overall Rating	Restrictive Features
1.5-7.5	u	s	s	s	u	s	s	unsuitable	low pH, sodic
7.5-12.0	s	s	s	s	u	s	s	unsuitable	sodic
12.0-20.0	u	s	s	s	u	s	s	unsuitable	high pH, sodic
20.0 -	Bentonite								

s = suitable

u = unsuitable

1 Land Quality Division, Guideline No. 1 (January, 1981)



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